# FARM MACHINERY AND PROCESSES MANAGEMENT IN SUSTAINABLE AGRICULTURE

Lublin, Poland 2019

# FARM MACHINERY AND PROCESSES MANAGEMENT IN SUSTAINABLE AGRICULTURE

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Edited by:
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# INTRODUCTION

Sustainable development is one of the most important and demanding challenges of the modern world. The concept of sustainable development is very well described by the 1987 Report of the World Commission on Environment and Development (WCED) - Our Common Future:

*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:*

> *The concept of 'needs', in particular, the essential needs of the world's poor, to which overriding priority should be given; and*
> *The idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.*

Sustainable agriculture is one of the major parts of the aforementioned perception of development. Sustainability in agriculture comprises of many aspects, such as technical, production, social, economic, environmental, etc. Despite rapidly rising populations , global agriculture has the potential to grow enough food for all. However, it cannot be at the cost of destroying resources and environment. There is a dire need for a fresh view on the resources and their management, and an urgent demand for new technologies and their application. Those needs and demands, in the context of the agriculture engineering, are the main concern and subject of this monograph.

The material presented in this monograph has been prepared by the participants in the X International Scientific Symposium on Farm Machinery and Processes Management in Sustainable Agriculture (FMPMSA ), which was held in November 2019, in Lublin, Poland. There are six subjects: (1) Machinery and Equipment, (2) Evaluation, Monitoring and Modelling, (3) Energy, (4) Processes, (5) Management and Economics and (6) Environment and Ergonomics.

The current monograph is the continuation of previous FMPMSA symposia, which started in 1994, with regular publications available on the Centre for Open Science webpage (https://depot.ceon.pl/handle/123456789/14348).

Sustainable development is not a fashion or a dream but a new approach to managing our resources to continuing human progress . It is in fact the only realistic chance to meet the needs of the present without compromising the ability of future generations to meet their own needs. It is a hope of all participants in the creation of this book that it will create more interest towards sustainable agriculture.

*Edmund Lorencowicz, Jacek Uziak, Bruno Huyghebaert*
*Editors*

# 1. MACHINERY AND EQUIPMENT

# 1.1. THE CONCEPT OF CONSTRUCTION OF A MOBILE AUTOMATIC DEVICE FOR FOREST REGENERATION TASKS AND AFFORESTATION OF FORMER FARMLAND AND RECLAIMED AREAS*

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**Keywords:** automatic device, forest regeneration tasks, afforestation, planter, container nursery, reduction of machinery inputs, agriculture 4.0.

## ABSTRACT
EU forestry does not currently have automatic planters, hence the project proposes to develop an innovative technology in which the key role will be played by an autonomous planter designed for establishing forest cultures and afforestation of former farmland and reclaimed areas with the use of seedlings with a covered root system (grown in container nurseries). The device will have a self-levelling traction system, a control system with a satellite navigation module to support autonomous navigation and planting site selection, a mechanism of planting spot preparation, a planting unit, an intelligent robotic arm to feed seedlings from containers to the planting unit according to a given algorithm, a container storage unit with an automated feeder, a drive unit with an electro-hydraulic control system, a control module, and a wireless remote control system. The autonomous planter will significantly reduce the cost and machine inputs during establishing forest cultures and afforestation of former farmland and reclaimed areas with the use of seedlings with a covered root system, and thus perfectly fits into the assumptions of agriculture 4.0.

## INTRODUCTION
By eliminating manual labour, the introduction of modern, automated technological systems meets the requirements of work humanisation in forestry. The use of advanced technological systems is also enforced by the need of business entities to function in the realities of market competition and the consequent need to reduce production costs (Tadeusiewicz *et al.*, 2017a, 2017b). Manual tasks in forest management, including planting, are characterised by a very high level of energy expenditure (Sowa, Kulak, 2000; Grzywiński, 2005). Under these conditions, the energy expenditure necessary to overcome "work resistance" is disproportionately large in comparison with the other components of physical workload: static effort and monotonous muscle work. The latter factor determines the specificity of workloads in jobs involving the semi-automatic level of technology (Sowa, 2009). The amount of energy expenditure, related to the degree of physical effort performed during a work shift, places manual planting in a group of hard and very hard labour (Grzywiński 2005, 2007). One of the most important factors that shape (mitigate) the level of fatigue in time is the distribution and length of breaks during work (Gallis, 2013). Due to a high share of breaks in a work shift, the level of shift utilisation in operational time is relatively low in non-advanced technologies, and amounts to approx. 70% (Horvat *et al.*, 2007; Marčeta *et al.*, 2014; Sabo, Poršinsky, 2005). Machine technologies are characterised by high productivity resulting not only from high efficiency but also from a smaller share of the duration of breaks (Ghaffarian *et al.*, 2007; Dvořak *et al.*, 2011). European forestry currently does not have automatic planters that would enable the establishment of forest cultures. The authors' work on the conceptual level shows that there is a technological and technical possibility to develop an autonomous

* The research is part of the project no. EO.271.3.11.2019, entitled "Mobilny automat do leśnych prac odnowieniowych oraz zalesiania terenów porolnych i rekultywowanych (RoboFoR)" [A mobile automatic device for forest regeneration tasks and afforestation of former farmland and reclaimed areas (RoboFor)]. The project has been financed by the Regional Directorate of State Forests in Warsaw.

afforestation robot that has no equivalent in the global forestry technology. Therefore, the aim of the project is to develop the construction of an autonomous robot and an innovative technology for establishing forest cultures and afforestation of former farmland and reclaimed areas.

## CURRENT METHODS OF PLANTING FOREST TREE SEEDLINGS

Planting the seedlings of forest trees, produced in container nurseries under controlled conditions, is usually done manually with the help of a planting wedge (Fig. 1). Manual placement of such a large number of seedlings in the soil requires enormous work expenditure, where, according to the catalogue of working time standards for forestry, manual removal of the soil cover and digging the soil on planting spots with a diameter of 0.4 m requires about 38 man-hours/ha under average conditions, whereas planting with the use of a planting wedge requires about 34 man-hours/ha. Additional work time expenditure is required to carry seedlings over an area that is being afforested (Regulation No. 99, 2004).


Fig. 1. Planting conifer seedlings with a tubular planting wedge: a) a planting wedge, b) planting from seedling bags, c) planting from a seedling cell container
*Sources*: www.drewno.pl., http://firmylesne.pl/images/source/kostur311.jpg, http://www.irvingplantstrees.com/default.aspx?id=38

Performing forest management tasks is cost-expensive not only due to the use of techniques and technologies at the manual or manual-mechanical level of technology, but also due to an increase in the share of deciduous species, and thus an increase in the share of multi-species stands and the introduction of deciduous undergrowth, which requires from all participants of this process not only higher qualifications but also greater workloads and costs (Grodecki 2008). In the perspective of several years, the introduction of machines operating in an automatic or semi-automatic system (Fig. 2) is necessary in view of the forecast problems related to employing low-skilled workers as well as the increasing costs of such activities (Sowa 2009; Kocel, 2013).
In Western European countries, Scandinavia and Canada, nurseries with a covered root system, and, then, container nurseries appeared primarily for economic reasons. This technology allows greater intensification of production, mechanisation and automation of work, which yields measurable results in the form of reduced production costs as compared to seedlings produced in a traditional way (Neruda, 2013).

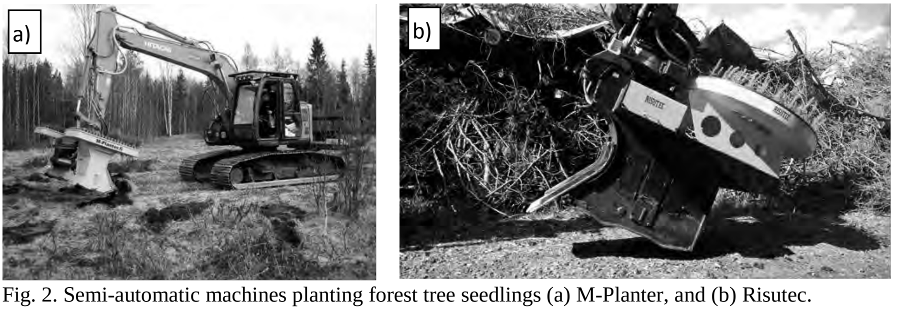


Fig. 2. Semi-automatic machines planting forest tree seedlings (a) M-Planter, and (b) Risutec.
*Sources*: http://www.m-planter.fi/Image/IMG_0487.jpg?rnd=1393261247 and: https://www.risutec.fi

In Poland, container nurseries were introduced for environmental reasons, when at the end of the 20th century Polish forestry needed an effective tool for forest regeneration after fires and for reclamation of degraded post-industrial areas (Kowalski 2007, Wesoły, 2009). In Poland, the production of this type of seedlings amounts to about 100 million units per year and steadily increases, thanks to the expansion of a network of container nurseries producing seedlings with a covered root system in plastic or polystyrene containers. This production is enough to fill about 20 thousand ha of area per year. In EU countries, forest fires are not uncommon. For example, in Portugal, Spain, France, Italy and Greece in 2007 alone, fires consumed a total of nearly 600,000 ha of forests, whose regeneration required the use of seedlings with a covered root system (Paschalis, 2012). Such a technology of seedling production is the most suitable for inoculation with suitable mycorrhiza, which has physiological and protective functions. Mycorrhized seedlings should be grown not only for the afforestation of forest soils degraded by large-surface fires but also in areas with multi-generational incompatibility of the biocenosis with the biotope and for the purpose of reclamation of difficult soils, such as military training grounds or areas near highways.

Reclamation of post-mining areas is an even more important problem. Afforestation is potentially the best strategy for sustainable recovery of mining sites to their previous form. Although post-mining sites differ significantly from natural ones (water and nutrient shortage, disturbances in nutrient relationships and soil pH as well as strong variation in the vertical and horizontal levels of soil), a possible scenario is the introduction of seedlings with a soil lump at the beginning of the process of creating forests in mining areas (Pietrzykowski *et al.*, 2015).

However, the global market of the demand for autonomous devices for planting forest tree seedlings with a covered root system is much broader. Only in Sweden forest regeneration amounts to around 200,000 ha/year and is mostly performed using this type of seedlings. A similar situation also occurs in such large forest economies as Finland, Germany, Spain, France or Norway (Bernadzki, 2006, Central Statistical Office, 2012). Predictions and estimates made by the present authors suggest that the robot's performance in its innovative technology will increase the planting efficiency in the forest area by at least 5 times (after tree felling and extraction). The robot's performance can be even greater in former farmland and reclaimed areas.

## THE AIM OF THE PROJECT AND CONSTRUCTION ASSUMPTIONS

The aim of the project is to develop the construction of an autonomous robot and an innovative technology for establishing forest cultures and afforestation of former farmland and reclaimed areas. European forestry currently does not have automatic planters that would enable the establishment of forest cultures. The experience (Tadeusiewicz *et al.,* 2017b; Ciechanowski *et al.,* 2018; Pari *et al.*, 2018; Szczepaniak *et al.*, 2018) and conceptual work of the consortium members have shown that there is a technological and technical possibility to develop an autonomous afforestation robot that has no equivalent in the global forestry technology. We proceed from the following assumptions: manual labour in afforestation, i.e. (a) preparing a planting spot, (b) placing a seedling on the spot, (c) the distribution of seedlings on an established forest plantation, can be planned according to the algorithms implemented in the planting robot.

The robot will have: (1) a self-levelling traction system, (2) a satellite navigation system that supports autonomous navigation in areas not cleared of tree stumps as well as planting location selection, (3) a planting spot preparation mechanism, (4) a planting unit, (5) an intelligent robot arm, i.e. one that operates according to algorithmised procedures, feeding seedlings from containers to the planting unit, (6) a container storage unit with an automated transporter, (7) a compact internal combustion hydraulic drive set with an electro-hydraulic control system, (8) a measurement and control module, (9) a wireless remote control system.

Seedlings grown in a container nursery in standard containers will be planted into the soil in an automatic system (without having to remove the seedlings first, which is associated with the harmful drying and partial disintegration of the root ball). The autonomous robot will have its own chassis, allowing for operation under difficult field conditions, a mechanism eliminating competitive vegetation around the planting spot and loosening the soil on the planting element's spot of operation, and a unit for soil compaction around a seedling, designed to stabilise it and eliminate air pockets, which inhibit the growth of the root system into undisturbed soil. Seedlings will be fed to the planting wedge by an intelligent robot arm that will remove seedlings from containers according to a specific algorithm. Then the wedge will be pulled out and the seedling will be pressed down with the force regulated by the soil kneading mechanism. The planting robot will have a container storage unit, programmed to replace an emptied container with another, full container. This will allow planting a given afforestation area without the need for the manual feeding of seedlings and supervision. The robot will move all over the working area using navigation systems or with the assistance of an operator, and bypass obstacles. A built-in satellite navigation system, along with a digital map of the working area, will be the basis for choosing the optimum movement trajectory, taking into account the need to reach a given point with a supply of containers with seedlings and other materials. Travel paths and geographical coordinates of seedling distribution will be recorded during operation. The data registered will enable the development of a map of the afforested area for the purpose of further monitoring of forest culture development during vegetation. The planting parameters (depth, site shape, seedling density) and the species composition will be programmed in accordance with the requirements of local forest breeding rules, with the use of a friendly interface. The robot's modular design will enable its further development.

## CONCLUSIONS

Assumptions of agriculture 4.0, striving to change labour costs and increase work automation in the necessity of developing new fully automated machines. They also include an automatic planter for establishing forest cultures and afforestation of former farmland and reclaimed areas with the use of seedlings with a covered root system.

As opposed to classical planting methods, the advantages of the proposed innovative automated system are as follows:

(1) elimination of manual labour - an employee controls the device's operation only remotely;

(2) increase in efficiency - extension of operating times, selection of the optimum driving trajectory;

(3) reduction of energy expenditure - elimination of surface soil preparation for the sake of complete planting spot preparation;

(4) shortening of the technological process - direct planting of seedlings grown in standard containers;

(5) increase in the rate of planting success in a forest culture, related to reduction of the post-planting stress, by (a) elimination of early removal of seedlings from containers, which causes the drying and flaking of the root ball, (b) optimisation of seedling verticality and root ball tightening;

(6) adaptation to work in areas not cleared of tree stumps and in sloping terrain - the application of satellite navigation systems and automatic levelling;

(7) the potential for system expansion.

The final product will combine technological solutions and IT applications that have so far been operating in remote areas of information technologies in industry, forestry and natural environment formation. The combination of satellite navigation (GPS) methods and the need to take into account information from other sources, necessary for the correct operation of the robot, as well as a variety of possible soil conditions and terrain configurations mean that the methods and algorithms developed in the project will probably be general enough to allow their transfer to other areas of application, such as transport. The autonomous planter will significantly reduce the cost and machine inputs during establishing forest cultures and afforestation of former farmland and reclaimed areas with the use of seedlings with a covered root system, and thus perfectly fits into the assumptions of agriculture 4.0.

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# 1.2. SPRAYER SETUP AND FOLIAR APPLICATION EFFECT ON MAIZE GROWTH CHARACTERISTICS USING DIFFERENT UREA CONCENTRATIONS

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**Keywords:** foliar fertilization, urea concentrations, nozzle height, knapsack sprayer

## ABSTRACT

The experiment was carried out in a plastic pot using maize crop. The objective was to study the influence of the sprayer setting on the crop growth characteristics. The tries are including two different nozzle heights 25 and 50 cm and four different concentrations of the urea fertilizer 0, 5, 10 and 15gm/l. The foliar spraying was carried out once a week for two months, after 4-6 leaves appeared. Plant height, number of leaves, leaf chlorophyll content, and leaf area were measured in this study. The preliminary results showed significant differences in foliar fertilization depending on the urea concentration, nozzle height, and the interaction between them. The combination of the urea concentration of 15 gm/l and nozzle height of 25cm was revealed the best growth characteristics compared to the control and other treatments.

## INTRODUCTION

Maize crop *(Zea mays L.)* is one of the most economically important crops in the world and comes in the third category after wheat and rice crop in cultivated area (Imran *et al.*,2014). Despite the expansion in crop cultivation, the qualitative and quantitative crop production decreases due to various factors as type of cultivated variety, climatic conditions, and method of fertilization. There are also factors related to the abundance of nutrients necessary for its growth and the quality of its grains as nitrogen (Ombuki, 2018; Braimoh and Velk, 2006; Urassa, 2015; and Chen *et al.,* 2018). One of the methods to improve maize yield is adding urea fertilizer which contains a high percentage of nitrogen (46% N). Maize considers one of the crops that are highly responsive to nitrogen fertilization (Sapkota *et al.,* 2017; Selassie, 2015; Leghari *et al.,* 2016). Nitrogen deficiency reduces the ability of the crop to absorb nitrogen from the soil depending on the growth stage that resulting in the growth cessation, yellowing leaves, and decreasing in the leaves chlorophyll content (Kandil, 2013; and Moraditochaee *et al.,* 2012). The previous studies have shown that the amount of soil fertilizer applied on the plant is lost because of the factors mentioned above (Roy *et al.,* 2006). To reduce the losses and to increase the benefit, the researchers applied a new method to adding fertilizer with a foliar application for absorption increasing up to 90% compared to the traditional method (Fageria *et al.,* 2009). By this method, it is a possible to spray different types of crops at different growth periods (Roy *et al.,* 2006; and Barranco *et al.*, 2010). Therefore, the main objective of this study was to investigate different urea concentrations and nozzle heights on the characteristics of maize growth using the foliar application.

## METHODS AND MATERIALS

A field experiment was carried out in the plastic pots in the PVC of Soil and Water Science Department, College of Agriculture, University of Basrah for the growing season 2019 using hybrid maize 34N84. The seeds were planted in pots weighing of 10 kg in silty clay soil. Samples of the soil were taken at a depth from 0 to 30 cm to measure the physical and chemical properties of soil that were mentioned in the Table 1.

Table 1. Some properties of physical and chemical Soil characteristics

| Character | Measuring unit | Average value |
|---|---|---|
| Electrical Conductivity (ECe) | Dc/m | 18.52 |
| Soil PH | - | 7.42 |
| Total available nitrogen | % | 42.93 |
| Organic Matter (OM) | gm/kg | 9.12 |
| Soil structure( sand, clay, silt) | gm/kg | 295.2, 312.3, 392.5 |

Foliar application spraying was done once a week at the evening when the crop has an average of 4-6 leaves. Four urea concentrations 0 (control, water only), 5, 10, and 15 g/l were used in this study. Knapsack sprayer was used in the experiments for applying foliar fertilization. Two heights 25 and 50 cm above the crop of the Flat fan nozzle 110 03 at 2 bar operating pressure were selected. The general description of this sprayer was shown in the Table 2.

Table 2: Knapsack sprayer description

| Knapsack sprayer model | Total tank capacity (litter) | Number of a nozzle mounted | Power source | Piston pump | Sprayer color |
|---|---|---|---|---|---|
| XF-16B | 16 | 1 | Manual | Internal | Blue |

**Maize growth characteristics**

Plant height: plant height was measured from the surface of the ground to the tip of the fully opened leaf

Leaves numbers: The total number of the leaves on the plant was measured by counting it manually.

Chlorophyll content: Leaf chlorophyll content was measured by chlorophyll meter SPAD-502.

Leaf area (LA): leaf area was calculated depending on the following formula (Mananze *et al.,* 2018):

$$LA = Lenght * width * 0.75 \tag{1}$$

**Statistical analysis**

Based on the results from this study, analysis statistical was performed using ANOVA table. The test of $L.S.D_{0.05}$ was used to compare the differences between the studied parameters.

## RESULTS AND DISCUSSION

### Effect of foliar urea concentration and nozzle height on plant height

As shown in Fig.1, significant differences were observed in plant height by increasing the number of spraying periods, urea concentrations, and nozzle height. Higher plant height 27.25cm showed a significant difference at the third spraying period compared to the other treatments and the control.

The same figure also showed the urea concentration significantly affects the plant height. Higher plant height value of 27.25 cm revealed with a relative increase of 58.78% in comparison to the control when the foliar fertilization was used with urea concentration of 15gm/l. Minimum plant height of 11.23 cm was recorded where no fertilizer (control) was used. Contrary, decreasing in the nozzle height led to significant increasing in the plant height. Higher plant height value 27.25 cm was observed with nozzle height 25 cm compared to nozzle height 50 cm and the control.

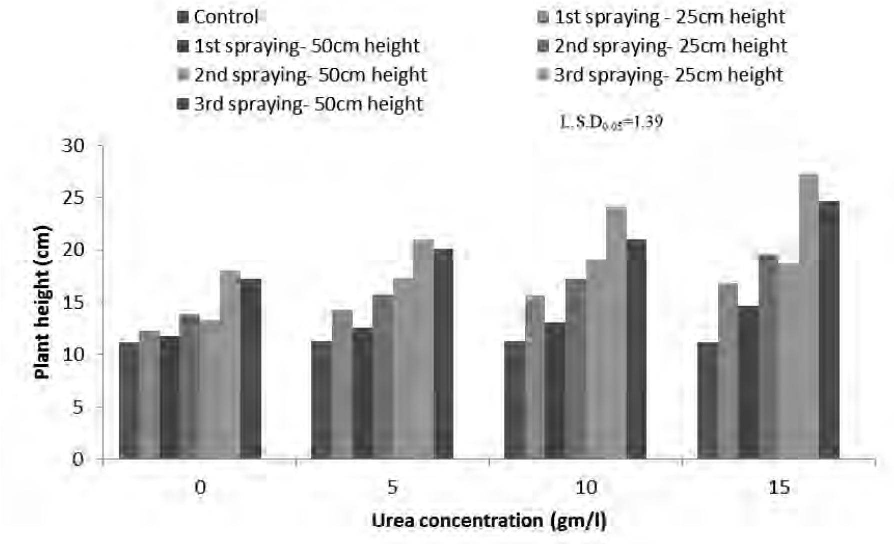


Fig.1. Effect of nozzle height and urea concentration on the plant height

**Effect of foliar urea concentration and nozzle height on plant leaves number**

The results indicated that there were significant differences between the urea concentration and the nozzle height in average of the leaves number. The third spraying (15 gm/l) significantly affected average of the leaves number (12.34-leaf) with an increase of 27.07 % compared to the control which recorded the lowest average of leaves number (9-leaf). The results also revealed significant effect of the nozzle height on leaves number. Higher average leaves number (12.34- leaf) was observed with nozzle height 25 cm compared to the nozzle height 50 cm and the control.

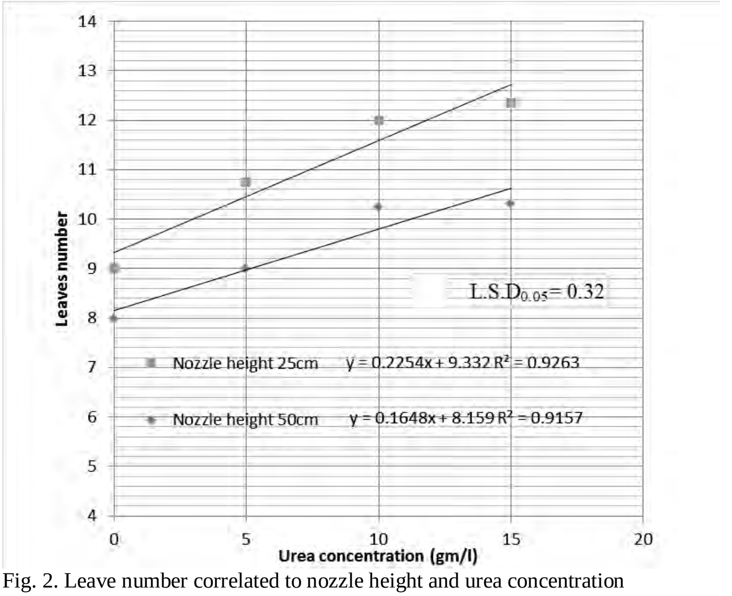


Fig. 2. Leave number correlated to nozzle height and urea concentration

**Effect of urea concentration and nozzle height on leaf area**

The results introduced significant differences between urea concentration and nozzle height in leaf area. Increasing of the foliar urea concentration led to significant increase in leaf area. Higher urea concentration (15gm/l) showed the highest average of leaf area (243.37cm$^2$) compared to the lowest average 207.5cm$^2$ of the control. The same figure also showed significant differences in the leaf area between nozzle heights (25 and 50cm). Higher leaf area (235.04 cm$^2$) was observed with nozzle height 25cm compared to the control and nozzle height of 50cm.

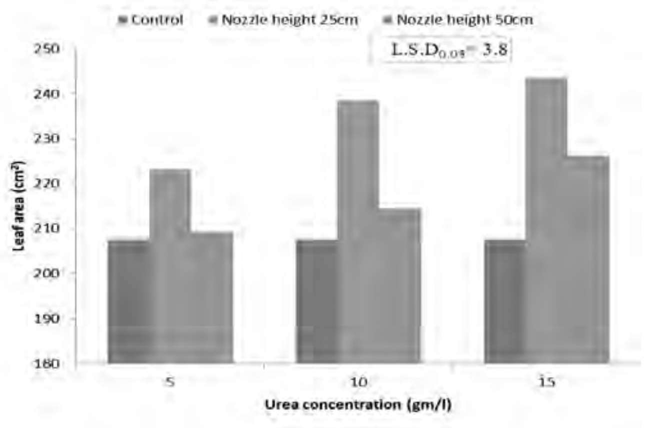


Fig. 3. Leaf area related to urea concentrations and nozzle heights

**Effect of foliar urea concentration and nozzle height and their interaction on leaves chlorophyll content**

The results as shown in the Fig.4 illustrated significant differences between urea concentrations and nozzle heights on the leaves chlorophyll content.

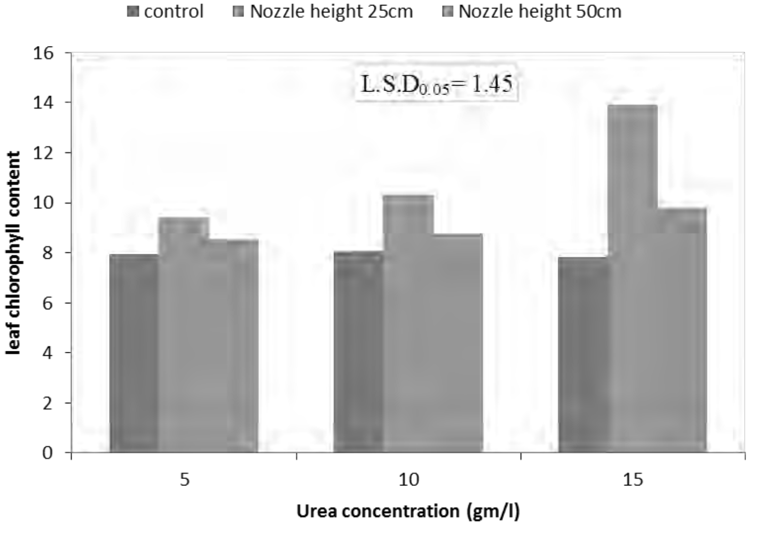


Fig. 4. Leaf chlorophyll content at different urea concentrations and nozzle heights combination

Leaves chlorophyll content reached to high average value (13.9 Spad) with urea concentration of 15gm/l and nozzle height of 25cm compared to the nozzle height 50cm and the lowest average value (7.95 Spad) of control.

## CONCLUSIONS

The outcomes of this present study demonstrated that it was a possible to improve plant growth characteristics by selecting suitable urea concentration and nozzle height. Higher values of the plant height, leaf area, and leaves chlorophyll content were observed in urea concentration of 15gm/l and nozzle height of 25cm compared to the control (spraying water only) and the nozzle height of 50cm.

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# 1.3. OIL SEED RAPE PLANT SPRAYING USING MULTIROTOR DRONE

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**Keywords:** UAV, multirotor drone, plant spraying, liquid deposition on plants, plant protection

## ABSTRACT

The use of unmanned aerial vehicles for plant protection may, constitute an important element of sustainable agriculture in the future. In the paper, are presented laboratory results of spraying tests of winter oilseed rape plant, in the flowering phase, with a multirotor drone. Lechler LU 120-02 flat fan spray nozzle was used for testing. The altitude of the drone movement over the plants was 0.5 m and 1.0 m; the speed was 1.3 $m \cdot s^{-1}$. Plant spraying was performed on the non rotating drone rotors and at speeds of 5000 and 6200 rpm. Liquid deposition was tested on samplers placed on three levels of rapeseed plants; upper and middle levels, and also on the lowest leaves. The influence of the speed of drone rotors on an improved uniformity and change in the volume of liquid deposited on individual plant levels was found mainly at the altitude of 0.5 m above the plants.

## INTRODUCTION

With the aid of drones, we may perform numerous agrotechnical procedures, such as plant spraying, both with chemical and biological agents, in order to combat plant pests (Berner & Chojnacki 2017a, Berner & Chojnacki, 2017b), fertilizer spraying, seed sowing and plant planting (Berner & Chojnacki, 2018; Diwate *et al.*, 2018). An important advantage of the use of drones in fieldwork is that soil and plant compaction with tractor and machinery wheels is avoided (Horn *et al.*, 2003) hence, there is no resulting crop damage (Moitzi *et al.*, 2017). Owing to these advantages of drones, they are most frequently used for plant protection purposes (Wei-Cai *et al.*, 2016; Zhou & He, 2016; Giles & Billing, 2015). In the future, they may contribute to complete robotization of many types of fieldwork, including plant protection and fertilization (Mogili & Deepak 2018).

For the purpose of the assessment of procedures performed with drones, it is most often that samplers are placed on several levels of plants. Based on drop traces on samplers, the volume of liquid deposited in the plant canopy can be assessed, and even the uniformity of the distribution of this liquid on the plant may be verified (Wei-Cai *et al.*, 2016; Berner B. *et al.*, 2018; Zhou & He 2016). The results of tests related to maize plant spraying with a multirotor drone point to the influence of the plant height and air stream on the plant spraying quality. The air stream from the drone rotor makes part of the liquid contained in the droplet stream be pushed into the lower parts of the plants (Berner *et al.*, 2018).

The efficacy tests of fungicide sprayed from the drone to combat wheat mildew demonstrate that the air stream directed downwards from the rotating rotors may increase markedly the penetration of drops into the plants. This procedure, when performed by the drone, yielded better results than when performed with the aid of an electrically driven knapsack sprayer (Qin *et al.*, 2018). It was found that the air stream from the drone rotors may have a positive impact on the penetration of drops inside the plant canopy. That was also observed that the shape of the drop stream may be changed under the influence of the air stream from rotating drone rotors. The air stream was the cause of changes in the transverse distribution of the liquid deposited on the nozzle patternator, which was sprayed with the aid of the DGTJ60-11002 nozzle installed on the drone (Pachuta *et al.*, 2018), and it had an influence on changes in the angle of the drop stream leaving the sprayers (Qing *et al.*, 2017).

Current structures of unmanned rotor air vehicles that are used in chemical plant protection perform procedures on the altitude from 1.0 to 3.0 meters above plants (Berner & Chojnacki, 2017c). In order to reduce the liquid drift, so that procedures performed with drones could be comparable to those performed with field sprayers, the flying altitude of drones over plants should not be greater than 0.5 m. In the literature, there is no evaluation of the quality of liquid deposition on plants with such a low flying altitude of drones.

Rape is one of the chief plants that are grown in Europe. In the BBCH rape blooming phase, these plants are sprayed to combat for example *Sclerotinia sclerotiorum*, *Alternaria brassicae* and noble rot. The quality of the drop stream produced on the drone will depend from the liquid pressure, type of sprayers installed, the impact of the air stream and the additives used in the liquid (Milanowski & Parafiniuk, 2017).

**The purpose of the study** was to evaluate the volume of the liquid spread from the drone that penetrates into the rape plant canopy and the uniformity of its distribution on the plants with changes in the drone flying altitude and the rotation speed of the drone rotors.

## MATERIALS AND METHOD

The tests were conducted in a laboratory. A truck was placed on a track that was positioned high. It was moved with a tension member with the aid of an electric motor. A drone was installed on the truck on its lower part. The drone possessed electric motors: DJI 4114, kV -400 and propellers sized 15 x 2,2". Under the drone rotor, on an extension arm attached to the drone frame, at a distance of 0.35 metre from the bottom surface of the propellers, a LU 120-02 flat nozzle manufactured by Lechler was installed. It was fed with a liquid through a conduit from an external feeding source. The liquid pressure in the sprayer was constant and it was 0.2 MPa. On three middle levels of the plants, samplers were placed with the sized 0.02 x 0.04 m made from polyester film, six items on each level, three items on the right plant and three items on the left plant. The lower samplers were positioned on the height of ca. 0.05 m above the ground, the middle ones at a distance of ca. 0.48 m over the lower samplers. The upper samplers were placed on the surface of the uppermost leaves on the plants: on the height of ca. 0.52 m above the middle samplers. After each travel of the drone, these samplers were always placed on the same leaves and in the very same places. Water was coloured with water nigrosine in the concentration of 0.5%. Once the liquid dried, the samplers were taken from the plants and they were stored in closed containers. The following factors were accepted for the purpose of the tests: the level of the sampler on the plant, the rotational speed of the drone rotors, the altitude of the drone over the plants.

Winter rape plants were used in the tests with the average height of 105 cm, in the flowering phase marked with number 60 according to the BBCH scale. The plants were placed in boxes under a frame with a truck with the drone was installed. They were arranged in the following manner: 8 plants in rows positioned transversely to the travelling direction of the drone and 5 plants in rows in parallel to the travelling direction of the truck. The spacing of the plants in the row that was parallel to the travelling direction of the truck was 0.21 m, and in the raw transverse to the truck travel it was 0.37 m. The line of the travelling path of the sprayer was symmetrically between the middle rows. The quality of liquid deposition on plants may depend from the altitude on which the procedure is performed and from the plant shape, and also from the precision of the drone movement over the plants (Tang *et al.*, 2018). The tests were performed with the sprayer being positioned over the plants on the height of H=0.5 m and H=1.0 m (Fig. 1).

Once the tests were complete, distilled water with constant volume was washed away from the samplers. The concentration of the colouring agent, which was proportional to the mass deposited on the spraying liquid samplers, was calculated based on the extinction of light passing through the liquid. Light extinction was determined with the aid of a spectro-photocolorimeter.

The travelling speed of the drone over the plants was 1.3 $m \cdot s^{-1}$ and it did not change during the tests. The tests were performed on the drone rotors that were not rotating: 0 revolutions per minute and with two rotational speeds of the rotors: 5000 and 6200 revolutions per minute.

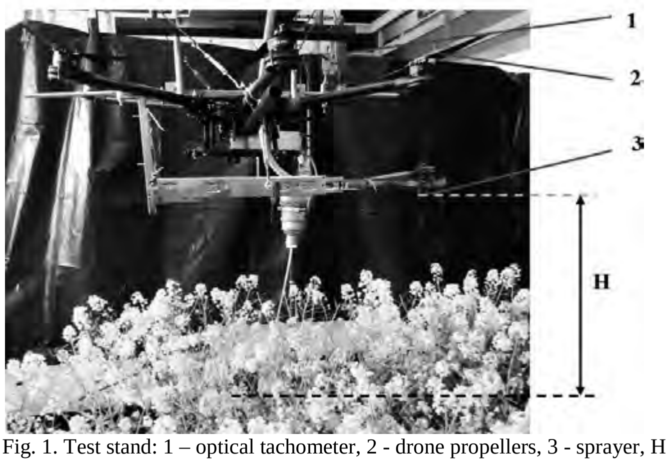

Fig. 1. Test stand: 1 – optical tachometer, 2 - drone propellers, 3 - sprayer, H - altitude of drone over plants

The thrust force of the drone that was determined for these values of rotations was 72.3 and 106.7 N respectively. The rotations of the drone rotors were counted with the aid of an optical revolution counter mounted on the drone and connected to a computer through a USB interface. The experiments were conducted by repeating each measurement three times.

## RESULTS AND DISCUSSION

The results obtained from the concentration of nigrosine were washed away from samplers in distilled water, underwent a three-factor variance analysis in order to determine the significance of the influence of the factors examined on the volume of the spraying liquid deposited on the samplers. Fig. 2 presents the average concentration values of nigrosine in distilled water after it has been washed away from the samplers attached on the upper, middle and lower levels of plants. As the concentration of the colouring agent in distilled water, which was used to wash the colouring agent from the samplers, is proportional to the volume of the liquid deposited on the samplers, it was accepted for further statistical calculations that the concentration of the colouring agent in the liquid is an equivalent of the volume of the liquid deposited on the sampler. The variance analysis conducted with the significance level of $p \leq 0.05$ on the test results demonstrated the significance of the influence of the level of the sampler on the plant and the significance of the influence of the rotational speed of the rotors. A reduction of the altitude from 1.0 m to 0.5 m resulted in an increased deposition of the liquid sprayed chiefly on the samplers located on the upper surface of the plants. This increase of the liquid deposition on the upper samplers occurred in both with and without rotation of the rotors. The work of the drone rotors had a significant impact on an increased deposition of the liquid on the samplers located on the middle level, and it had an insignificant impact on an improved deposition of the liquid on the lower samplers, on leaves under the plants.

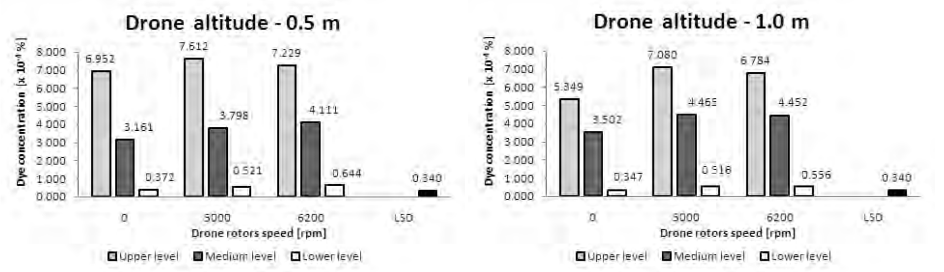


Fig. 2. Deposition of liquid sprayed from the drone on samplers depending on the level on which the sampler was placed on the rape plant, the rotational speed of the drone rotors and the altitude of the position of the sprayer with the drone over the plants (LSD - Lower Significant Difference)

A variance analysis of the test results with the significance level of $p \leq 0.05$ demonstrated no significance of the influence of the position of the drone with the sprayer over the plants on the average values of the deposition of the liquid on the samplers on all the levels of the plants. With the altitude of 0.5 m, the average concentration of the colouring agent in the liquid was $3.822 \cdot 10^{-4}$ %, and with the altitude of 1.0 m, it was $3.672 \cdot 10^{-4}$ %, whereas the smallest significant difference was $0.340 \cdot 10^{-4}$ %. The variance analysis demonstrated the significance of the impact of the altitude of the drone with the sprayer over the plants in combination with the rotational speed of the rotors (Fig. 3). This is particularly evident between the results of the deposition of the liquid with no rotations of the rotors and the results with the rotating rotors for both altitudes. No significant difference was found in the concentrations of the colouring agent with the speeds of 5000 and 6200 rpm. The rotations of the drone rotors in relation to their non-presence (0 - rpm) resulted in an increase of the liquid sedimented on the samplers. The most probable reason of this is a reduction of the angle of the stream of the liquid sprayed under the influence of the stream of air from the rotating drone rotors, which causes a concentration of the liquid in the middle section of the drop stream.

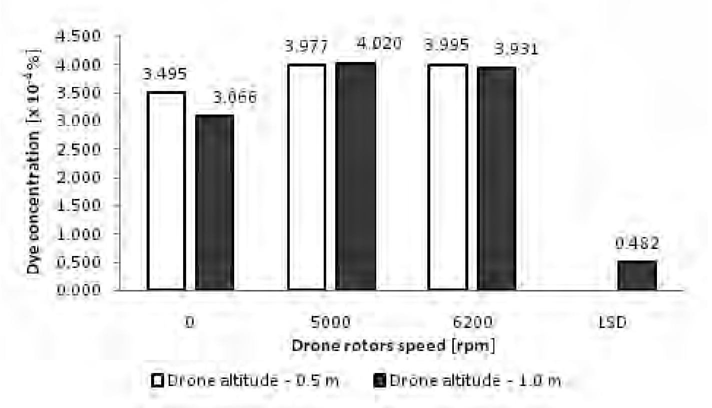


Fig. 3. Influence of the altitude of the drone with the sprayer over the plants and the rotational speed of the engines on the average values of the liquid deposited on the samplers from the three levels of the plants

A diagram (Fig. 4) was also made of changes to the uniformity index – CV for the liquid deposited on the samplers placed on the three levels of the plants depending on the speed of the rotors, according to Equation 1.

$$CV = \frac{100}{c_m}\sqrt{\frac{\sum(c_i - c_m)^2}{3}}\ [\%] \qquad (1)$$

where:

$CV$ - uniformity index of the sedimentation of the liquid on the samplers, %

$c_i$ - average concentration of colouring agent in the liquid washed away from the samplers on the i-th level

$c_m$ - average concentration of the colouring agent in the liquid washed away from the samplers determined for the samplers from three levels

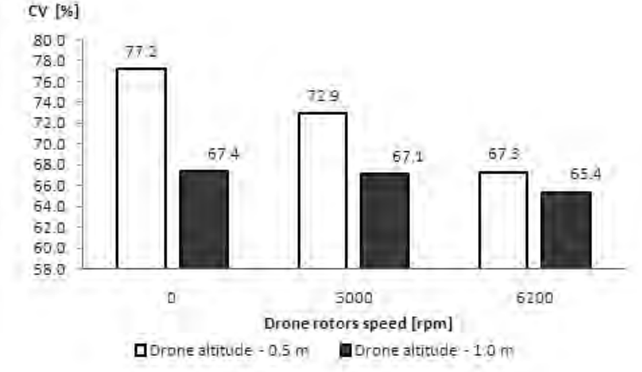


Fig. 4. Influence of the altitude of the drone with the sprayer over the plants and the rotational speed of the engines on the uniformity index of the deposition of the liquid on the levels of the plants - CV

The results presented in Diagram 5 demonstrate the influence of an increase of the rotational speed of the drone rotors on an improvement uniformity of the sedimentation of the liquid on the rape plants on the altitude of 0.5 m over the plants. With a higher altitude of 1.0 m over the plants, the impact of the rotational speed of the rotors on any change to the uniformity was negligible.

## CONCLUSIONS

As a result of tests, an influence was found of the stream of air coming from the rotating drone rotors on an improved uniformity of the sedimentation of the liquid on the plants. Significant changes occurred both on the upper surface of the plants and on the middle level, while there were insignificant changes on the lower level under plants. This proves a beneficial effect of the air stream, whose primary purpose is lifting and moving the drone over the plants. The strongest influence of the air stream and the rotational speed of the drone rotors on an improved uniformity and the changes of the volume of liquid sediment on the individual levels of plants was found on the altitude of 0.5 m over the plants. The stream of air coming from the drone caused a significant increase of the average volume of the liquid deposited on the plants, yet this is the result of the concentration of the stream of drops under the influence of the pressure of the flowing stream of air.

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## 1.4. INFLUENCE OF BALING PROCESS ON THE QUALITY OF FODDER - FIRST EVALUATION

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**Keywords:** square baler; forage quality; forage fibres; soil impurities

## ABSTRACT

The livestock sector requires fodder of excellent quality, which is mainly characterized by its nutritional composition, that is the content in carbohydrates (fibre and sugars), proteins and other constituents present to a lesser extent, such as minerals and vitamins. As known, fibrous carbohydrates are represented by the neutral detergent fibre (NDF), which is divided into two portions: indigestible NDF and potentially digestible NDF. The aim of this study was to analyse the nutritional composition of fodder, in terms of fibre, in order to evaluate the possible influence of the different operating machines on the content of the fibre itself. Therefore, three different prismatic chamber balers were considered for the tests, which operated simultaneously on the same hay field. The results of first experimental tests highlight that the baling process performed by the tested balers has poor influence on the quality of the fodder.

## INTRODUCTION

The evolution of the number and size of the livestock sector companies and the continuous improvement of the productive potential of the cows, highlights increasingly the need to have hays of excellent quality and nutritional characteristics (Bortolazzo *et al.*, 2009; Sun *et al.*, 2010). In general, the use of good quality fodder should also be promoted for the maintenance of an optimal state of well-being and animal health, as well as to strengthen the increase in profitability of livestock farms (Cazzato *et al.*, 2012). The better quality of hay fodder requires careful control of all the harvesting phases from mowing to baling. This last phase allows, depending on the baling process performed by the baler implement, to give a product more or less clean from the point of view of impurities (Guerrieri *et al.*, 2019; Anifantis *et al.*, 2018). In the definition of hay quality, great importance is given to sanitary hygienic characteristics which can be summarized in the content of mycotoxins, clostridia (anaerobic bacilli), which in turn generate health problems for cows and consequent qualitative decay of cheeses (Cazzato *et al.*, 2013). Often the presence of clostridia and mycotoxins derives from the terrain presence inside fodder. In this regard, it is by now consolidated the link between the terrain presence in the ration distributed to the cows and the onset of defects of late swelling of the cheese, due to the proliferation of spores of clostridia that pass from the animal to the faeces and reach the milk through the contamination of the cowshed environment (Parsons *et al.*, 2006). The concept of digestibility of the different food components and the low presence of molds and toxic substances are part of the quality of the fodder (Kalu *et al.*, 1990). To obtain an adequate diet for dairy cows it is necessary to characterize and know the real nutritional value of the foods that are used in the company. Each fodder is characterized by its nutritional composition, that is the content in carbohydrates (fibre and sugars), proteins and other constituents present to a lesser extent, but still important for the body, such as minerals and vitamins (Yupeng *et al.*, 2019). Vegetable carbohydrates are divided into structural (fibrosis), i.e. those that form cell walls, and non-structural (non-fibrous). Fibrous carbohydrates are represented by the content of neutral detergent fibre (NDF), available for attack by rumen bacteria, which use them as an energy source for their growth and for the formation of volatile fatty acids. Therefore, they represent an important energy source for the ruminant. Only a portion of fibrous carbohydrates is completely indigested by bacteria and animals, which consists of lignin and some protein fractions and fibre fractions related to them. The NDF is then divided into two portions: indigestible NDF and potentially digestible NDF (Van Soest and Robertson, 1985).

Taking in mind the aforesaid, the aim of this study was to analyze the nutritional composition of fodder, in terms of fibre in order to evaluate the possible influence of the different operating machines on the content of the fibre itself.

## MATERIALS AND METHODS

Experimental tests were executed in order to evaluate the influence of the baling process performed by three different balers on the content of fibres inside fodder and the quality of the fodder itself in terms of nutritional composition. Therefore, three different prismatic chamber balers were considered: Cicoria Big Baler HD 1270 T (Figure 1), New Holland 1290 PLUS (Figure 2) e Krone Big Pack (Figure 3). During the tests, the three machines operated simultaneously on the same field. Using a special drill, three samples of fodder were taken from the prismatic balers produced by each machine, according to an experimental scheme with randomized blocks. For the statistical analysis, three theses were taken into account, corresponding to the samples belonging to the bales obtained respectively from: Cicoria machine (thesis 1), Krone machine (thesis 2) and New Holland machine (thesis 3). Furthermore, three repetitions were considered for each thesis (Gomez & Gomez, 1984; Manetto *et al.*, 2017).

Fig. 1. Large square baler Cicoria HD 1270 T

Fig. 2. Large square baler New Holland 1290 PLUS

Fig. 3. Large square baler Krone Big Pack

The collected samples were then processed in the laboratories of the Department of Agricultural and Environmental Science of the University of Bari Aldo Moro, following these steps:

a) to remove the humidity and to standardize the initial conditions all obtained samples, previously weighed, were submitted to ventilated drying at 65 °C for 3 hours in using the forced ventilation stove HOLITY model M60-CF BASIC (Namiti Srl, Italy);

b) to establish the dry matter rate, the dried samples were weighed once again using the electronic analytical balance ABT model 220-5DM (KERN & SOHN GmbH Industry, Germany);

c) to obtain a fineness of 2 mm, the samples were ground and sifted through the hammer-type laboratory mill ERKAYA model HM 210 (Erkaya Laboratory Instruments & Flour Improvers Ltd. Co., Turkey).

After determining the dry substance content, useful to evaluate the NDF value, the dried and ground samples were analysed in order to determine the fibres and so to establish the quality of fodder. The vegetable fibres are heterogeneous set of substances characterized by rumen degradation and highly variable intestinal digestibility. Fibres are composed by pectins and glucans (soluble fractions), cellulose (insoluble fraction), hemicellulose and lignin. The analysed predictive fibres components of the forages were: i) the neutral detergent fibre (NDF); ii) the acid detergent fibre (ADF). The detergent analysis developed by Peter Van Soest is today one of the main evaluation sets of fodder and feed for animal nutrition. This method performs a sequential fractionation of fibre fractions in NDF and ADF.

## RESULTS AND DISCUSSION

Following the methods developed by Van Soest, the analyses allowed to evaluate:

- the neutral detergent fibre (NDF), which estimates the content of hemicellulose, cellulose and lignin, reflecting the amount of fodder that the animal can consume. It needs to consider that, an increase in the percentage of NDF usually corresponds to a decrease in the amount of dry matter ingested;
- the acid detergent fibre (ADF), which estimates the cellulose and lignin content. This value highlights the animal's ability to digest fodder, taking into account

that an increase in ADF corresponds to a decrease in the fodder's digestibility capacity;

The results obtained from the first test carried out using the described machines are summarized in Figure 4.

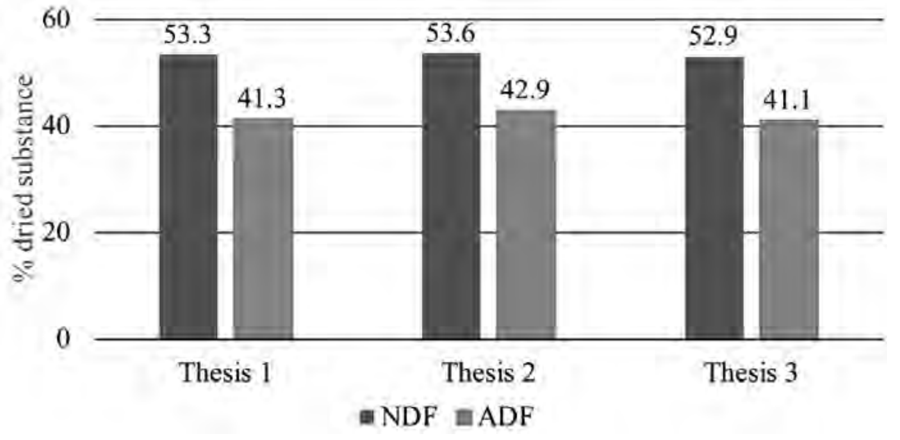


Fig. 4. Average obtained results concerning some predictive parameters of fodder fibres

Among the three theses, the maximum percentage difference has been about 1% for the neutral detergent fibre (NDF), whereas about 4% for the acid detergent fibre (ADF) (Figure 4). Therefore, analysing these first average results seem that the baling process performed by the tested balers has poor influence on the quality of the fodder. Nevertheless, further tests and analyses are in progress in order to confirm this statement.

**CONCLUSIONS**

The use of quality fodder is a key element to improve the productive results, health and well-being of the cows. Field tests were carried out using three different large balers produced by different manufacturers in order to assess the influence of each corresponding baling process on the content of fibres inside fodder and then its nutritional composition. The three considered machines had similar technical characteristics but different systems to produce the prismatic bales. The obtained results emphasize that the different types of baling process performed by the tested machines do not affect the fibre content of the forage, taking into account that all the machine worked in the same day and on the same field. Probably, the analysed predictive fibres components, that is the neutral detergent fibre (NDF) and the acid detergent fibre (ADF), are much more affected by the time or the methods of conservation.

Finally, although the data is still being processed, these first results allow us to highlight the effectiveness of the methodology used, also providing inspiration for subsequent work.

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# 1.5. SELECTION METHOD OF AIRCRAFT TYPE FOR AERIAL SPRAYING OF FORESTS

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**Keywords:** agricultural aviation, efficiency of aerial application

## ABSTRACT
Many types of aircraft are available for aerial application of pesticides in forests. They differ significantly in terms of operating parameters such as operating speed, turning time and swath width. The diversity of forest habitats results in the fact that insect population reduction measures are carried out over areas of irregular shapes and varying sizes. Therefore, the selection of an aircraft is not a trivial task. To address this problem, the author puts forward an algorithm for selecting the aircraft type. It allows for specific conditions of the treatment operation and its objective is to achieve either the highest efficiency or the lowest unit cost of the treatment.

## INTRODUCTION

Due to the structure of forest habitats and the selection of species, Polish forests are particularly vulnerable to rapid and massive outbreaks of leaf-eating insects. To keep forests alive, one needs to react promptly. Therefore, the protection of Polish forest relies on aerial insect population control measures. Recent technological development in positioning systems and electronically controlled sprayers provides the aerial applicators with reasonably priced tools that enable precise and safe administration of pesticides even over small areas. However, the economic efficiency of aerial treatment is conditioned by the selection of the carrier of the spraying system. The choice of spraying aircraft is limited due to the considerable cost of their acquisition and maintenance. Currently, the Polish State Forests use four types of aircrafts equipped with dedicated spraying systems. Their parameters are listed in Table 1.

Table 1. Aircrafts used by the Polish State Forests

| Type | Model | Tank capacity, l | Swath width, m | Average operating speed, km/h | Average 180° turnaround time, s |
|---|---|---|---|---|---|
| Single-engine piston aeroplane | PZL M-18 Dromader | 2500 | 40 | 177 | 98 |
| Single-engine piston aeroplane | Antonov An-2 | 1350 | 40 | 162 | 48 |
| Helicopter | Mi-2 | 600 | 30 | 86 | 26 |
| Gyroplane | Zen-1 | 150 | 17 | 90 | 60 |

The research aimed to provide a method for selecting the aircraft type most suitable for a particular aerial treatment operation according to the characteristics of the area to be treated (size, shape, distance from the airport) to maximize efficiency or to minimize unit cost of the operation. In literature (Bungescu *et al.*, 2011, Giles & Billing 2014, Bzowska-Bakalarz *et al.*, 2015), there are no studies comparing operational and economic parameters of various aircraft.

## MATERIALS AND METHODS

### Theoretical analysis of aerial spraying operation

The first analysis of an agricultural aerial treatment process is attributable to Baltin in 1959 (Rowiński 1994) who broke down the spraying cycle into the following operations:

- Preparation time (preparation of pilot and aircraft for take-off, refuelling the aircraft, refilling the tank with the plant protection product),
- $T_c$ – flight time that comprises:
  - ✓ Time to arrive at the plot to be treated and to return to the airport,
  - ✓ Working flight time with the spraying system on – flight along the subsequent flight paths over the treated plot,
  - ✓ Total turnaround time (all time spent to change the position between the subsequent flight paths),
  - ✓ Time to arrive at the subsequent plots (if a number of separate locations are to be treated in the same operation).

This analysis focuses on the flight time $T_c$, ignoring the preparation time. The total flight time can be expressed by the following formula:

$$T_c = \frac{\Sigma r}{V_p} + \frac{F}{B\,V_r} + n\,T_n \qquad (1)$$

where:
$\Sigma r$ – the sum of the distances between the airport and the treated plots
$V_p$ – average aircraft cruising speed
n – the number of the flight paths (swaths) over the plots
F –area of the treated plots
B – swath width
$V_r$ –operating speed (during spraying)
$T_n$ –time of a single turnaround

Formula (1) was the basis for the algorithm for selecting the best type of aircraft for an aerial treatment operation according to the particular conditions of this operation. The ratio of the operation efficiency $W_h$ was expressed as:

$$W_h = \frac{F}{T_c} \qquad (2)$$

where F, $T_c$ are as in Formula (1).

### Characteristics of the test plots

The object of analysis were interventions to reduce the population of leaf-eating forest insects recorded for north-western Poland between 2013 and 2015. The sample comprised 230 aerial spraying operations conducted by means of various carriers over 292 plots of the total area of 62,532 ha. Each operation was characterised by following data: the total treated area (ha), the flight time (h), the distances between the airport and the target plot (km) and the distances between the plots in the case that a number of plots were treated during the same aerial operation (km), the number of flight paths over each plot, the average length of a flight path in the operation (m). These were the basis for calculating the operation efficiency (ha/h), the unit cost of aircraft deployment (PLN/ha) and the total unit cost of operation (PLN/ha) that is the sum of aircraft deployment cost, the cost of plant protection product and the cost of ground operations.

The plots treated in the course of the above operations were of various shapes and sizes, which came from the natural diversity of forest stands and the variability of the spatial distribution of insects. Moreover, the operations differed significantly in terms of distances between the airports and the target plots. Distribution parameters of the plots, divided according to the insect species to be controlled, are summarized in Tables 2 and 3.

Table 2. Characteristics of the sample of forest plots subject to aerial spraying

| Insect species | Number of treated plots | Treated area, ha | | | | Median | Std. dev. | Shapiro-Wilk test p-value |
|---|---|---|---|---|---|---|---|---|
| | | Total | Smallest plot | Largest plot | Mean plot size | | | |
| *Dendrolimus pini* | 58 | 52,699 | 44.5 | 3514 | 909 | 566 | 903.4 | <0.00001 |
| *Operophtera ssp.* | 226 | 9,399 | 4 | 623 | 41.6 | 20.5 | 64.3 | <0.00001 |
| *Melolontha ssp.* | 8 | 434 | 4 | 105 | 54.2 | 42.8 | 40.2 | 0.202 |

Tab. 3. Characteristics of the sample of forest plots subject to aerial spraying (continued)

| *Dendrolimus pini* | | | | *Operophtera ssp.* | | | | *Melolontha ssp.* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean length of a flight path in a particular plot, m | | Distance from airport to target plot, km | | Mean length of a flight path in a particular plot, m | | Distance from airport to target plot, km | | Mean length of a flight path in a particular plot, m | | Distance from airport to target plot, km | |
| min. | max. | min. | max. | min. | max. | min. | max. | min. | max. | min. | max. |
| 487 | 7395 | 3.0 | 72.2 | 198 | 2739 | 1.8 | 71.1 | 542 | 781 | 6.3 | 37.9 |

## RESULTS

The efficiency of agricultural operations achieved by aircrafts during agricultural operations are presented in Table 4.

Table 4. The efficiency of agricultural operations achieved by aircrafts during agricultural operations in ha/h

| Aircraft model | *Dendrolimus pini* ha/h | | | *Operophtera ssp.*, ha/h | | | *Melolontha ssp* , ha/h | | | Mean efficiency ratio, ha/h | Std. Dev. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | min. | max. | mean | min. | max. | mean | min. | max. | mean | | |
| M-18 | 51.50 | 267.86 | 134.75 | 14.18 | 101.54 | 50.99 | 25.56 | 52.00 | 35.42 | 81.43 | 54.5945 |
| An-2 | 25.50 | 312.25 | 168.96 | | | | | | | 168.96 | 64.4319 |
| Mi-2 | | | | 6.14 | 74.47 | 40.85 | | 49.00 | | 41.04 | 15.9457 |
| Zen-1 | | | | 4.67 | 27.73 | 14.17 | | | | 14.17 | 6.1361 |
| General | | | 164.00 | | | 40.19 | | | 38.13 | 114.34 | 79.4411 |

The Spearman rank correlation coefficients for the relationship between the operation efficiency ratio and features of the treated plots are listed in Table 5. Statistically significant correlations (at $p < 0.05$) are marked bold.

Table 5. Spearman rank correlation coefficients between the efficiency ratio and plot qualities according to the aircraft model

| Plot feature | M-18 | An-2 | Mi-2 | Zen-1 |
|---|---|---|---|---|
| Area, ha | **0.932247** | **0.654565** | **0.783648** | **0.643956** |
| Mean length of the flight path, m | **0.885816** | **0.685742** | **0.323232** | **0.577094** |
| Distance between the airport and the plot, km | -0.207537 | **-0.501834** | **-0.392787** | -0.090408 |

To visualize the distribution of input, scatter plots of efficiency ratios against the area of the treated plot and against the mean length of a flight path are presented, respectively, in Figures 1 and 2.

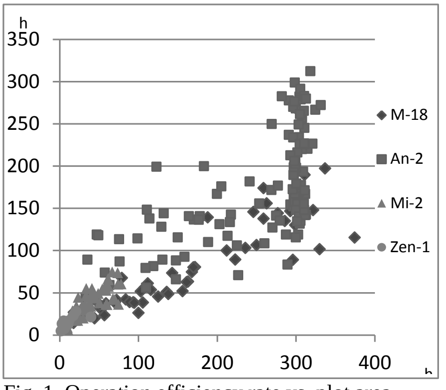


Fig. 1. Operation efficiency rate vs. plot area

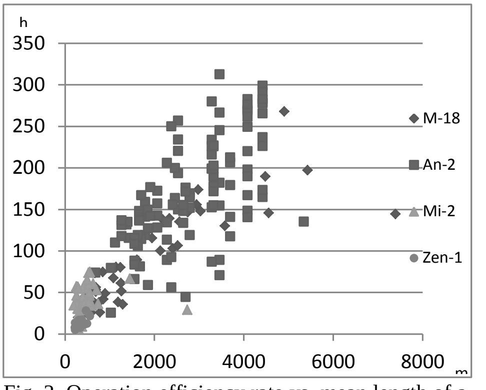


Fig. 2. Operation efficiency rate vs. mean length of a flight path over the plot

**ALGORITHM FOR AIRCRAFT SELECTION**

As the efficiency of an aerial operation conducted by means of a particular aircraft is conditioned by a number of plot-related factors, it is not possible to provide simple rules of aircraft selection. Therefore, the author puts forward a selection algorithm based on Formula (1).

To use the algorithm, the planner needs to collect the input parameters characterizing each aircraft in consideration, namely: the operating speed, the turnaround time, and the unit contract price per hour of the service. The variables related with particular conditions of the operation are the area of the plot to be treated, swath width, the number of turnarounds, the sum of the lengths of flight paths and the distance from the airport.

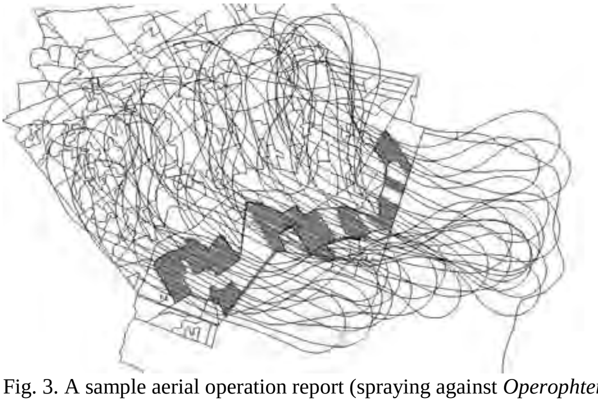

Fig. 3. A sample aerial operation report (spraying against *Operophtera ssp.*)

Figure 3 presents an example of a real aerial operation – track log from GPS AGRO system while spraying a 64-ha plot of oak forest against *Operophtera ssp;* the operation was conducted by means of M-18 aircraft and the airport was located 60 km from the target plot.

The total flight time of this operation was 1 hour and 52 minutes, including time to arrive from the airport to target and back of 40 minutes. Therefore, the efficiency rate of this operation calculated according to Formula (2) was 28.9 ha/h.

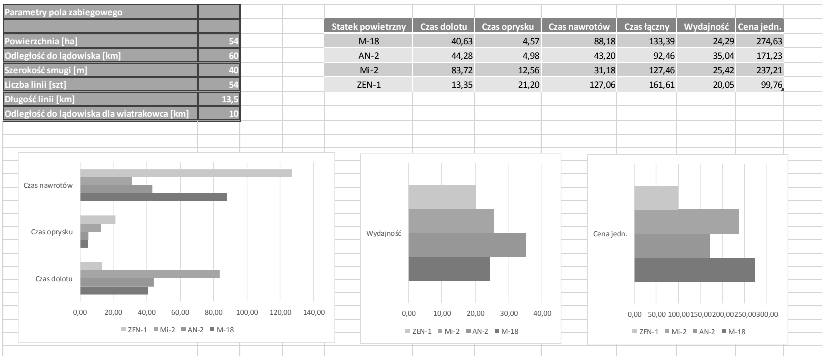


Fig. 4. Computer application of the algorithm – user interface presenting an example of a comparative analysis

The proposed algorithm allows the user to compare the components of the flight and expected efficiency rates and unit cost of conducting this operation by means of other potentially available aircrafts. Figure 4 presents the user interface of the computer application of the algorithm with results of a sample analysis.

## CONCLUSIONS

1. The efficiency of aerial spraying operations and their cost of aircraft deployment are differently affected by the factors related with the plots to be treated though, regardless of the aircraft, they both are strongly dependent on the area of the plot and on the average length of the flight path.
2. The proposed algorithm, designed to support decisions on selection of an aircraft for a particular operation, enables the user to easily compare the theoretical efficiency rate (ha/h) and unit cost (PLN/ha) of deploying each aircraft in consideration.

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# 1.6. USING DRONES TO TRACK THE DEVELOPMENT OF MAIZE CULTIVATION

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**Keywords:** precision agriculture, quadcopter, RGB imaging, variety maize, vegetation indices

## ABSTRACT

The subject of study in this article is a field planted with maize. There was a video made by the drone equipped with an RGB camera in the months from April to August 2019. Subsequent processing of the photographic material was made. The resulting digitized surface model (DSM) was created as a result of the orthomosaic of the maize. Vegetation indices was calculated: VARIgreen and ExG. On this basis, conclusions were drawn for the development of the observed maize variety DEKALB DKC4541.

## INTRODUCTION

Unmanned aerial vehicles (drones) are a technology that is rapidly gaining popularity in both manufacturing and scientific communities. They offer an easily accessible air platform that can accommodate a variety of aerial imaging with very high spatial and temporal resolutions. Advances in accuracy, cost-effectiveness and miniaturization of new technologies, including GPS and computer processors, are contributing to the widespread adoption of this innovative remote monitoring platform. Approximately 88.5% of genotype research publications in the last 5 years have been focused on the use of drones for remote control, (Yang G, *et al.*, 2017). Important for drone research applications was the gap that they filled between the expensive use of LIDAR aircraft and the limitations of resolution when using satellite and aerial remote sensing, (Holman, *et al.,* 2016).

From the vegetation regions observed the reflection of waves was registered from the frequency spectrum, which is a mixture of vegetation, soil colour, environmental impact, shade and moisture. Over the last two decades, more than forty vegetation indices (VIs) have been developed to look for ways to improve vegetation information and minimize the effects of natural factors. (Bannari A., *et al.,* 1995)

The index had to be particularly sensitive to vegetation canopies, insensitive to soil brightness, insensitive to soil colour, slightly influenced by weather, environmental effects and solar geometry of illumination, as well as sensor monitoring conditions, (Jackson, 1983). The monitoring conditions are second only to the brightness of the soil. Therefore, the soil colour index is a correction that doubles the sensitivity of plant indices. By analogy with NDVI, this index correction is determined by the following equation: (R-G)/(R+G), where R is the mean reflection in red, G is the mean reflection in green.

In order to compare the vegetation indices of VIs, their initial ranges are standardized by linear scaling on a byte scale from 0 to 255. This procedure made it possible to compare all VIs that use the same sample of data. Sensor conclusions are specific to this data set and should not simply extend to other situations and geographical locations. However, the results show that differences in plant indices values are insignificant for certain crops and soil types. This means that every VI has the same meaning and utility.

In other cases, when the stages of crop and plant development differ more, values of specific VI not only mean different changes in the colours (which might be more or less useful for interpretation), but they also become slightly stronger distinguishing mark for some crops, (Mróz M. & Sobieraj A., 2004).

The purpose of the study (Gitelson, *et al.*, 2002) was to investigate the information content and spectral effects of crops in the visible and near-infrared spectrum and to develop a technique for remote estimation of the vegetation fraction (VF). However, indices had limitations, some of which were due either to the choice of bandwidth or to the fact that mid-year levels of NIR reflection decreased with increasing VF. This behaviour hindered the use of NIR for evaluation in moderate to high crop cover.

In (Laliberte & Rango, 2009), an optimal segmentation scale and the most appropriate textural measures were identified to distinguish bare land, shrubs and grassy vegetation using unmanned aircraft. A working solution were developed to monitor pastures using unmanned aerial vehicles. Pixel-based analysis was performed for a selected pixel window based on object image analysis.

The technical features and configuration of the quadcopter were defined (Tores-Sanches *et al.*, 2012) and the spatial and spectral requirements for the acquisition of images by two sensors were evaluated: conventional video camera and six channel multi-spectral camera with exceptional ability to discriminate weed presence in a sunflower field at an early plant stage for subsequent rescue treatment. The steps for preparing and using a drone with the two cameras were described, as well as the importance of flight altitude, pixel size on the ground, sensor properties and spectral image information. The widely used vegetation indices NGRDI and ExG were used to distinguish soil from vegetation, for which only the reflection data from the RGB camera was required.

An innovative practical solution to the problem was proposed (van der Wal *et al.*, 2013) the influence of cloud cover over the field from which they wanted to obtain photo material. With a drone-mounted radar sensor was used to "see" through the clouds, like the similar Green Seeker and N-Sensor sensors. Generally, the resolution of the satellites was 6.0 to 0.5 m. On the other hand, the drone could fly at a wind speed greater than 8 m/s and its flying time was generally between 10.00 and 14.00 during the day. The probability of receiving timely useful information from the satellite was about 20%, and that for drone photos was 45 to 70% independent of the weather conditions. Drones were a valuable addition to satellite surveillance.

To distinguish living plant material from the soil background, several indices were tested and successfully identified for weeds based on chromatic RGB coordinates, (Woebbeke *et al.*, 1995). The indices include r-g, g-b, (g-b)/(r-g) and 2g-r-b. Saturation or shade of colours were also used to distinguished weeds from soil. This value, expressed by the Excess Green Index = 2g-r-b on the green chromatic coordinate, distinguishes weeds from the soil background. This index worked well for both shaded and non-shaded solar conditions. It was used to design weed sensors and to control spraying where weeds are found.

The purpose of the present study is to collect video information (sufficient digital images) for the development and condition of a field sown with maize. Calculate the relevant vegetation indices of the digitized information available from the RGB reflected light maps which are to be analysed from the point of view of the development and condition of the crop.

## MATERIAL AND METHOD

The Phantom 4 Pro drone with RGB camera FC6310_8.8_4864x3648 and DJI's Mavic 2 Pro drone equipped also with RGB camera were used for the study. The subject of the shooting was a field of 230 acres with coordinates: 43030'46.156 "; N, 270 40 '54,469 “E. Flight height 100 m. In the western part of the field, maize Dekalb DKC4541 ФАО 370 was planted on April 29 and 30, 2019 (day from the beginning of the year - 120) with a row spacing of 0.7 m and 0.20 m. The direction of the rows was east - west. A drone video recording equipped with an RGB camera took place in the months of April, May, June, July and August 2019.

The RGB Mavic 2 Pro drone camera had a built-in matrix 1/2,3“ CMOS, with effective pixels 12,35 Mp; lens with viewing angle $78,8^0$, focal length 20 мм, aperture f/2,2; image distortion less than 1,5%; focal length from 0.5 m to infinity; ISO for photos from 100 – 1600, for video from 100 to 3200, maximum image size 4000x3000; image format JPEG.

The Phantom 4 Pro drone had a built-in camera with a one-inch additional metal oxide sensor that captured the red-green-blue reflected light. The camera had 840 lens with aperture f/2.8 and resolution 4864 * 3648 = 17 743 872 pixels, (17.7 MPx). Main parameters of RGB imagery acquisition system: Wheelbase 350 mm; Weight 1388 g; Flight time 30 min; Communication radius 5 km; Speed 72 km/s; Image sensor 1-inch CMOS; RGB colour space sRGB; Lens focal length 8.8; Lens field of view 84 ISO range 100–12,800; Shutter speed 8–1/8000 smm/24 mm.

The processing of the captured image of the crop and the corresponding digitized surface model (DSM) was performed with the software product Pix4Dmapper version 4.4.12.

## RESULTS AND DISCUSSION

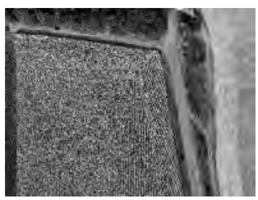
More than 300 photos were taken for each experiment. Fifty photos were separated from them which show the condition of the same plot of land, (Fig. 1.).

a) 22.04.2019

b) 20.05.2019

c) 28.06.2019

d) 31.07.2019



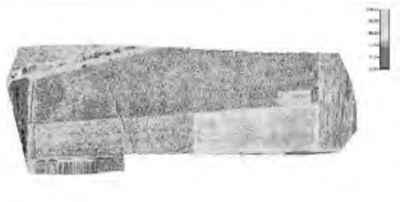
e) 27.08.2019

Fig. 1. Pictures of the surveyed plot of land by date

a) 22.04.2019 - soil without sowing

b) 20.05.2019 - 21 days from sowing

c) 28.06.2019 - 59 days from sowing



d) 31.07.2019 - 92 days from sowing

e) 27.08.2019 - 119 days from sowing

Fig. 2. Maps of reflected light from the test plot: R - 660 nm; G - 550 nm; B - 470 nm .

On the Pix4Dmapper software maps (Fig. 2), the three reflected wavelengths are color-coded using the generalized Grayscale index, where the smallest fraction has the blue reflection.

$$Grayscale = 0.2126 * R + 0.7152 * G + 0.0722 * B \tag{1}$$

where R, G and B are the average values of the respective reflected colours determined by the Pix4Dmapper program.

The vegetation indices of the RGB information obtained are calculated using the following formulas: VARIgreen - Visible Atmospheric Resistance Index green, (Gitelson, *et al.*, 2002):

$$VARIgreen = \frac{R_{Green} - R_{Red}}{R_{Green} + R_{Red} - R_{Blue}}; \tag{2}$$

ExG - Excess Green Index, (Woebbeke *et al.*, 1995):

$$ExG = 2g - r - b \tag{3}$$

where:

$$g = \frac{R_{Green}}{R_{Green} + R_{Red} + R_{Blue}};\ r = \frac{R_{Red}}{R_{Green} + R_{Red} + R_{Blue}};\ b = \frac{R_{Blue}}{R_{Green} + R_{Red} + R_{Blue}}$$

Their change by date is shown as graphs in Figure 3.

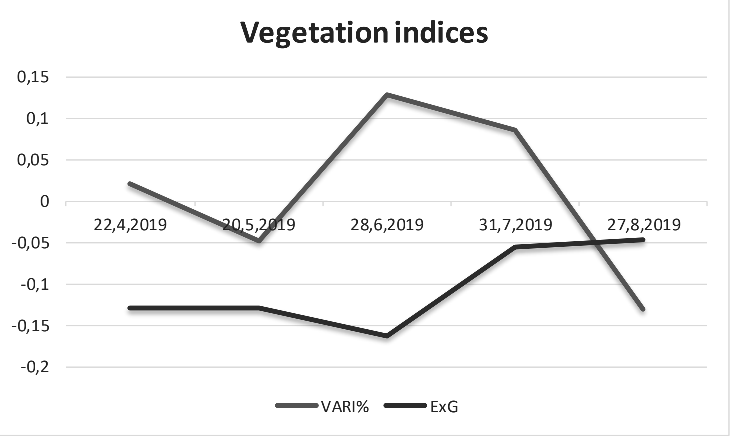



Fig. 3. Vegetation indices.

In practice, during the April shoot, (Fig. 1a, Fig. 2a), no vegetation was observed in the field, i.e. this is the picture of bare soil. In the second survey in May (Fig. 1b, Fig. 2b), maize plants emerged in the first - second leaf phase, so the indices are close to zero. Real vegetation can be seen in the months of June and July (Figs. 1c, d, and Figs. 2c, d) as the indices increase.

**CONCLUSIONS**

Video information was collected with a remote controlled unmanned aerial vehicle for the development and condition of a field sown with maize variety DEKALB DKC 4541 in the form of digital images with an RGB camera. Maps of reflected light were compiled, and statistics was obtained for a specific plot of land in the months of April, May, June, July and August with the software product Pix4Dmapper version 4.4.12. A summary index of the RGB reflection was calculated as well as the corresponding vegetation indices, VARIgreen and ExG with the digitized information available from the RGB reflected light maps. The analysis of the graphs for the change in the vegetation of maize from its sowing to August showed that the development and condition of the crop was very good.

The plants are in the stage of milky maturity and the ripening of the grain is about to be completed.

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# 1.7. SUGAR BEETS GROWN IN THE ONE AND TWO-STEP STRIP-TILLAGE SYSTEM AT DIFFERENT SOIL CULTIVATION DEPTHS

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**Keywords**: sugar beet, strip-till, plant density, yield quality, sugar content

## ABSTRACT
Modifications in soil cultivation affect the quality and quantity of the yield of sugar beets. The crop density, yield and the external quality of sugar beet roots are highly dependent on the preparation of soil. The sugar beet production technology with the soil cultivation system, which includes selection of the cultivation depth, affects a wide range of yield characteristics, such as the root processing quality, the size and shape of the root system. The aim of the study was to determine the dependence between the depth of soil cultivation in the strip-tillage system used for sugar beet production and the state of the plantation after the emergence of crops as well as the yield quality and quantity. The study included one and two-step strip-till technologies. The systems were evaluated according to the dynamics of crops' emergence, density, yield and external and internal quality of sugar beet roots.

## INTRODUCTION
The basis for agricultural production is the pursuit of the obtained highest possible yield with appropriate quality for consumption, processing and storage. Apart from the climate and soil conditions, the technique of agrotechnical procedures largely influences the sugar beet yield quality and quantity. It ensures the adequate depth of cultivation, regular sowing depth as well as adequate and timely treatments (Koch *et al.*, 2009, Mikita & Gutmański, 2002). The agricultural technique is decisive to the yield volume and quality, including the external quality of roots. The soil cultivation technology affects the productivity of crops, because it is simultaneously decisive to the dynamics of plants' growth at an early phase of their development and it provides plants with favourable conditions for growth and development until they are harvested (Gaj *et al.,* 2015, Mioduszewska *et al.*, 2018). Well-balanced emergence affects crop density and it is decisive to the plantation density and regularity. These factors are essential for the high technological quality of yield and minimal loss during the harvesting of roots (Michalska-Klimczak & Wyszyński, 2010). Individual agrotechnical procedures are supposed to guarantee yield stability and adequate technological properties of roots for sugar extraction.
The traditional cultivation system with soil reversion is the most common. However, in recent years, for economic and environmental reasons, the classic tillage system has been replaced by simplified systems, including the strip-tillage system (Kataoka et al. 2009). Apart from the reduced energy outlay resulting in lower costs of production, simplified technologies (without ploughing) have significant influence on protection of the environment (Erdal *et al*., 2007). Lower intensity and frequency of treatments applied to soil protect it from degradation, aid natural biological processes and maintain its productivity (Cavalaris & Gemtos, 2002, Tarkalson *et al.*, 2012).
The sugar beet production technology with the soil cultivation system, which includes selection of the cultivation depth, affects a wide range of yield characteristics, such as the root processing quality, the size and shape of the root system (Mioduszewska *et al*., 2018). Therefore, the aim of the study was to determine the dependence between the depth of soil cultivation in the one and two-step strip-tillage system used for sugar beet

production and the state of the plantation after the emergence of crops as well as the quality and quantity of yield.

## MATERIALS AND METHODS

A field experiment was conducted on the farm in Trzcianka, Commune of Kuślin, Greater Poland Voivodship, Poland. The experiment included nine sugar beet cultivation technologies. Cultivation in the strip-till system was carried out with Duro France aggregate (one-step technology) and Kuhn Striger aggregate (two-step technology) at depths of 15, 25 i 35 cm. In the one- and two-stage strip-till technology also it was used the variant with undersowing fertilizer. As control in the experiment, ploughing was used. The following 9 technologies were analysed:

1. **SO** – Control – traditional system (ploughing), depth 25 cm
2. **STN** – Strip-till – STRIGER + undersowing fertilizer, depth 25 cm,
3. **ST15** – Strip-till – STRIGER + without undersowing fertilizer, depth 15 cm,
4. **ST25** – Strip-till – STRIGER + without undersowing fertilizer, depth 25 cm,
5. **ST35** – Strip-till – STRIGER + without undersowing fertilizer, depth 35 cm,
6. **DFN** – Strip-till – DURO FRANCE + undersowing fertilizer, depth 25 cm,
7. **DF15** – Strip-till – DURO FRANCE + without undersowing fertilizer, depth 15 cm,
8. **DF25** – Strip-till – DURO FRANCE + without undersowing fertilizer, depth 25 cm,
9. **DF35** – Strip-till – DURO FRANCE + without undersowing fertilizer, depth 35 cm.

Two-stage strip-till cultivation consisted of autumn and spring cultivation using Kuhn Striger aggregate. The first stage was carried out in November, the second on the day of sowing, where the same rows were cultivate as in the fall. Then, after loosening the soil strips, seeds were sown with a Kuhn Maxima seeder. One-stage strip-till cultivation was carried out simultaneously with sowing, in one pass, using the aggregate consisting of the Duro-France Strip-till machine and the Monosem NG seeder. Other agrotechnical procedures, such as fertilisation and treatments, were identical in all the systems and they were conducted according to the sugar beet growing guidelines.

The experiment was planned in block system in three repetitions. The every plot area was 110 x 10.8 m. The sugar beets were sown on 21 April. In theory, the sugar beet seeds were spaced at 18 cm from each other.

The state of the plantation after the emergence of crops was evaluated on the basis of the emergence dynamics, the distribution of plants in rows and the crop density. The emergence was recorded every second day after the appearance of the first sugar beet seedlings at the phase of cotyledons. In each plot all emergences of sugar beets in an area of 10 $m^2$ were counted in three replicates.

The distribution of plants in rows was evaluated as follows. In each plot 100 consecutive distances between plants in randomly selected rows were measured at an accuracy of 5 mm in three replicates. According to the methodology of the International Sugar Beet Institute in Brussels (IIRB – L'institut International de Recherches Betteravières) the measurement results were classified into one of the three categories: double sowing, normal spacing and overspaced sowing [Vandergeten *et al*., 2004].

The final density of plants was calculated by counting plants in randomly selected sites of an area of 10 $m^2$ in three replicates in each plot.

The state of the plantation before harvest was evaluated according to the yield of roots and the morphological traits of the roots, i.e. their length, maximum diameter and weight and sugar content in roots. In order to measure the morphological traits the root

tops were cut off manually at the upper line of the living shoot buds. The root length was measured from the site where its top was cut off to the end of the tail with a diameter of 10 mm. The diameter was measured at the widest part of the proper root. Before the roots were weighed, their tops had been cut off and cleaned. 100 roots were collected from three randomly selected rows in each plot and their length, maximum diameter and weight were measured.
The yield of the roots from each plot was measured according to the weight of 300 roots and the final density of sugar beets. The sugar content of sugar beets was checked in the Pfeifer & Langen sugar factory laboratory in Środa Wielkopolska.

## RESULTS

The first emergences of sugar beets in the experimental plots began 15 days after the seeds had been sown. This means that there were average conditions in the plantation. It is assumed that under favourable conditions sugar beets start emerging 7-12 days after sowing the seeds, under average conditions – 14-18 days after sowing, whereas under unfavourable conditions – even as late as 30 days after sowing. During the first measurement the smallest number of seedlings was noted in the system where the soil was cultivated at two stage strip-till technology at a depth of 15, 25 and 35 cm. This technologies was characterised by the most dynamic and unequal emergence of the plants. The emergence was the most balanced in the one stage strip-till technology. The one stage systems, where cultivation at depth 25 and 35 cm was carried out, was characterised by the largest number of emerged plants at all the five terms of measurements. All the nine cultivation systems were characterised by similar dynamics of emergence. The number of consecutive emerging plants varied comparably, without considerable deviations. The dynamics of emergence is illustrated in Figure 1.

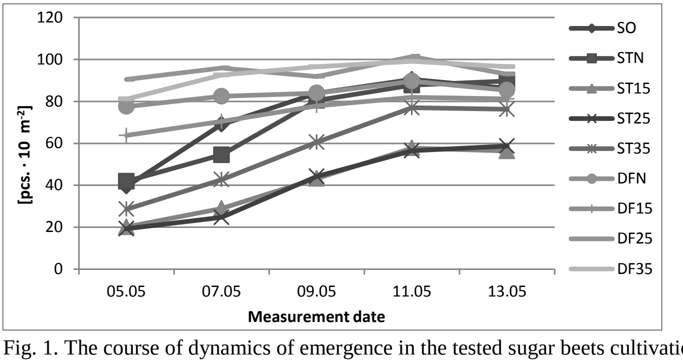


Fig. 1. The course of dynamics of emergence in the tested sugar beets cultivation systems

The two-stage strip-till technology with the cultivation depth of 15 and 25 cm (variant ST15 and ST25) was characterized by the lowest percentage of emerged plants. A tendency was observed that along with the increase in the depth of cultivation, the field capacity of emergence increases, such a tendency is noticeable in one-stage and two-stage belt cultivation (tab. 1). The field emergence capacity was not satisfactory in the systems where the soil was cultivated at two stage system.

Table 1. The average percentage of emerged plants in the tested sugar beets cultivation systems [%]

| Tillage system | SO | STN | ST15 | ST25 | ST35 | DFN | DF15 | DF25 | DF35 |
|---|---|---|---|---|---|---|---|---|---|
| Percentage of emerged plants | 69.30 | 72.40 | 45.40 | 47.30 | 61.40 | 68.30 | 65.40 | 75.00 | 77.90 |

The density of plants was diversified in all technologies (Fig. 2). The highest final density of plants, i.e. 93 000 and 96 600 plants per hectare, was noted in the one stage strip-till system where the soil was cultivated respectively at a depth of 25 and 35 cm. The lowest density, i.e. 56 300 and 58 700 plants per ha, was observed in the two stage strip-till system where the soil was cultivated at a depth of 15 and 25 cm. In addition, it was found that for strip tillage technologies, as the soil cultivation depth increases, the plant density increases.

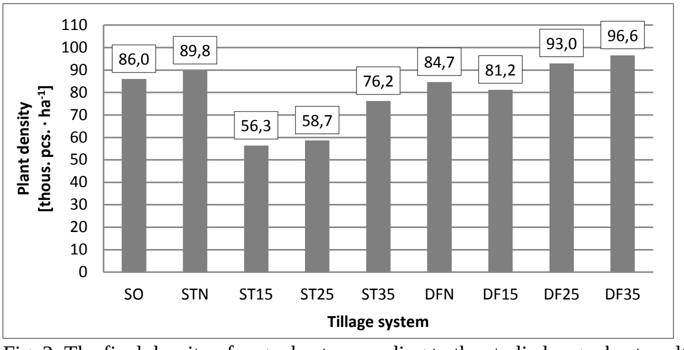


Fig. 2. The final density of sugar beets according to the studied sugar beets cultivation system

Adequate distribution of plants in a row is very important not only for good density of the plantation but also for minimal loss of roots during harvest. The analysis of the results showed that the highest percentage of adequately distributed plants in a row resulted from the plough technology and two stage strip-till technology where the soil was cultivated at depth of 35 cm (both 88.6%). It was also noted that the two-stage strip-till cultivation system is characterized by a more even distribution of plants in a row compared to a one-stage system (Table 2).

Table 2. The percentage of adequately distributed plants in a row according to the studied sugar beets cultivation system [%]

| Tillage system | SO | STN | ST15 | ST25 | ST35 | DFN | DF15 | DF25 | DF35 |
|---|---|---|---|---|---|---|---|---|---|
| Percentage of adequately distributed plants | 88,6 | 88,3 | 84,3 | 87,0 | 88,6 | 85,3 | 80,0 | 77,3 | 82,3 |

The biometric traits of sugar beet roots are very important at harvest and they may affect the technological value of raw material and its suitability for processing into sugar. Based on the analysis of the results, it was found that the roots of the greatest length occurred in one-stage strip tillage to a depth of 35 cm (27.8 cm). The roots with the smallest length of 18.3 cm were in two-stage technology (variant STN, ST15 and ST25) (Fig. 3). In one-stage strip tillage, it can be clearly seen that as the depth of cultivation increases, the sugar beet root length increases.

The soil cultivation systems did not differ significantly in the diameter of sugar beet roots (Fig. 4). The smallest average maximum diameter of 8.4 cm was observed in the strip-till system, made in two stages with 35 cm deep cultivation. In the remaining variants, the average maximum root diameter was in the range of 9.1 to 9.6 cm.

Sugar beets, depending on the studied soil cultivation technology, did not differ significantly in terms of the mass of sugar beet roots (Fig. 5). Root weight less than in ploughing system (SO) was noted only in two-stage strip-tillage system (variant STN and ST35), in other variants the values were higher. In all cultivation technologies tested, the average beet weight was higher than 700 g.

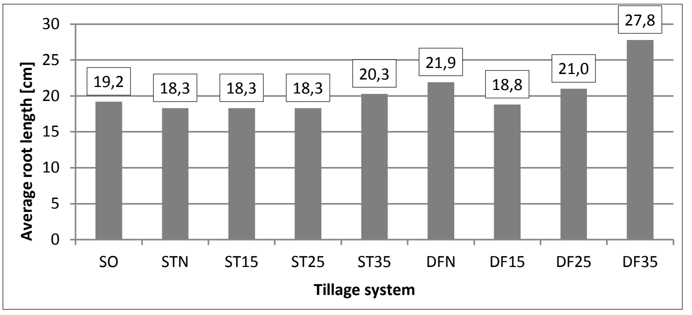


Fig. 3. The average sugar beet root length according to the studied sugar beets cultivation system

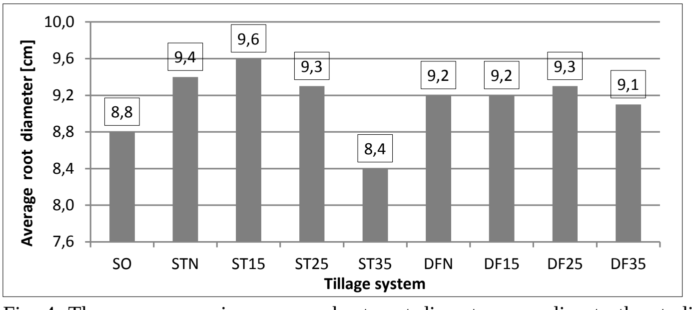


Fig. 4. The average maximum sugar beet root diameter according to the studied sugar beets cultivation system

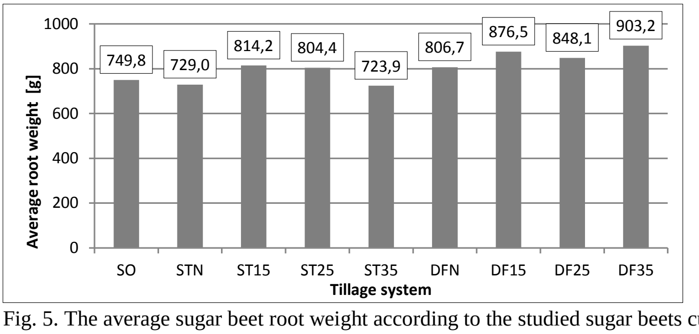


Fig. 5. The average sugar beet root weight according to the studied sugar beets cultivation system

Based on the analysis of the yield quantity, it was shown that the two-stage strip-till system causes a decrease of root yield as compared to ploughing system, while the one-stage strip tillage systems contribute to an increase in the yield of roots (tab.3). It was also found that the yield increases with the depth of cultivation in both one- and two-stage strip-till cultivation. The differences in the amount of yield between the examined technologies ranged from 1.4 $t \cdot ha^{-1}$ to even 40 $t \cdot ha^{-1}$.

Table 3. The roots yield according to the studied sugar beets cultivation system [$t \cdot ha^{-1}$]

| Tillage system | SO | STN | ST15 | ST25 | ST35 | DFN | DF15 | DF25 | DF35 |
|---|---|---|---|---|---|---|---|---|---|
| Root yield | 71,4 | 64,8 | 45,8 | 47,2 | 55,1 | 68,3 | 71,1 | 78,8 | 87,1 |

After analysing the sugar content in the roots, it appears that the least (17.5%) contained beet roots sown in ploughing technology. The highest sugar content was found in beets obtained from technology including one-stage strip-till cultivation to a depth of 15 cm (18.88%). In other cultivation variants, the sugar content ranged from 17 to 18% (tab. 4). It can therefore be concluded that two-stage and one-stage strip tillage contribute to an increase in sugar content in sugar beet roots.

Table 4. The sugar content in sugar beet roots according to the studied sugar beets cultivation system [%]

| Tillage system | SO | STN | ST15 | ST25 | ST35 | DFN | DF15 | DF25 | DF35 |
|---|---|---|---|---|---|---|---|---|---|
| Sugar content | 17,75 | 18,04 | 17,95 | 17,89 | 18,55 | 18,1 | 18,88 | 18,36 | 18,16 |

## CONCLUSIONS

Analysing the examined variants of sugar beet cultivation it is impossible to clearly indicate the best technology in terms of quantity and quality of yield. However, it has been shown that strip-till technology is a beneficial alternative for sugar beet growers who want, among others reduce the cost of sugar beet production, while maintaining a good quality yield at a constant high level. Moreover based on the analysis of the results, the six main conclusions were made. Firstly, one-stage strip tillage does not reduce the beet root yield compared to the traditional system. Next, that, cultivation in the strip-till system affects the increase in sugar content in sugar beets compared to traditional technology, regardless of the depth of soil cultivation. Moreover, the shallower strip tillage to a depth of 15 cm affects the increase in sugar content compared to cultivation to a depth of 25 and 35 cm. It was also found, that an increase in the depth of cultivation in a one-step strip-till system results in an increase in root length and root mass. In addition, it has been shown, that sugar beets cultivated in one-stage srip-till technology is characterized by better dynamics of emergence as compared to plough cultivation. Furthermore with the increase of the depth of cultivation, the plant density increases, especially in one-stage strip-till cultivation.

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## 1.8. INFLUENCE OF SOIL TILLAGE AND LONG-TERM FERTILIZATION ON THE AGGREGATE SIZE DISTRIBUTION AND SEEDBED ROUGHNESS

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**Keywords:** tillage, seedbed preparation, aggregate size, long-term fertilization

### ABSTRACT
Primary tillage and seedbed preparation are determining processes for the seedbed structure. In experiments on different sites the tillage effect and the long-term fertilization effect on the aggregate size distribution in the seedbed was analysed. Seedbeds with different roughness were prepared with different primary tillage implements (mouldboard plough, cultivator, short disc harrow) and various Power Take-Off (PTO)-speeds of the power harrow. An additional experiment analyses the long-term fertilization effects (unfertilized, mineral fertilizer, farmyard manure) on aggregate size distribution in the seedbed. The results show, that soil tillage and the long-term fertilization system influence the aggregate size in the seed bed in different manner. Soil tillage with cultivator loosened the soil more intensive than mouldboard plough. The loosening effect of the cultivator is strongly determined by the line distance and number/kind of the post tools. The increase of PTO-speed from 300 to 1000 1 $min^{-1}$ resulted in a finer seed bed. Long-term fertilized arable soil with farmyard manure had larger soil aggregates than un- and mineral fertilized soil.

### INTRODUCTION

Tillage improves soil conditions for germination and subsequent plant growth by altering the aggregate size distribution, which affects the mechanical, physical and agronomic properties of the soil. Seedbed preparations are of importance because of the opportunity to create a desirable structure that allows optimum crop production (Adam and Erbach, 1992). Seedbeds tend to be a compromise between conditions for plant growth and properties for traction and tillage. The effects of aggregate size on soil physical properties may help to design seedbeds qualitatively with the best compromise between such conflicts (Braunack and Dexter, 1992).

Aggregate size distribution and pore structure affect many soil functions and root growth. The aggregate structure is associated with soil genesis and management practices applied (Lipiec *et al*. 2007). A fine seed bed, which mostly consist of aggregates <5 mm is suitable for plant emergence (Braunack, 1995; Guérif *et al*. 2001; Håkansson *et al*., 2002). For mitigating sealing and soil erosion, the ideal seedbed should have larger aggregates, e.g. 15 mm (Cadena-Zapata *et al*., 2002), to enhance water infiltration and delay water runoff. (Braunack and Dexter, 1989). Therefor the aggregate size distribution in the seedbed is an important control variable for cropping, which can be influenced by the type of tillage implement and soil water content during tillage processes (Adam and Erbach, 1992; Braunack and McPhee, 1991). Finer seedbeds can be produced at lower soil water contents and with increasing number of implement passes (Braunack and McPhee, 1991).

Braunack and Dexter (1992) suggested that further work should focus on stratified seedbeds where aggregates of the appropriate size can be placed to enhance germination and emergence, omit surface crusting and reduce compaction and soil erosion. Results by Nasr *et al*. (1995) showed a decreased and delayed seedling emergence in seedbeds with increased aggregate sizes.

The soil physical properties are spatially and temporally different within a field. The challenge is to get more homogenous aggregate sizes over the field with inhomogeneous soil properties during seedbed preparation. The technical solution would be a real time control of the machine depending on soil maps or on online soil measurements (Riegler-Nurscher *et al*., 2019). The main parameter investigated in this paper, the aggregate size, can be approximated by soil roughness. Many methods for soil roughness measurement have been proposed over the years.

This paper deals with the influence of different tillage operations (mouldboard plough, cultivator, disc harrow, power harrow) and long-term fertilization (unfertilized, mineral fertilizer, farmyard manure) on size distribution of aggregates in the seedbed.

## MATERIALS AND METHODS

### Site description

The field experiments were carried out at the Experimental Station of the University of Natural Resources and Life Sciences, Vienna (BOKU) in Groß-Enzersdorf (48°12'1.79" N, 16°33'33.75" E) and on a farm in Krummnussbaum (48°12'4.22" N, 15°9'31.29" E) with different soil properties (Table 1).

Table 1. Characteristics of the soils on the trial sites

| | Groß-Enzersdorf | Krummnussbaum |
|---|---|---|
| Sand (g $kg^{-1}$) | 360 | 100 |
| Silt (g $kg^{-1}$) | 440 | 700 |
| Clay (g $kg^{-1}$) | 200 | 200 |
| Soil texture | silty loam | loamy silt |
| Organic matter (g $kg^{-1}$) | 16.3 | 12.8 |
| Volumetric water content ($m^3$ $m^{-3}$) | | |
| 0-5 cm | 0.24 | 0.34 |
| 5-10 cm | 0.22 | 0.38 |
| Soil type (FAO 2006) | Calcaric Chernozem | Cambisol |

At the location Groß-Enzersdorf, the soil conditions with the moisture content of 23.7% in the top soil during tillage and seedbed preparation (second half of August 2016) were suitable. In contrast, at location Krummnussbaum the experiment took place at the beginning of November with wet soil conditions (total rainfall in October 2016 was 78 mm).

### Experimental design and management

The trials for analysing the tillage effect in Groß-Enzersdorf and Krummnussbaum were in randomized block design with three replicates. Each plot had a length of 140 m in Groß-Enzersdorf and 200 m in Krummnussbaum. Plot width was 6 m for both. For creating seedbeds with different degrees of fineness, different primary tillage implements and PTO (Power Take-Off)-speed for seedbed preparation were used (Table 2). At the experimental site Groß-Enzersdorf the PTO speed for driving power harrow was set constant with 540 1 $min^{-1}$. Three PTO levels (300, 540 and 1000 1 $min^{-1}$) were chosen for the seedbed preparation at the site Krummnussbaum. The tool speed of the power harrow tines was calculated with the constant rotor-revolution/PTO-input revolution quotient of 0.527. The tool speed was for 300 PTO-input revolution 2.5 m $sec^{-1}$, for 540 PTO-input revolution 4.4 m $sec^{-1}$ and for 1000 PTO-input revolution 8.3 m $sec^{-1}$.

Table 2. Experimental design for analysing the tillage effect

| | Groß-Enzersdorf | Krummnussbaum |
|---|---|---|
| Primary tillage | Mouldboard plough (n[a)]=36)<br>Cultivator shallow (n=36)<br>Cultivator deep (n=36) | Mouldboard plough (n=9)<br>Cultivator (n=9)<br>Short disc harrow (n=9) |
| Seedbeed preparation | Power harrow<br>(PTO: 540 1 $min^{-1}$) | Power harrow<br>(PTO: 300, 540, 1000 $min^{-1}$) (n=3) |

a) Number of soil samples for sieving

Ploughing was carried out with a reversible 4 furrow mouldboard plough (Pöttinger Servo 35 S, Grieskirchen, Austria) with working width of 160 cm, tillage depth of 25 cm and average working speed of 6.5 km $h^{-1}$. The plough was equipped with bar-point shares and manure-burying coulters.

Cultivation was done with a wing sweep cultivator (Kerner Galaxis 300, Aislingen, Germany), which had a tine distance of 84 cm and a line distance of 42 cm. Behind the two tine bars three rotary hoes for crumbling and a wedge ring roller for crumbling and depth adjustment were mounted. The working width was 300 cm and working depth was set constant for deep cultivation with 30 cm and for shallow cultivation with 8 cm. The average working speed was 6.5 km $h^{-1}$.

Another implement was the short disc harrow (Amazone Catros 3001+, Hasbergen-Gaste, Germany) with a working width of 300 cm. It was equipped with 2x28 toothed discs (Ø 510 mm) with a disc distance of 250 mm and rear roller for working depth control and re-compaction. The working depth was set constant with 150 mm. Disc harrowing was done with an average working speed of 9.0 km $h^{-1}$.

Seedbed preparation was done by the 300 cm width power harrow (Pöttinger Lion 303.12 Classic, Grieskirchen, Austria) with 12 tine-rotors. Re-compaction and working depth adjustment were obtained with equipped prism packer roller (Ø 500 mm; row spacing: 12.5 cm). In the trial, the working depth was set at 50 mm. The average working speed was at Groß-Enzersdorf 6.1 km $h^{-1}$ and at Krummnussbaum 5.0 km $h^{-1}$.

For testing the fertilization effect in summer 2017, soil samples were taken from the long-term fertilization trial (started in 1906) at the Experimental Station of the University of Natural Resources and Life Sciences Vienna (BOKU) in Groß-Enzersdorf. Winter-rye in monoculture is fertilised with three fertilization variants (1) unfertilized, (2) NPK mineral (117 kg N $ha^{-1}$, 100 kg P2O5 $ha^{-1}$, 150 kg K2O $ha^{-1}$) und farmyard manure (20 t $ha^{-1}$). Soil type is Calcaric Chernozem with 25% clay, 64% silt and 11% sand. Soil tillage was done with mouldboard plough followed by combined seedbed preparation and drilling. After harvest, the straw was removed from the field and the stubble processed with a disc harrow in mid-August.

**Soil sampling and sieve analysis**

The soil samples were taken carefully with a spade (25 × 25 cm) from the seedbeed horizon (0-5/7 cm) and filled in a paper bag. Before sieving, the soil samples were air-dried in a glasshouse. 36 samples were taken of each treatment in Groß-Enzersdorf and three samples per treatment in Krummnussbaum. For testing the fertilisation effect, six soil samples per treatment were taken from the topsoil (0-8/10 cm).

The dry sieving analysis (mesh size: 40 mm, 20 mm, 10 mm, 5 mm, 2.5 mm, 1.25 mm und < 1.25 mm) was carried out with a vibratory sieve shaker (Retsch AS 200, Haan, Germany) with the adjusted amplitude of 1.3 mm and acceleration of gravity of 18.75 g). One sieving analysis took 2 × 15 sec. The sieving fractions were weighted with a precision scale (0.1 g).

The mean-weight diameter (MWD) was calculated with the seven sieving fractions according equation 1.

$$MWD = \frac{\sum(n_i \times d_i)}{\sum n_i} \quad \ldots (1)$$

where: MWD: mean-weight diameter (mm)
$n_i$: weight of the sieving fraction in the mesh size i (g)
$d_i$: mean diameter of the mesh size i (mm)

## Statistical analysis

All analyses were conducted using IBM® SPSS® Statistics 21. The requirements for analysis of variance were tested with the Levene test and assessment of normal distribution of residues. One-factorial analysis of variance was carried out for soil aggregate fractions and mean-weight diameter for testing treatments (soil tillage implement, PTO-speed of the power harrow). Multiple comparison tests to separate means were carried out with the Student-Newman-Keuls procedure ($p<0.05$).

# RESULTS

## Tillage effect

The primary tillage influenced the aggregate size distribution in the seedbed (Table 3). Mouldboard plough and the following seedbed preparation with power harrow showed a coarsely structured seedbed. When a cultivator was used for primary tillage it was finer. The proportion of the aggregate fractions > 20 mm was in the seedbed after ploughing and seedbed preparation with 34.4% statistically higher than after the cultivator-treatments (deep: 22.6%, shallow 17.5%).

Table 3: Soil aggregate fractions (%) and mean-weight diameter in the seedbed horizon after different tillage operations (plough, cultivator) and seedbed preparation with power harrow, n=36, experimental site Groß-Enzersdorf

| | Plough | Cultivator deep | Cultivator shallow |
|---|---|---|---|
| > 40 mm | 18.3$^{c}$ [1)] | 10.3$^{b}$ | 4.9$^{a}$ |
| 20 – 40 mm | 16.1$^{b}$ | 12.3$^{a}$ | 12.6$^{a}$ |
| 10 – 20 mm | 15.9$^{a}$ | 15.9$^{a}$ | 16.3$^{a}$ |
| 5 – 10 mm | 14.4$^{a}$ | 15.4$^{a}$ | 15.8$^{a}$ |
| 2.5 – 5 mm | 11.3$^{a}$ | 13.5$^{b}$ | 15.0$^{c}$ |
| 1.25 – 2.5 mm | 9.1$^{a}$ | 11.9$^{b}$ | 12.3$^{b}$ |
| < 1.25 mm | 15.1$^{a}$ | 20.6$^{b}$ | 22.1$^{b}$ |
| **MWD (mm)** | **19.9$^{c}$** | **14.3$^{b}$** | **11.3$^{a}$** |

[1)] Significant differences for the tillage implement effect are shown with small superscript letters.

The fine aggregates (< 2.5 mm) proportion with 24.2% was significantly lower after ploughing than in the cultivator treatments (deep: 32.5%; shallow: 34.4%). The stronger crumbling effect of the cultivator is explained by the mechanical stress onto the soil through the cultivator tools (wing sweep, rotary hoes and wedge ring). The differences in crumbling through mouldboard plough and cultivator are also shown in the mean-weight diameter of the aggregates.

Due to wet soil conditions at the tillage operation on the experimental site Krummnussbaum, the seedbed was coarser than in Groß-Enzersdorf (Table 4). Adam and Erbach (1992) found larger aggregates at the moisture content greater than the plastic limit, than soils at moisture content less than the lower plastic limit. The disc harrow resulted in a finer seed bed than mouldboard plough and cultivator. This is caused by a better crumbling effect through the toothed discs and rear roller. The PTO-speed effect on crumbling is shown in Table 5. The increase of PTO-speed from 300 to 1000 1 min-1 resulted in a finer seed bed.

Table 4. Soil aggregate fractions (%) and mean-weight diameter in the seedbed horizon after different tillage operations (plough, cultivator, disc harrow) and seedbed preparation with power harrow, experimental site Krummnussbaum

| | Plough (n=9) | Cultivator (n=9) | Disc harrow (n=12) |
|---|---|---|---|
| > 40 mm | 33.5 | 22.3 | 16.7 |
| 20 – 40 mm | $21.7^{a1)}$ | $31.8^{b}$ | $26.8^{ab}$ |
| 10 – 20 mm | 18.8 | 22.7 | 22.5 |
| 5 – 10 mm | 11.9 | 12.4 | 15.5 |
| 2.5 – 5 mm | $7.1^{ab}$ | $5.9^{a}$ | $9.1^{b}$ |
| 1.25 – 2.5 mm | $3.8^{ab}$ | $2.4^{a}$ | $5.0^{b}$ |
| < 1.25 mm | $3.2^{ab}$ | $2.5^{a}$ | $4.4^{b}$ |
| **MWD (mm)** | 30.7 | 27.5 | 23.0 |

[1)]Significant differences for the tillage implement effect are shown with small superscript letters.

Table 5. Soil aggregate fractions (%) and mean-weight diameter in the seedbed horizon after different primary tillage operations (plough, cultivator, disc harrow) and PTO-revolution of the power harrow (300, 540, 1000 1 $min^{-1}$), n=3, experimental site Krummnussbaum

| | Plough | | | Cultivator | | | Short disc harrow | | |
|---|---|---|---|---|---|---|---|---|---|
| | 300 | 540 | 1000 | 300 | 540 | 1000 | 300 | 540 | 1000 |
| > 40 mm | $57.8^{b1)}$ | $23.2^{a}$ | $19.4^{a}$ | $37.6^{b}$ | $23.3^{b}$ | $5.9^{a}$ | 19.8 | 21.3 | 8.8 |
| 20 – 40 mm | $13.6^{a}$ | $27.7^{b}$ | $23.7^{b}$ | $29.3^{a}$ | $29.7^{a}$ | $36.5^{a}$ | 26.0 | 27.9 | 26.4 |
| 10 – 20 mm | $13.0^{a}$ | $22.0^{b}$ | $21.3^{b}$ | $17.5^{a}$ | $23.3^{b}$ | $27.4^{b}$ | 22.2 | 21.3 | 24.1 |
| 5 – 10 mm | $7.3^{a}$ | $12.9^{b}$ | $15.6^{b}$ | $8.6^{a}$ | $12.4^{ab}$ | $16.3^{b}$ | 15.1 | 14.2 | 17.3 |
| 2.5 – 5 mm | $4.2^{a}$ | $7.3^{b}$ | $9.9^{b}$ | $3.7^{a}$ | $6.1^{b}$ | $7.8^{b}$ | 8.4 | 8.1 | 10.8 |
| 1.25 – 2.5 mm | $2.2^{a}$ | $3.7^{ab}$ | $5.5^{b}$ | $1.5^{a}$ | $2.6^{ab}$ | $3.2^{b}$ | $4.5^{a}$ | $3.9^{a}$ | $6.7^{b}$ |
| < 1.25 mm | $2.0^{a}$ | $3.1^{ab}$ | $4.5^{b}$ | $1.9^{a}$ | $2.6^{a}$ | $2.9^{a}$ | $3.9^{a}$ | $3.4^{a}$ | $6.0^{b}$ |
| **MWD (mm)** | $41.5^{b}$ | $26.9^{a}$ | $23.6^{a}$ | $34.8^{c}$ | $27.6^{b}$ | $20.2^{a}$ | 24.6 | 25.8 | 18.7 |

[1)]Significant differences for PTO-revolution effect are shown with small superscript letters.

## Fertilization effect

The long-term fertilization of the arable soil with farmyard manure resulted in a rougher seedbed in comparison to mineral fertilized and unfertilized soil (Table 6). The mean-weight diameter with 9.3 mm for the treatment with farmyard manure was significantly higher than the MWD for the long-term mineral fertilized plots. This effect is caused by the enriched soil organic matter through organic manure (Figure 1).

Table 6. Soil aggregate fractions (%) and mean-weight diameter in the seedbed horizon after different fertilization, n=6, experimental site Groß-Enzersdorf

| | Unfertilized | NPK mineral | Farmyard manure |
|---|---|---|---|
| > 40 mm | 0.2 | 0.0 | 2.3 |
| 20 – 40 mm | 8.8 | 6.2 | 11.0 |
| 10 – 20 mm | 13.6 | 12.7 | 15.6 |
| 5 – 10 mm | 15.9 | 14.8 | 16.2 |
| 2.5 – 5 mm | 17.0 | 16.6 | 16.1 |
| 1.25 – 2.5 mm | 15.5 | 16.1 | 15.9 |
| < 1.25 mm | 29.3 | 33.6 | 22.9 |

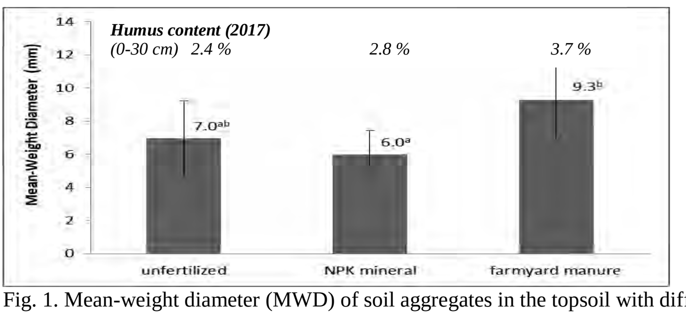


Fig. 1. Mean-weight diameter (MWD) of soil aggregates in the topsoil with different long-term fertilization

## CONCLUSIONS

- Crumbling effect of a cultivator was greater than of mouldboard plough.
- PTO-input revolution for power harrow affected the aggregate size distribution in the seedbed significantly.
- Long-term fertilization with farmyard manure increased the soil humus content and the mean-weight diameter of soil aggregates in the seedbed.

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# 1.9. THE DROP SIZE DISTRIBUTION AND SYMMETRY AROUND THE CENTRELINE OF THE SPRAY FAN

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**Keywords**: pesticide application; nozzle; flat fan; spray pattern

## ABSTRACT
The aim of this research was to investigate the drop size distribution of the standard flat fan nozzle in different positions of its spray fan. Moreover, the symmetry of the drop size distribution of the spray fan was checked by comparing the right and left side of the spray fan. Drop size distribution was measured by laser diffraction device (Sympatec GmbH-HELOS-VARIO/KR). There were fifteen measurement positions alongside the spray fan, seven position on the right side and the same number on the left beside one measurement on the spray fan centreline. The measurements were done with 3.0 bar pressure and in 50cm bellow the nozzle tip. The results showed that almost two-third of the spray volume is consisted of drops sizes ranging from 100 to 300µm. The two sides of the spray pattern were identical at the middle positions (near the centreline) for all drop size ranges. However, there was a slight difference between right and left side of the spray pattern concerning the drop size ranges at the edge positions.

## INTRODUCTION
Spray particle size influences the spray coverage and drift. The British Crop Protection Council (BCPC) in 1985 set the origin of standardization of spray droplet sizes with the droplet size classification, which was designed to enhance efficacy (Doble, Matthews, Rutherford, & Southcombe, 1985). ANSI/ASAE approved S572.1 in March 2009 to be the American National Standard, and adding new categories (extremely fine and ultra-coarse) to the classification. The test of this standard (ASABE S572.1, 2009), which can be conducted by nozzle manufacturers, is based on spraying water through reference nozzles. The measurements of droplet spectra must be with the same instrument (laser-based instrument), operator, measuring method, sampling and scanning technique, and in a similar environmental condition (Klein, Golus, & Kruger, 2011). There are different parameters related to the drop size that need to be defined. Those parameters include: $D_{v10}$; $D_{v50}$; $D_{v90}$; $D_{32}$ or Sauter mean diameter (SMD); the relative span (RS) etc. The $D_{v50}$ or the volume median diameter (VMD) is the most important and frequently used parameter to characterize the drop size of certain spray; it is usually used to compare different nozzles concerning their average drop size. It defines the drop size diameter, where a 50% fraction of the total volume of the spray sample has smaller diameter than this measured size (diameter) and the other 50% is larger than this value. Since the $D_{v50}$ indicates the average drop size, it is not good

indicator for the small size drops that are responsible for drift (Schick, 2008). The nozzle classification into one or more droplet size categories is influenced by the flow rate, spray pressure, and physical changes to nozzle geometry and operation. Depending on the selection of those factors and other operational conditions, the nozzle can be classified (ASABE S572.1, 2009). In general, values of the $D_{v50}$ are the indicator of the drop size of certain nozzle spray. The $D_{v10}$, $D_{v50}$, and $D_{v90}$ according to BCPC are used to classify a spray as: very fine, fine, medium, coarse, and very coarse (Doble, Matthews, Rutherford, & Southcombe, 1985). This classification was set using reference to standard nozzles representative for each category. The values were used also to produce a graphic curve for the cumulative volume of the reference nozzles to compare it with any tested nozzles. The (ASABE S572.1, 2009) also used the calculated values of $D_{v10}$, $D_{v50}$, and $D_{v90}$ to create a relationship between cumulative volume and droplet size spectra. However, this standard added three more spray categories besides previous categories from BCPC, namely: Extremely fine (XF); extremely coarse (XC) and Ultra Coarse (UC).

The off-target losses caused from using fine droplets could eventually result in spray drift and evaporation. However, coarse droplets with a high volume result in relatively low coverage percentage and may be rebound or scattered from the target (Hilz & Vermeer, 2013). Using coarse foliar sprays results in more off-target deposition on the ground and eventually this will move in surface (run-off) or into ground water (Matthews, 2004). Knowing the size distribution and velocity of drops, as well as the way of spray transporting to the target will determine the coverage uniformity and often the biological efficacy. It affects the possible number of drops that could be lost as drift or as ground deposition (not on target). For that reason, it is important to take control of the atomization and transport process, especially the distribution of drop size (Matthews G.A., Clayton J., & Bals T., 2016). Small size drops are spread relatively further than larger size drops on the leaf surfaces and remain longer as well. This makes them more efficient in penetrating of pesticide active ingredient into leaf tissues (Xu, Zhu, Ozkan, & Thistle, 2010). To test and compare spray from different agricultural spray nozzles and technologies, the laser diffraction for drops sizing method is quick and easy method to do this. Although it has a potential bias to the results of the absolute measured drop size from a given system just like other measurement or sampling technique (Fritz, *et al.*, 2014). (Chapple & Hall, 1993) indicated that sampling the long axis of the spray cloud is more representative than the short axis and it can give a complete assessment of the entire spray cloud; it is also important to position the nozzle precisely before sampling.

Flat fan nozzles produce a wide spectrum of drops across their long and short axis with different distribution of the drop sizes in every point within those axes. Therefore, it is important in order to gain a holistic idea about the spray of certain nozzle to know the differences of those drops and its distribution in every position across the spray pattern. It is important also for the flat fan nozzles to deliver a symmetric spray volume to both sides of the spray pattern centreline (left and right side of the centreline) because of the necessity to have overlapped spray between the adjacent nozzles. The objectives of this research was to characterize the flat fan nozzle concerning its drop size distribution in different positions of its pattern. Moreover, to investigate the drop size distribution symmetry of the spray pattern around its centreline.

## MATERIALS AND METHODS

Flat fan nozzle was used in the tests (Table 1), the spray of this nozzle is composed of drops with different sizes; the size of those drops defined by their diameter. When there are many drops with different sizes, the drop size distribution is used to define the volume proportion (in percentage) of certain size ranges as compared with the total volume.

Table 1. Nozzle specifications provided by the manufacturer (TeeJet, Spraying Systems)

| | |
|---|---|
| Name | Extended Range Flat Fan, XR 110/03 VP |
| Nominal flow rate* | 1.18 l/min |
| Working pressure range | 1.0-4.0 bar |
| Spray angle* | $110^0$ |
| Material | Polymer |
| Drop size | Medium-fine (depending on pressure) |

*measured at 3.0 bar pressure

The drop size ($D_{v50}$) and drop size distribution of the spray cloud was measured with the Sympatec GmbH-HELOS-VARIO/KR device, which uses the physical principles of Laser Diffraction (LD). It is designed for complete precision measurements to typically ±1% deviation regarding the standard meter (Sympatec GmbH, 2012). According to (ASABE S572.1, 2009), traversing the nozzle spray through the laser is an acceptable method for data sampling, or by combining the data of several readings from samples, which are representative of the spray cloud and then calculating droplet sizes. The long axis was divided into seven positions in each of the left and right side of the pattern (with 10cm intervals) near the centreline position, this will give us a 15 positions across the long axis and 140cm total length of sampled pattern. Measurements were taken 50cm under the nozzle orifice and with three replicates. The sampling was done progressively by moving the nozzle, which was fixed by trailer containing the nozzle holder and solenoid valve, horizontally alongside a rail with the help of motion controlling software. During the sampling period, the nozzle was stationary, and when the time of sampling was completed, the nozzle moved to the next position. Release of water during sampling was controlled with a remote button, which activates and deactivates the solenoid valve. The measurements were performed using tap water, that was stored inside 20 litter steel tank, and air (from air compressor) was compressed through a pressure regulator inside this tank to maintain the desired pressure for sampling. Two calibrated pressure gauges were used to monitor the pressure: the first one for the air from air compressor, and the second before the nozzle to show the spray pressure before sampling. The measurements included the below parameters:

1- $D_{v50}$ (volume median diameter): defines the drop size (diameter in µm), where a 50% proportion of the total volume of the spray sample has this measured size (diameter) or less.

2- The volumetric percentage of different drop size ranges; those ranges included: ≤ 100µm; 100-200µm; 200-300µm; 300-400µm; 400-500µm; ≥500µm.

Measuring the skewness gives an idea about the degree of asymmetry of a distribution around its mean. This distribution can be considered symmetric if the right and left side look the same. Symmetry of the two sides of the spray pattern was visually tested concerning the drop size distribution in each side of the spray pattern. Each measured drop size range on one side of the spray was compared with the other side of the spray, and the results for these comparisons will show (visually) the skewness for the spray pattern around its centreline.

## RESULTS AND DISCUSSION

Values of the $D_{v50}$ across the long axis of the spray pattern and at 3.0 bar pressure are presented in Table 2. The values decreased gradually from the edges to the centreline where the lowest value (162µm) of the $D_{v50}$ happened.

Table 2. The spray $D_{v50}$ (µm) across the spray pattern at 3.0 bar pressure

| Positions across the spray pattern, cm* | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **L70** | **L60** | **L50** | **L40** | **L30** | **L20** | **L10** | **0** | **R10** | **R20** | **R30** | **R40** | **R50** | **R60** | **R70** |
| 296 | 260 | 226 | 208 | 193 | 178 | 166 | 162 | 166 | 180 | 192 | 203 | 215 | 243 | 278 |

*R; L: right and left side of the spray pattern, respectively.

In Figure 1, the drop size distribution results are presented, each marker point in the graph is averaged value of nine measurements (three sample nozzles replicated three times). The drop size (µm) distribution depending on the volumetric percentage of the total sample volume was presented as ranges with 100µm intervals.

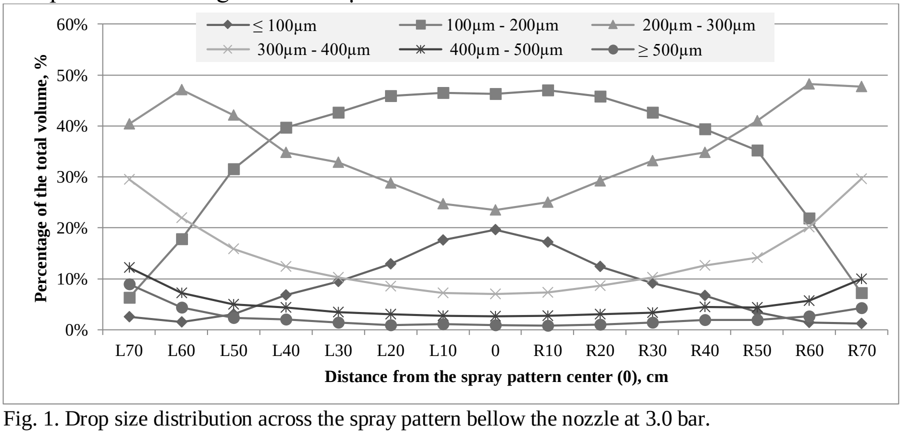


Fig. 1. Drop size distribution across the spray pattern bellow the nozzle at 3.0 bar.

Small volume of the drops larger than 500µm makes it practically better practice to sum all of them up in one range, which is ≥ 500 (the range contains drops with size from 500 to 3000µm). Drop size range smaller than 100µm has the biggest percentage at the middle position of the spray pattern, and starts to decrease towards the edges of the pattern until it reaches almost zero percentage. This indicates that the small drop sizes (which tend to drift) are concentrated in the centre of the spray pattern and disappear at the edges of the pattern. The percentage of this drop size range (≤ 100µm) in the centreline position was 19.6%. The same behaviour was noticed for the drop size range 100-200µm, but the volumetric percentage was higher than the ≤ 100µm range, and this percentage started to decrease near the edges of the pattern. The volumetric percentages in this range (100-200µm) in the centreline position were 46.4%. The drop size ranges 200-300, 300-400 and 400-500µm shared the same behaviour concerning the distribution across the spray pattern. Those ranges increased starting from the centreline and had their highest values on the far edges. However, there were a few exclusions in some positions, which can be noticed from the graph. Also, the volumetric percentages for those ranges were different, the range 200-300µm had the highest percentage in the all the pattern positions, followed by the range 300-400µm, while

the range 400-500µm had the least percentage comparing with the previous ranges in the all pattern positions, as well. There was a small percentage of the drop size larger than 500µm in the all positions of the spray pattern.
The drop size distribution regardless of the position (averaged values of all positions) is shown in Figure 2. Almost two-third of the spray volume is consisted of drops sizes ranging from 100 to 300µm with the absence of the drops larger than 500µm.

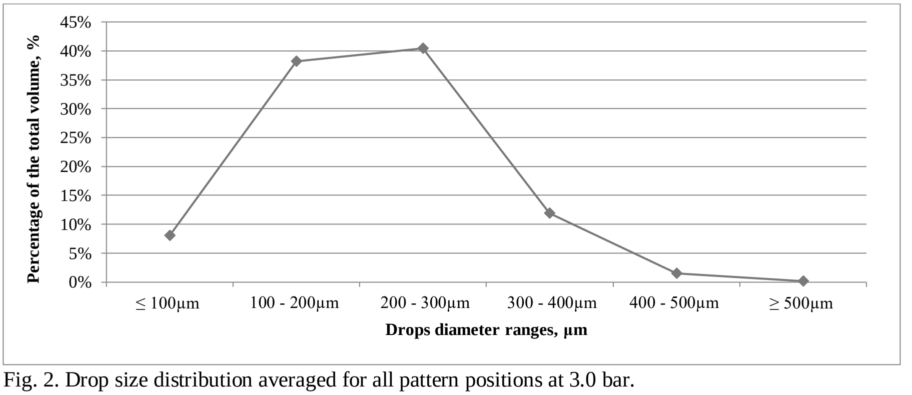


Fig. 2. Drop size distribution averaged for all pattern positions at 3.0 bar.

A visual comparison for the symmetry of the distribution of the drop sizes are presented in Figure 3. Only a few positions along the spray pattern were considered on those graphs: 70, 50, 30, and 10 cm to the left and right side of the centreline, in order to make the graphs visually better.

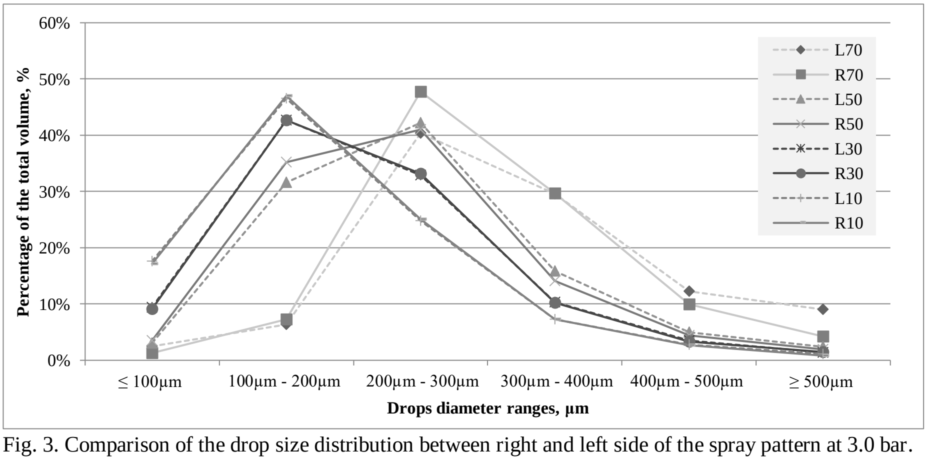


Fig. 3. Comparison of the drop size distribution between right and left side of the spray pattern at 3.0 bar.

We can notice from this graph that the two sides of the spray pattern were identical at the middle positions (10 and 30 cm from the centreline) for all drop size ranges. However, there was a slight difference between right and left side of the spray pattern concerning the drop size ranges at the edge positions (50 and 70 cm from the centreline).

## CONCLUSIONS

Depending on the circumstances and results of this study we can conclude the following:

1- Almost two-third of the spray volume is consisted of drops sizes ranging from 100 to 300 μm.
2- Drops size smaller than 200μm are concentrated in the centre of the pattern, they started to decrease as we move to the edges.
3- The two sides (right and left side) of the spray pattern were identical at the middle positions (near the centreline), and had a slight difference at the edge positions.

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# 1.10. THE EFFECT OF PLOUGH MODIFICATION ON SOIL PENETRATION RESISTANCE

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**Keywords:** hardpan layer, conventional ploughing system, soil penetration resistance, cone index, three-point hitch dynamometer

## ABSTRACT
Modification of the design of mouldboard plough is important to avoid or reduce the soil compaction forming, even though this change has been caused an increase, in the ploughing energy requirements. The aim of this study was to modify and develop the design of mouldboard plough, by adding an extra part (heavy duty tine), that works below the ploughing layer immediately after wheel pass on the bottom of the furrow, using a various settings of tine (depth and width), at different speeds to loosen the effect of wheel pass before it buries by the soil that cutting during ploughing operation. The effect of plough modification achieved a disturbed and loosening the compacted layer after wheel pass in the furrow, led to reducing the value of cone index.

## INTRODUCTION

Plough pan is a compacted layer of soil that is difficult for roots or water to penetrate (Gliński, *et al*., 2011). It often forms just below the depth of ploughing, when, over the years, repeated ploughing orients all of the soil particles in the same a direction and depth, causing a compacted layer of soil (Hossne *et al*., 2015). Ahmad *et al*. (2010) mentioned that this layer has a value of penetration resistance more than 2 MPa which is considered to be the critical value for root penetrate deeply into the soil. It has a low permeability and infiltration rate, which, increases the potential for runoff and erosion, limits productivity, the accumulation of lower amounts of water and makes plant susceptible to temporal drought stress (Raza *et al*., 2005; Manor & Clark, 2001; Esser, 2016). Moreover, one of the most important factors causing an increase in the soil strength in that layer is the wheel pass running in the ploughing furrow during tillage operation. The compaction of the soil caused by machinery traffic in agriculture is a big problem across wide areas of the world and is one of the most important factors causing the physical degradation of the soil and it has considerable consequences for crop production and the environment (Keller & Arvidsson, 2004; Filipović, 2011).

## PROBLEM DISCUSSION

In the conventional ploughing system, the top layer of soil is usually loosened by using a mouldboard plough. According to Anusontpornperm *et al*. (2014) cumulated studies dating back for a decade, have found that the existence of a plough pan is very common. At a depth just below the ploughing layer, about 20 cm below the surface of the soil, a compacted layer develops, it is commonly called the plough pan or hardpan, and it forms at a depth of between of 20 and 35 cm below the soil surface (Gysi 2000). This dense layer has a thickness of around 10-15 cm. However, this varies from field to field and within fields. Hardpan could be the source of negative influences on the physical properties of soil, such as higher bulk density, lower soil porosity percentage, and higher soil strength when compared to the topsoil and underlying horizontal. This explains its adverse effect on soil properties, plant activity, and land erosion by runoff. The most important external factors that have a direct effect leading to the formation of this layer are the ploughing implement action causing the smearing of the soil and also, the tractor wheels running in the opened furrow during ploughing operations.

## OBJECTIVE AND RESEARCH METHODOLOGIES

The aim of this study is to modify and develop the mouldboard plough design by adding an extra part (chisel tine), that works below the ploughing layer immediately after wheel pass on the bottom of the furrow, which has been previously opened in the last run of the ploughing operation. This leads to soil loosening, therefore reduced soil penetration resistance.

A mounted type of reversible mouldboard plough, in-furrow ploughing system was used. The plough was modified by adding an extra component (chisel tine) which was combined to the frame of the plough by the Henryk Batyra Company in Lublin, Poland (Figure1). The tine was working in the centre of the wheel pass in the furrow during the ploughing operation. The experiment was conducted using the complete randomized block design with three replications. The first treatment was the tine setting (depth and working width below the mouldboard plough) with five levels: NO TINE represented the normal plough without an extra tine (control), TINE1D10 and TINE1D15 represented a 5 cm tine width which worked below the ploughing layer at a depth of 10 and 15 cm respectively. TINE2D10 and TINE2D15 represented a 10 cm tine width that worked below the ploughing layer at a depth of 10 and 15 cm respectively. The second treatment was three forward speeds 1.94, 3.9 and 6.3 km·h$^{-1}$.

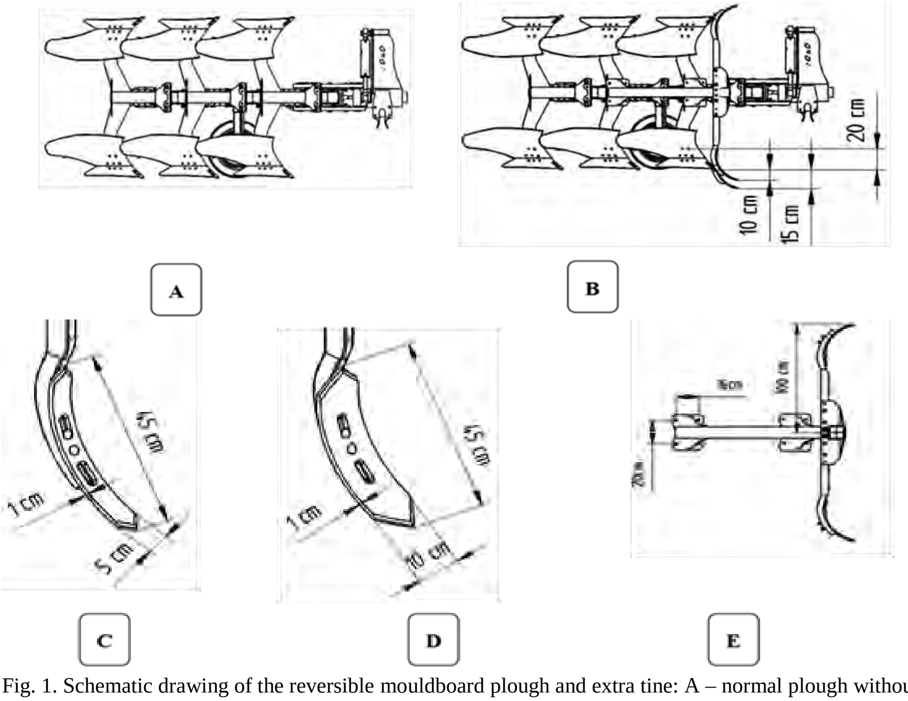


Fig. 1. Schematic drawing of the reversible mouldboard plough and extra tine: A – normal plough without tine, B – modified plough, C – TINE1, D – TINE2, E – tines with shanks.

To determine soil penetration resistance, Eijkelkamp penetrologger was used after wheel pass on the furrow (before and after tine action), at three levels of soil depth below the ploughing layer 0–5, 5–10 and 10–15 cm, that corresponded to a soil depth of 20–25, 25–30, 30–35 cm from the ground surface (Figure 2).

To measure horizontal force of the implement, an adjustable three-point hitch sensoring dynamometer with a horizontal force capacity of 100 kN was used. It was located between the tractor and an implement. It was made by Polish company in Poznań, Poland (Figure 3).

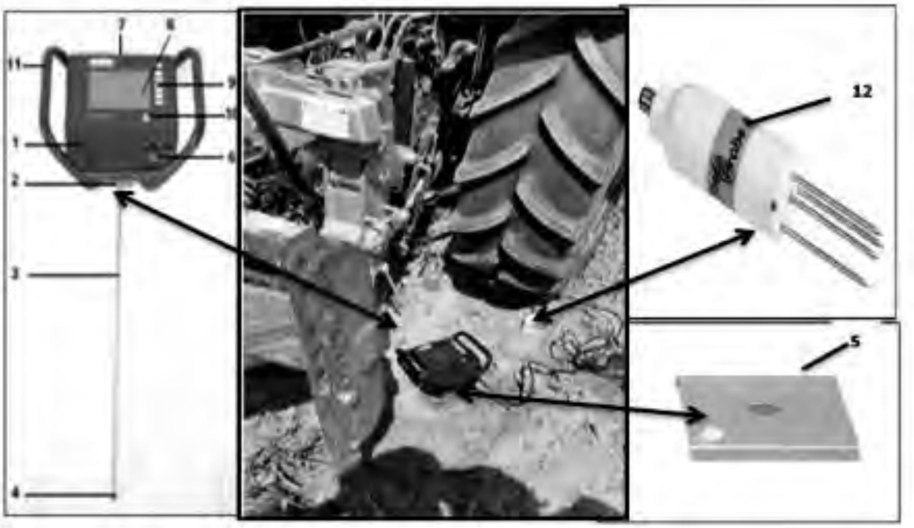

Fig. 2. Eijkelkamp penetrologger: 1– water–resistant housing, 2– impact absorber,3– bipartite probing rod, 4 – cone, 5– depth reference plate, 6– communication port, 7– GPS antenna, 8– LCD screen, 9 –. control panel, 10 – level, 11– electrically insulated grips, 12 – soil moisture measuring sensor.


Fig. 3. Adjustable three-point hitch sensoring dynamometer with a horizontal force capacity of 100 kN.

## RESULTS

Figure 4 shows that the magnitude of the horizontal force for all tine settings (depth, width) operating below the mouldboard plough were significantly higher than that of the NO TINE treatment, and it tends to be increasingly significant ($p \leq 0.05$) with tine depth and its width, this becomes pronounced when the tine depth was increased from10 to 15 cm, the figure shows that TINE2D15 recorded the highest value of mean horizontal force (13 kN), due to the its higher working depth and width. Moreover, at the same working depth, the horizontal force was significantly increased by TINE2 in comparison with TINE1, this could be due to the effect of tine width. Although, TINE2D10 had twice the width of TINE1D15, a lower horizontal force was recorded, this indicates that the effect of tine width was less than the effect of its depth on the horizontal force.

Figures 5 shows that at depth of 20-25 cm, an increase in penetration resistance was produced by the NO TINE treatment compared to the other soil depths. This could be the result of a wheel pass on the bottom of the furrow during ploughing operation, thus increased soil compaction, the effect decreased with soil depth, probably for two reasons, firstly, the effect of wheel traffic decreased with soil depth, secondly, soil depth of 25-30 cm has been previously compacted and exceeded the critical value of 2 MPa, therefore, it was less affected by the tire pass. The cone index was significantly decreased ($p \leq 0.05$) after the operation of the tine, within the hardpan layer, this was due to the fact that the soil has been tilled and pulverized which leads to less resistance to penetration into the soil.

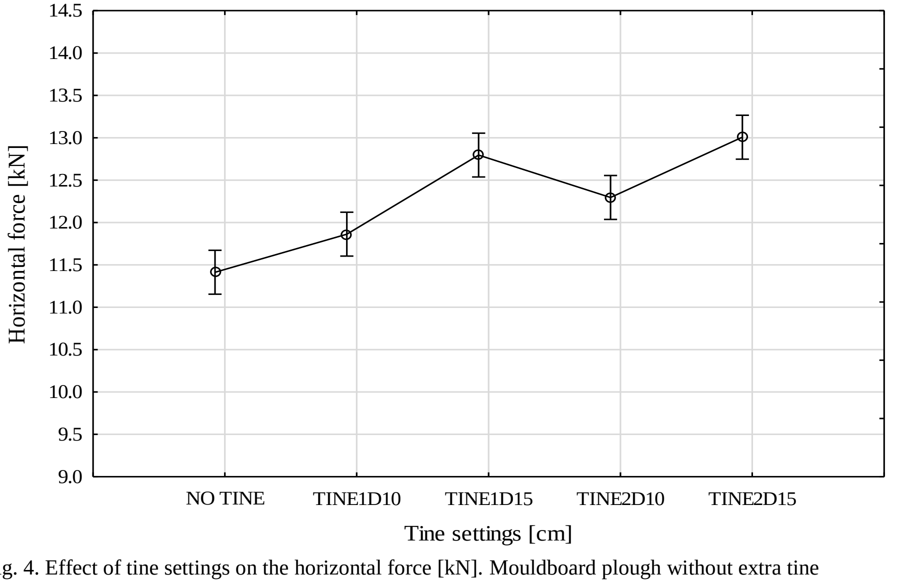


Fig. 4. Effect of tine settings on the horizontal force [kN]. Mouldboard plough without extra tine (NO TINE), plough with tine of a width of 5 cm (TINE1), plough with tine of a width of 10 cm (TINE2), working depth of tine (D).

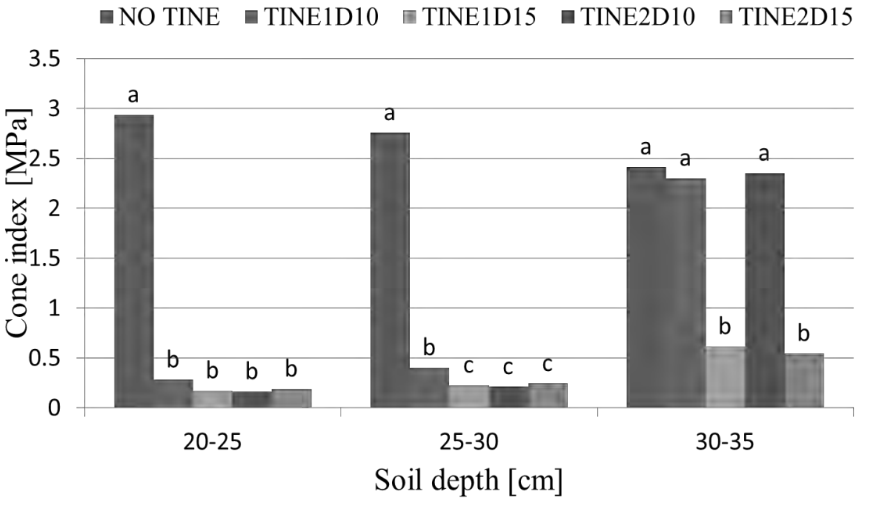


Fig. 5. Effect of tine settings on the Cone index [MPa]. The mouldboard plough without an extra tine (NO TINE), plough with tine at a width of 5 cm (TINE1), plough with tine at a width of 10 cm (TINE2), tine working depth (D). Means followed by the same letter are not significantly different according to the Tukey test ($p \leq 0.05$).

## CONCLUSIONS

1. An increased in horizontal force requirement by modified plough in comparison to normal one, this increasing was higher affected by increasing extra tine depth than its width. The values of the mean horizontal force for NO TINE, TINE1D10, TINE1D15, TINE2D10, and TINE2D15 were 11.41, 11.86, 12.79, 12.29 and 13 kN respectively.

2. The cone index (soil penetration resistance) [MPa] depends on the soil condition and the changes to its properties. The wheel traffic on the bottom of the furrow during ploughing operation using a plough without an extra tine produced a higher value of penetration resistance.

3. The modified plough resulted in a disturbed and stirred the hardpan layer below wheel pass in the furrow. The values of the mean cone index at a soil depth of 20-25 cm were 2.94, 0.28, 0.17, 0.16 and 0.19 MPa for the NO TINE, TINE1D10, TINE1D15, TINE2D10 and TINE2D15 respectively. The cone index values at a soil depth of 25-30 cm, were 2.76, 0.40, 0.23, 0.21 and 0.24 MPa. The values of penetration resistance of soil depth of 30-35 cm were 2.41, 2.30, 0.61, 2.35 and 0.54 MPa. It is obvious from these results that the cone index is considerably decreased by all of the tine settings compared with the traditional plough (NO TINE).

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# 2. EVALUATION, MONITORING AND MODELLING

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# 2.1. PERFORMANCE EVALUATION OF A DEVELOPED LOW-COST FLOATING FISH CAGES FOR AQUACULTURE

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**Key words**: Aquaculture industry, floating fish cage, growth rate, performance.

## ABSTRACT

Floating cages developed of bamboo and plastic of 2.0 x 1.1 x 2.0 m dimension each, which was constructed with two interlaced nets, with mesh sizes 0.01875 m for outer and 0.00625 m for the inner of blue and white colours to overcome part of fish production limitation. High mortality rates of 68.5 and 62% were recorded for *C. gariepinus* in white and blue nets respectively after about 24-120 hrs of stocking while *O. niloticus* had high adaptability rate with low mortality rate of 2.5% and 3.5% respectively from the white and blue net cages within same period.

## INTRODUCTION

Fish farming and farming of other sea animals started in many countries in the world not too long ago, taking Nigeria as example, it started about 50 years ago according to Olagunju *et al.*, (2007*)*, of which it is yet to meet its domestic fish production need for the masses. Ozigbo *et al.,* (2014), opined that Nigerians consumes more fish than any country in Africa and are enlisted among the world's largest fish consumers amounting to 1.5 million tons of fishes annually. Despite being one of the largest fish consumers, more than 900,000 metric tons are being imported into Nigeria while approximately 450,000 metric tons of fish are locally produced per year, as stated by Ozigbo *et al.* (2013). Fish culturing encompass the raising of fish in tanks and ponds, usually for food and sales. The demand for fish, a major source of protein is growing daily giving rise to more effective ways of raising fish in cages.

Cardia and Lovatelli (2015) also reiterated that the increasing quest for land and water, with the increasing need for aquatic protein had facilitated the advance innovative ideas of aquaculture engineers and entrepreneurs to develop the water cage system towards the growth of aquaculture resources in free water bodies as shown in figure 1. Over the years, different choice of materials has been used to design and construct fish cages of different sizes.


Fig. 1. Picture of imported fish cage system
Source:https://www.shutterstock.com/image-photo/fish-farm-sea-view-mountain-floating-414753016#

The development of a cage system made from local readily available materials is inevitable if the productions of fisheries would meet the demand in the Nation with low income. The development of a cage system made from local readily available materials is inevitable if the productions of fisheries would meet the demand in the Nation with low income. Most of these fish farmers are of limited economical resources to acquire the big and costly imported cage system. This work was to develop a novel fish cage system, made from local and cheap sourced material of reasonable durability was designed, fabricated and evaluated.

## METHODOLOGY

A low-cost floating cage system fabricated from a locally sourced material, bamboo and plastic materials were both installed in Oyan dam to evaluate their durability and performance under a full loading capacity of the cage. These were to determine their functionality and suitability for aquaculture farmers in Nigeria in raising fishes at less cost of production. The two materials, Bamboo and Plastic drum were sourced locally which were readily available in the environment. Biochemical Oxygen Demand, temperature and ammonia content of Oyan dam water was determined for favourable water environment for fish breeding. Other reason for chosen these two materials were in terms of cost of producing the floating cage system, material market accessibility and adaptability in the river with plastic and bamboo installed and anchored in the river, Figures 2 and 3. The cages were also in two different types in terms of netting colour (blue and white colours) used to form the cage bag where the fishes were cultured. Four cages were stocked with 200 fishes of two species (*C. gariepinus* and *O. niloticus*) with initial sizes of 5 and 1 g respectively, making 400 *C. gariepinus* and 400 *O. niloticus*, and a total of 800 fishes in all. Weights of the fishes were measured with digital weighing machine SF-400, at stocking and subsequently monitored every week for eight weeks. The fishes were fed thrice daily with 15 grams of special feed (feed composition of protein content > 65%, moisture content < 10%, ash < 18% and fat < 8% of various pellet size), a blend obtained from Asero Market, Abeokuta, Nigeria. During cause of culturing the fishes for eight weeks the mortality rate was monitored every day, precisely in the evening time when the fishes were fed. The mortality rate of the cultured species was determine using equation (1) Olaniyi *et al.,* (2013):

$$\text{Mortality rate (\%)}=\frac{\text{Number of fish that died during the experiment}}{\text{Number of fish at the beginning of the experiment}} \text{ x } 100 \qquad (1)$$

Growth performance of the cultured species were carefully studied, and the growth parameters calculated using equations 2 and 3, Olaniyi *et al.,* (2013).

$$\text{Average daily weight gain (ADG)} = \frac{Final\ mean\ weight - Initial\ mean\ weight}{Days} \qquad (2)$$

$$\text{Specific growth rate (SGR)} = \frac{Ln\ final\ weight - Ln\ initial\ weight}{Days} \text{ x } 100 \qquad (3)$$

Fig. 2. Plastic drum floating fish cages installed and anchored on Oyan dam, Abeokuta, Nigeria

Fig. 3. Bamboo floating fish cages installed and anchored on Oyan dam, Abeokuta, Nigeria

## RESULTS AND DISCUSSION

Oyan Lake was found suitable for installation of the floating cage system in that the farmers were cooperative, and the environment had no adverse effect on the culturing of fishes. The physical qualities and parameters of the water; Biochemical Oxygen Demand (2.3-4 mg/l), pH (6.5-7.5), temperature (24-36 $^0$C) and ammonia (<1%) content were found favorable for the breeding because of the presence of both national and international fish farmers. The yield and growth rate of the two species of fish cultured (*C. gariepinus* and *O. niloticus*) monitored and measured in the designed cage are as presented in Tables 1, 2, 3 and 4. Table 1 and 2 presents the mortality rate observed while culturing the fishes. It's was observed that the morality rate of *C. gariepinus* was higher than that of *O. niloticus*. The mortality of each of the fish samples are presented in Figures 4 and 5. It was observed that the mortality rate for *C. gariepinus* increased at early stage of stocking but decreases after 48 hours.

Table 1. Mortality rate in *C. gariepinus*

| No of hrs | White net (g) | Blue net (g) |
|---|---|---|
| 24 | 43 | 38 |
| 48 | 47 | 48 |
| 72 | 30 | 26 |
| 96 | 12 | 9 |
| 120 | 5 | 3 |
| Total | 137 | 124 |
| Mortality rate | 68.5 % | 62 % |

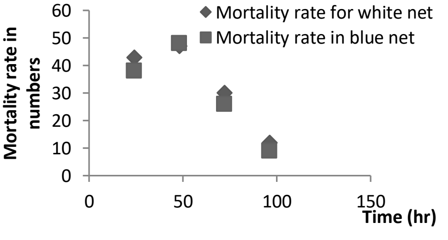


Fig. 4. Mortality rate of *C. gariepinus* during culturing in Oyan dam

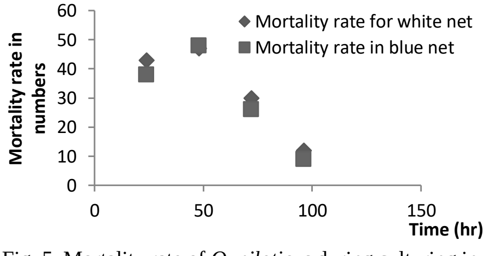


Fig. 5. Mortality rate of *O. niloticus* during culturing in Oyan dam.

Table 2. Mortality rate in *O. niloticus*

| No of hrs | White net (g) | Blue net (g) |
|---|---|---|
| 24 | 1 | 2 |
| 48 | 2 | 1 |
| 72 | 1 | 1 |
| 96 | 1 | 2 |
| 120 | 0 | 1 |
| Total | 5 | 7 |
| Mortality rate | 2.5 % | 3.5 % |

This could mean that the *C. gariepinus* took 48 hrs to adapt to the water in the Oyan dam. However, *O. niloticus* there was no clear-cut response to time in terms of adaptation to the water bodies. It was observed for *O. niloticus* that subsequent time it took to adapt was 120 hrs to the cage and water environment, but the percentage of mortality rate was found to be higher for *C. gariepinus*. Hen *O. niloticus* were of better variety for breeding in Oyan dam. This is strongly indicated by the result of mortality rate observed between the two species of the fish cultured in the dam. The average mortality rate for *C. gariepinus* is 66.75 % while that of *O. niloticus* is 3%. This shows that 97% of the *O. niloticus* survived and were ready for harvest hence raising *O. niloticus* in the cage system had 63.75% survival rate higher than of *C. gariepinus*.

Tables 3 and 4 shows that more weight was gained in white nets than in blue nets. For the two breeds, a different gain of weight of 52.0 g was observed between white and blue net for *C. gariepinus* while for *O. niloticus*, 54.5 g difference within the period of breeding investigation which was analyzed statically using a t-test. There was a significant effect of the net color on the weight gained which was found higher in the white net but lesser in the blue net. The t- test to verify this was conducted and the result showed that there were significant differences between the weight gained in the two different nets for both *C. gariepinus* and *O. niloticus* at 0.0158 and 0.0247 at 95 percent confidence level respectively. Further graphs of the growth characteristics of the *C. gariepinus* and *O. niloticus* are given in Figures 6 and 7. The relationship of mass gain per hour rate of growth for *C. gariepinus* cultured in white ($Y_w$) and blue (Yb) nets are given as;

$y_{wc} = 8E\text{-}05x^2 + 0.087x - 20.009$
$R^2 = 0.9998$
$y_{bc} = 4E\text{-}05x^2 + 0.1138x - 12.402$
$R^2 = 0.9965$
$y_{bt} = 6E\text{-}05x^2 + 0.017x - 5.1625$
$R^2 = 0.9965$
$y_{wc} = 3E\text{-}05x^2 + 0.195x - 3.788$
$R^2 = 09985$

This result in Figure 8 also shows that the breeding of *C. gariepinus*, although had more mortality rate but the fish grew faster than the *O. niloticus* as shown in the growth rate. For *C. gariepinus* (catfish), the average growth rate gain per hr is 1.6 E-4 g/hr and 8 E-5 g/hr for white and blue netting respectively. Possibly the white net had an advantage of not obscuring the light rays which maybe the reason that affects the feeding of the fishes in the blue net.

Table 3. Growth rate of *C. gariepinus*

| No of weeks | No of hrs | No of minutes | No of seconds | White net (g) | Blue net (g) |
|---|---|---|---|---|---|
| 1st | 0 | 0 | 0 | 5 | 5 |
| *2nd | 168 | 10080 | 604800 | No reading | No reading |
| 3rd | 336 | 20160 | 1209600 | 65 | 60.5 |
| 4th | 504 | 30240 | 1814400 | 98.7 | 81.7 |
| 5th | 672 | 40320 | 2419200 | 134.2 | 101.1 |
| 6th | 840 | 50400 | 3024000 | 170.7 | 139.9 |
| 7th | 1008 | 60480 | 3628800 | 211.3 | 168.1 |
| 8th | 1176 | 70560 | 4233600 | 259.19 | 207.2 |

Table 4. Growth rate of *O. niloticus*

| No of weeks | No of hrs | No of minutes | No of seconds | White net (g) | Blue net (g) |
|---|---|---|---|---|---|
| 1st | 0 | 0 | 0 | 1 | 1 |
| *2nd | 168 | 10080 | 604800 | No reading | No reading |
| 3rd | 336 | 20160 | 1209600 | 15.2 | 11.4 |
| 4th | 504 | 30240 | 1814400 | 37.7 | 23.6 |
| 5th | 672 | 40320 | 2419200 | 53.2 | 35.1 |
| 6th | 840 | 50400 | 3024000 | 79.1 | 47.5 |
| 7th | 1008 | 60480 | 3628800 | 102.7 | 61.3 |
| 8th | 1176 | 70560 | 4233600 | 131.7 | 77.17 |

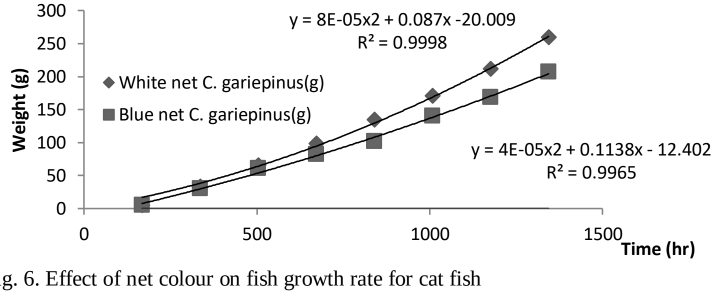


Fig. 6. Effect of net colour on fish growth rate for cat fish

The cost estimate of the developed floating fish cages made of bamboo was N127,700 ($418.7) and plastic materials was N139,100 ($456.1) to produce 52.7 kg of *O. niloticus* (Tilapia) and 103.7 kg of *C. gariepinus* (Catfish) per crop. Therefore, it could be seen that it will be more convenient for local farmer to set up and maintain a floating fish cage than spending millions of Naira to acquire imported cages, having seen that most materials can easily be acquired.

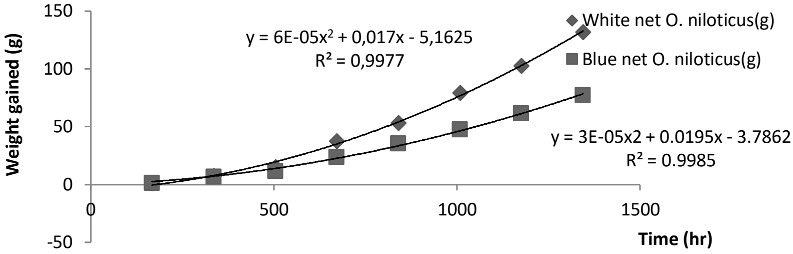

Fig. 7: Effect of net color on the growth rate for tilapia

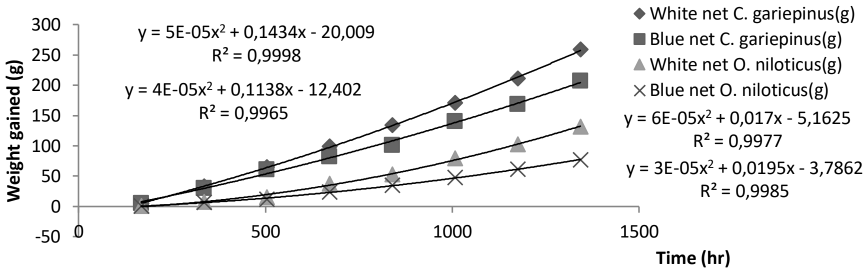

Fig. 8. Fish growth rate

## CONCLUSION AND RECOMMENDATION

A new indigenous fish floating cages system were developed from locally sourced materials; plastic and bamboo, were evaluated on full load condition of two fish species namely; *C. gariepinus* and *O. niloticus*. These cages were used successfully in raising the fishes in three months with no failure of the structure, the mortality rates shoed that *O. niloticus* were found to have a better and adaptability rate over *C. gariepinus* and hence average farmer could conveniently and economically adopt this fish production.

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## 2.2. A SIMPLE METHOD TO PREDICT SPRAY DRIFT FROM SOME OF THE TECHNO-METEOROLOGICAL PARAMETERS

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**Keywords***:* nozzle type, nozzle height, wind velocity, spray drift, sedimentation time mode

### ABSTRACT

Spray drift can be resulted from air movement of the tiny particle droplets to the non-intended target during the spraying application. In the field, different attempts have conducted to predict spray drift and they are many compared to wind tunnel experiments. The main purpose of this study is to investigate a simple method to predict spray drift measured in a wind tunnel. Various models carried out at IRSTEA-Montpellier in France using different parameters. Laboratory tests were performed with different experimental setups using three nozzle types including standard flat fan nozzle, flat fan air induction nozzle (single jet) and flat fan air induction nozzle (twin jets). All these nozzles were at the same angle and size (110 02); with three nozzle heights 40, 60 and 80 cm and three wind velocities 2, 4, and 7.5 m/s. The results showed that wind velocity and nozzle height are the most important factors which have affected on spray drift. The results also demonstrated that it is impossible to predict spray drift as function of the downwind distance. Whereas, there is an alternative method to estimate spray drift using sedimentation time mode depending on nozzle height and wind velocity for different nozzle types.

### INTRODUCTION

Spray drift can be resulted from air movement of the tiny particle droplets to the non-intended target during the spraying application ASAE (2009). Several factors as nozzle type, operating pressure, nozzle height, and wind velocity, can affect spray drift during the spraying process Nuyttens *et al.* (2007); Miller *et al.* (2011), and Douzals and Alheidary (2014). Many studies are conducted on spray drift in the field according to ISO (2005) resulting in a high variability of spray drift values due to the vibration of nozzle height, topography, unstable meteorological conditions (as wind velocity, air temperature, air stability, and relative humidity) at the time of spraying application Zhu *et al.* (1995); Carig (2004); Nuyttens *et al.* (2005); and Bulter Ellis *et al.* (2017). Furthermore, these field measurements are costly and not repeatable at the same working conditions. The wind tunnel is an alternative method to measure spray drift with an acceptable average in dispersion in the laboratory experiments ISO (2008) and Alheidary *et al.* (2018). In several studies the spray drift is measured depending on downwind distance by using the parameters mentioned above separately in wind tunnel experiments De Schampheleire *et al.* (2008); Yarpuz-Bozdogan and Bozdogan (2009); Grella *et al.* (2017); and Bulter Ellis *et al.* (2017). It is noteworthy; all these studies used one nozzle mounted on the boom for measuring spray drift. Therefore, the main goal of this present study is to shed light on a simple method for spray drift prediction in wind tunnel experiments depending on some of the techno-meteorological parameters (nozzle height and wind velocity) using sedimentation time mode for different nozzle types.

### MATERIALS AND METHODS

The laboratory study was conducted in wind tunnel IRSTEA-Montpellier as shown in Figure 1.

Fig. 1. View of wind tunnel IRSTEA

The internal dimensions of working section in wind tunnel were 2m width, 3m length, and 9m distribution test bench which consists 180 grooves (5cm width *10cm length). There is a mobile device of 3m width (60 tubes) to collect spray deposit from each channel. Depending on nozzle flowrate, the measurements will automatically stop when the volume of water collected reaches to 500 ml. then the system saves data and automatically pass to the next distance until 7th position (9m) from the nozzle location.

**Nozzle characteristics**

Three nozzle types were used in this study as shown in Table 1.

Table 1. Characteristics of studied nozzle types

| Nozzle type | Nozzle angle/size | Nozzle color | Nozzle flowrate, l/min | VMD*, µm |
|---|---|---|---|---|
| Stantard Flat Fan (FF) | 110 02 | Yellow | 0.64 | 164.9 |
| Flat Fan air induction AIFF Single (single jet) | 110 02 | Yellow | 0.73 | 434.6 |
| Flat Fan air induction AIFF Twin (Twin jet) | 110 02 | Yellow | 0.73 | 380.0 |

*VMD is Volume Median Diameter

**Nozzle setup**

Wind tunnel of IRSTEA-Montpellier consists of short boom with 4 nozzles (50 cm distancing between two adjacent nozzles). Different nozzle heights were tested 40, 60, and 80 cm. The nozzle was in frontal position (perpendicular towards wind velocity direction).

**Spray drift measurements**

Measuring spray drift in the wind tunnel was carried out using French protocol (a long du percentagen of exposure) with distribution test bench. After setting the intended parameters, the volume of water was collected. Then, the volume was converted into flowrate. After that the cumulated flowrate was calculated. Finally, spray drift percentage was obtained by inverse of the cumulated flowrate using the following formula (Douzals, Alheidary, 2014):

$$D_{r_i} = 1 - \sum q_i \qquad (1)$$

where: $Dr_i$ is drift percentage at position i; $q_i$ is the flowrate at position i.

All measurements were measured at a constant operating pressure of 2.5 bar and were repeated three times. Then the averages of these measurements were calculated separately.

**Sedimentation time mode**

According to the results obtained by Douzals and Alheidary (2014) as shown in Fig.2a, there was a good relationship between sedimentation of the spray drift and the distances.

After analysis the above curves of the spray drift (Fig. 2 a), the spray drift percentages were equal in 2, 4, and 7.5 m distances from the nozzle location. This means that a sedimentation time was a constant for different distances and called "Sedimentation Time" Fig.2b.

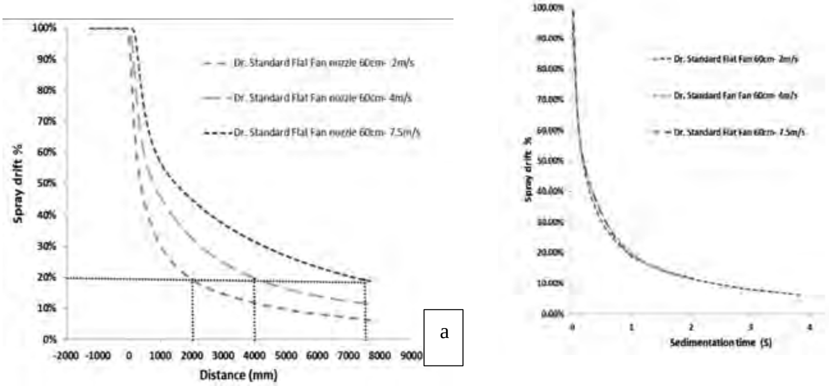


Fig. 2: (a) Effect of wind velocities on spray drift percentage at different distances (b) Expression of the spray drift

The sedimentation time was calculated as following:

$$ST = D/V \quad 2)$$

ST: is the Sedimentation Time (s); D: is the distance (m); V: is the wind velocity (m/s)

**Meteorological conditions**

During the present laboratory study in wind tunnel experiments, three artificial wind velocities were selected of 2, 4, and 7.5m/s. Air temperature and relative humidity were 20ºC and upon 90% respectively.

**Statistical analysis**

Spray drift data were statistically analysed using Graph pad software.

## RESULTS AND DISCUSSION

**Effect of nozzle type on spray drift percentage**

According to the results as shown in Figure 3, nozzle types have a significant effect on spray drift percentage. Lower drift percentage was observed with flat fan air induction nozzle single jet (FFAI) compared to the standard flat fan nozzle and flat fan air induction twin jet (FFAI Twin jet) at the same working conditions.

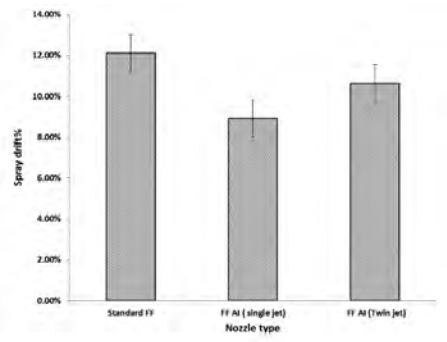


Fig. 3. Effect of nozzle types on spray drift percentage

At 5 m for example, drift percentages were 12.11%, 8.93% and 10.63% for standard flat fan, flat fan air induction single jet, and flat fan nozzle air induction twin jet nozzle respectively.

**Effect of nozzle height on spray drift percentage**

According to the results from this study as shown in Fig. 4, nozzle height affected significantly on the spray drift percentage. Increasing of the nozzle height had a high significant effect on the increasing in the spray drift percentage.

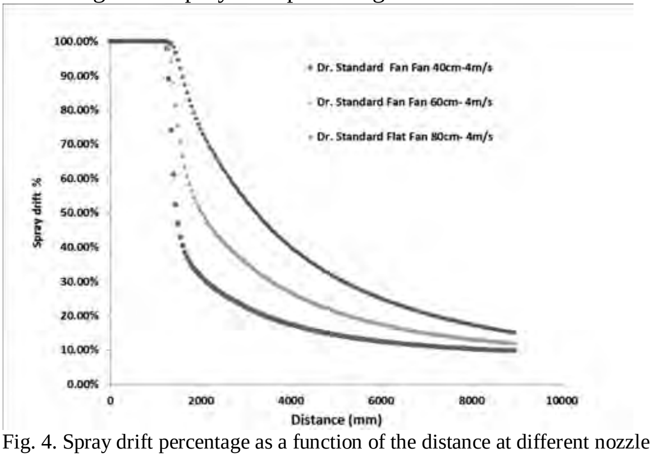


Fig. 4. Spray drift percentage as a function of the distance at different nozzle heights

The Farthest nozzle height from the surface of ground allows moving tiny spray droplets from the target to another site that rise with increasing of the wind velocity.

When the results of spray drift percentages in Fig. 4 were represented as a function of the sedimentation time, it is possible to predict spray drift percentage for different nozzle heights easily as shown in Fig 5.

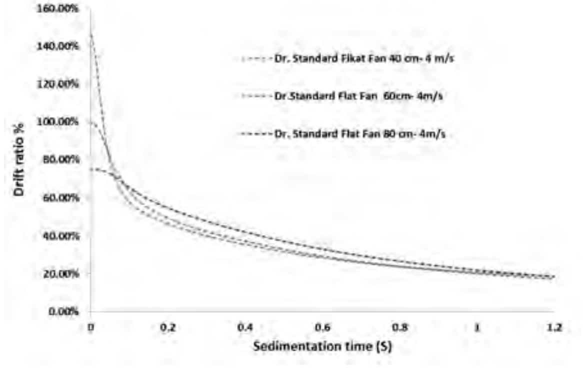


Fig. 5. Representation of the spray drift percentages according to sedimentation time at different nozzle heights

**Effect of wind velocity on spray drift percentage**

The effect of artificial wind velocity on spray drift percentage measured in wind tunnel experiments. A high significant effect of the spray drift percentage was elucidated with increasing of the wind velocity at the time of the measuring in Fig. 6. Higher artificial wind velocity (7.5 m/s) resulted in higher spray drift percentage for all nozzle types in contrary to lower wind velocity (2m/s).

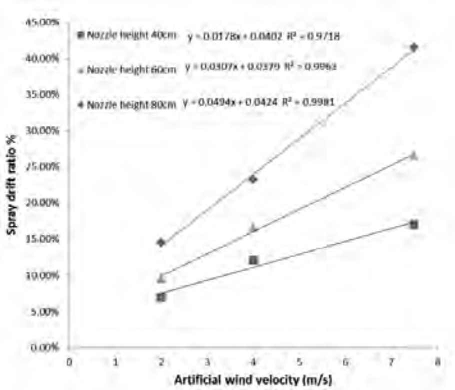


Fig. 6. Expression of the spray drift percentages according to the effect of wind velocity

The spray drift percentages in Fig. 6 could be recalculated as a function of the sedimentation time at different wind velocities, the results of this mode revealed that all artificial wind velocities were at approximate spray drift percentages (Fig.7). For example, at 1s of the sedimentation time, spray drift percentages were 19.18%, 20.04%, and 19.21% for wind velocities 2, 4, and 7.5m/s, respectively.

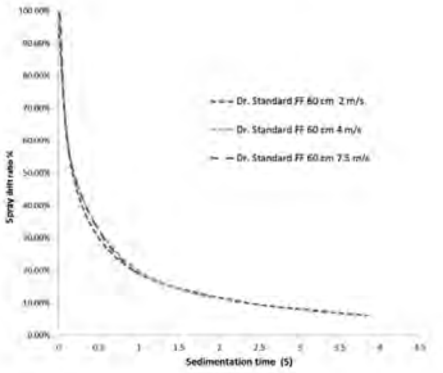


Fig. 7. Spray drift percentages according to sedimentation time mode at different wind velocities

## CONCLUSION

The main conclusions of this study clearly showed effect of nozzle types, nozzle heights, and wind velocities on spray drift percentage. Lower spray drift percentage observed with lower wind velocity and air induction nozzles. For both of the air induction nozzle single jet and air induction nozzle twin jet, there were no significant differences in spray drift percentages between them. Also, the results detected a possible method using sedimentation time mode to predict spray drift percentages from the nozzle height and wind velocity.


## ACKNOWLEDGEMENTS

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## 2.3. UAV IMAGES 3D MODELLING TECHNIQUES FOR QUANTIFY TREE ROW VOLUME

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**Keywords:** Unmanned Aerial Vehicle, object-based image analysis, tree row volume

## ABSTRACT

The use of pesticides in agriculture contributes to increase crop productivity but, at the same time, it could increase human health and environmental pollution risks. Directive 2009/128/EC drives the farmers to achieve a sustainable use of pesticides by reducing these impacts. Precision farming represents a new approach in order to reduce the amount of pesticides applied and to increase the automatic site-specific crop management. The aim of this paper is the estimation of the Tree Row Volume (TRV) by using Unmanned Aerial Vehicle images 3D modelling methods. The research was conducted in a super high-density olive orchard, located in Valenzano (Bari – Italy). All the olive crowns were reconstructed by the photogrammetric software. The average error on the estimate of the TRV is 3%, considering the total and cut TRV. This method could be adapted to other similar woody crops allowing a considerable reduction in time and labour of measuring tasks.

## INTRODUCTION

Precision agriculture is an environmental and economic management strategy that uses information and communication technology (ICT) to acquire data that leads to decisions aimed at agricultural production. Thanks to the use of UAV that fly over the land, the extrapolation of valuable information for the optimal management of agricultural companies has accelerated (Ampatzidis *et al.,* 2019; Castrignanò *et al.,* 2018; Comba *et al.,* 2018; De Castro *et al.,* 2018; Dewi *et al.,* 2020). With the remote sensing service for precision agriculture we take care of checking the "health status" of the crops. It is a technique designed to promptly manage the limiting factors of the production system, a site-specific management (Anifantis, 2017; Russo *et al.,* 2016) in which the decision on the application of resources and agronomic practices are dictated by the variability detected on the field within the crop in progress (Ezenne *et al.,* 2019; Gavioli *et al.,* 2019; Jiménez-Brenes *et al.,* 2017; Peña *et al.,* 2018; Sanz *et al.,* 2018; Torres-Sánchez *et al.,* 2015; Torres-Sánchez *et al.,* 2014; Torres-Sánchez *et al.,* 2018). A site-specific management means that inputs (water fertilizers, pesticides, agronomic operations, etc.) are applied only where, when and what is necessary to maximize the desired result, which in most cases is the most income and lower environmental impact (Díez *et al.,* 2016; Zarco-Tejada *et al.,* 2018). The use of these recent technologies has aroused greater environmental awareness and attention to human health by both consumers and producers, along with awareness of the economic costs of treatment by farmers. All this has led to the spread of integrated and organic agriculture. In the case examined, an innovative automatic method was presented to estimate the volume of the row of trees (TRV) (Codis *et al.,* 2018) in a very high-density olive grove using UAV images. All the olive crowns were thus reconstructed by the photogrammetric software. This method could be adapted to other similar wood crops by allowing a significant reduction in time and job measurement work.

## MATERIALS AND METHODS

The research was carried out at the experimental farm "P. Martucci" of the University of Bari located in Valenzano, Bari, Italy, where the tree row volume (TRV) of a super high-density olive orchard has been estimated using the images of a model of unmanned aerial vehicle (UAV).  The field examined consists of 25 rows including 15 different cultivars. The study was performed to clarify the correlation between TVR calculated using OBIA techniques with the TRV measured with manually devices in situ. The procedure for estimating the TRV of the SHD olive grove measured with UAV devices was based on a close-up photogrammetry from UAV and the use of object-based image analysis techniques (OBIA). The Light Spectrum images were acquired by a DJI SPARK UAV, a regular grid with the follow specifications reported in Table 1 was performed:

Table 1. UAV's specifications

| Item | Specifications |
|---|---|
| frontal overlap | 75% (at list) |
| lateral overlap | 60% (at list) |
| flight height | 15 m |
| image size | 3968x2976 pixels |
| field of view (FOV) | 81.9 ° |
| ground sampling distance (GSD) | 0.68 cm / pixel. |

The most suitable flight plan for the analysis was set to reduce the battery consumption. The drone is flown at an altitude of 15 m along the entire plot, taking a photographic series. Numbered markers have been placed, first on the software and then positioned in the field, taking as reference points the vertices of the quadrilateral (Fig.1).

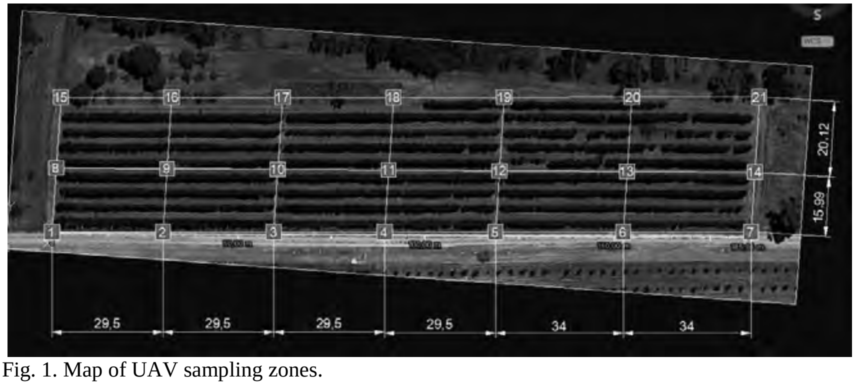
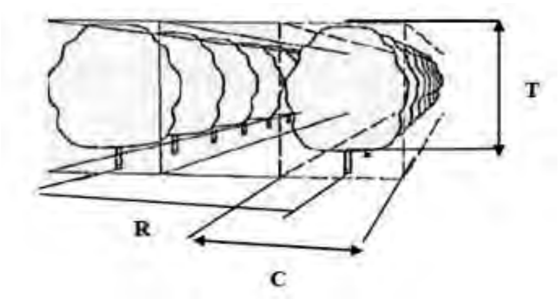



Fig. 1. Map of UAV sampling zones.

The UAV equipped with a sensor carried out a detailed photographic survey field. The drone flew six times at low altitude, with a height of 15 m above the ground, making photo shoots with a 70-75% overlap to make mesh reconstruction as close to reality as possible. After each landing of the vehicle, with a flight duration of 12 minutes, the workers provided for the replacement of the batteries and for the recovery of the data stored during the flight for their definitive processing. The photogrammetric 3D map was loaded and processed on Pix4Dmapper software, which through a series of steps, builds the dense cloud and the mesh of all the olive crowns.

The total TRV of the SHD olive grove was calculated. The mean value of height, width and thickness for each cultivar has been calculated, this average value has been multiplied by the number of trees of each cultivar. The TRV calculated using the 3D photogrammetric method was compared with the TRV calculated using the literature formula (Fig.2).




$$TRV = \frac{T \cdot C \cdot 10000}{R} \ [m^3/ha]$$

TRV: $m^3$/ha

T: tree high [m]

C: tree thickness [m]

R: tree interrow [m]

Fig. 2. Tree row volume formula.

## RESULTS AND DISCUSSION

The valid sizing, necessary for the reconstruction of the arboreal volume, was obtained using direct measurements, which are measured by means of the metric wheel and a rigid meter, and indirect measurements, which derive for example from the calculation of the volume performed on direct measurements. All the olive crowns were reconstructed by the photogrammetric software (Fig.3). The average error on the estimate of the TRV is 3%, considering the total and cut TRV. This method could be adapted to other similar woody crops allowing a considerable reduction in time and labour of measuring tasks.

| | | | |
|---|---|---|---|
| | VOLUME 1 | VOLUME 2 | VOLUME 3 |
| Area<br>Cut volume<br>Waste volume<br>Total volume | 2392.48 $m^2$<br>1004.73 ± 21.84 $m^3$<br>-29.96 ± 10.50 $m^3$<br>974.77 ± 32.34 $m^3$ | 2426.03 $m^2$<br>907.83 ± 20.80 $m^3$<br>-16.81 ± 10.16 $m^3$<br>891.02 ± 30.96 $m^3$ | 2354.13 $m^2$<br>938.08 ± 13.98 $m^3$<br>-39.01 ± 16.96 $m^3$<br>899.07 ± 30.94 $m^3$ |
| | VOLUME 4 | VOLUME 5 | VOLUME 6 |
| Area<br>Cut volume<br>Waste volume<br>Total volume | 2185.01 $m^2$<br>707.18 ± 12.39 $m^3$<br>-31.48 ± 17.17 $m^3$<br>675.71 ± 29.56 $m^3$ | 2565.09 $m^2$<br>949.52 ± 26.75 $m^3$<br>-23.39 ± 10.18 $m^3$<br>926.13 ± 36.92 $m^3$ | 2394.34 $m^2$<br>827.40 ± 27.40 $m^3$<br>-7.17 ± 6.17 $m^3$<br>820.23 ± 33.58 $m^3$ |

Fig. 3. Tree row volume of the olive crowns reconstructed by the photogrammetric software


## ACKNOWLEDGMENTS

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# 2.4. THE USE OF POLYNOMIAL TRANSITION CURVES FOR TRAJECTORY OF MOTION PLANNING

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## ABSTRACT
The paper presents the way of using polynomial transition curves in trajectory planning. The method of determining the function of curvature and angle of tangent to the profile of the curve determined by the linear function as well as the third, fifth, seventh and ninth degree polynomials is presented. A calculation algorithm was formulated for a selected motion path composed of two transition curves. For the analysed trajectory variants, the courses of kinematic quantities were determined and compared. The algorithm proposed in the paper, using transition curves, ensures the continuity of the normal acceleration course and can be used to plan the trajectory of movement of agricultural aggregates and machines, autonomous vehicles, mobile robots, manipulators and CNC machines.

## INTRODUCTION
Planning trajectories of agricultural aggregates motion with particular consideration of ride on the headland during cultivation work is of significant interest for many researches. In the papers by Oksanen and Visala (2004) as well as by Oksanen (2007) the aggregate in the form of tractor with a trailer is defined as a ground vehicle which is modelled as a dynamic system moving with a planar motion. To shorten the turn trajectory length, the paths were generated using the Bézier splines. Length minimization is possible due to the cost function application. Cariou *et al*. (2010) presented the way of trajectories generation and motion control for autonomous manoeuvre of the agricultural aggregate on the headland using clothoids and arc of circle curves. The motion paths were defined for a given vehicle taking into consideration a minimal rotation radius. The values of clothoid proportionality coefficient were calculated from the maximal angular velocity for the frontal wheel and vehicle velocity during moving back along the curves. The researchers found out that in this way the trajectories with a continuous curvature for a vehicle can be prepared. Backman *et al*. (2012) used the spiral connection method for modification of the shortest path that is the Dubin spiral. This method can be applied for smoothing or restraint of the curvature of any trajectory. The paper by Sabelhaus *at al*. (2013) presents the method of motion trajectory formation using the clothoid which enables connection of paths of different curvatures. As the researchers found out the movement forward and back can be planned using the Dubin curves as well as the modified Reed and Sheep ones. The authors analysed seven different agrotechnical manoeuvres to be used during the ride on headland. Koc (2014) presented the analytical modelling of the transport way curvature based on the differential equations. He analysed the transition curves with the curvature described by the linear function, polynomial and trigonometric functions. The paper by Sabelhaus *et al*. (2015) discusses planning of turn manoeuvres using the CC-Circle method which allows to determine possible trajectories of machine movement with some constrains e.g. of minimal turn radius. According to the authors the use of CC-Circle makes calculations simpler and the trajectory composed e. g. of a straight line and clothoid can by applied for any manoeuvres. Tharmin et al. (2016) analysed the turn manoeuvre on the headland accomplished by the experimental unmanned mobile robot. The vehicle moves along the earlier established trajectory in the form of Bézier curve with the optimal path taking into consideration

characteristics of mobile robot drive and steering. The effectiveness analysis was made from the actual difference between the planned and achieved movement trajectory. Planning of movement trajectory composed of two rectilinear segments connected by two clothoids with the arc of circle curve is presented in the paper by Boryga *et al.* (2017). The proposed algorithm ensures continuity of displacement, velocity and acceleration for the planned movement trajectory. Wang and Noguchi (2018) proposed application of adaptation turn algorithm (DCB) while steering the aggregate movement during the turn on headland with optimization in actual time depending on the local conditions. The changes e.g. of soil properties or vehicle speed under the local conditions result in divergences and necessity of making corrections. This is most often done by adding a straight path or continuous curvature which makes the movement of aggregate on the headland longer. The paper presents the way of using polynomial transition curves in planning trajectories of agriculture machines movement during the ride on the headland. It was planned to apply the transition curves whose curvature is described by the linear function as well as the third, fifth, seventh and ninth degree polynomials. Motion parameters courses were determined and compared for the analysed trajectory variants. The results are presented in the graphical form.

## CURVATURE AND THE ANGLE OF THE TANGENT TO THE CURVE OF POLYNOMIAL TRANSITION CURVES

The curvature of the planar curve is defined as:

$$\kappa(l) = \lim_{\Delta l \to 0} \frac{\Delta\theta}{\Delta l} = \frac{d\theta}{dl} \tag{1}$$

where: $\Delta\theta$ - the angle between the tangents to the curve on the arc ends, $\Delta l$ - the arc length.

The function $\theta(l)$ is defined by the relation:

$$\theta(l) = \int \kappa(l)dl \tag{2}$$

but the coordinates of any point on the transition curve are calculated from:

$$\begin{bmatrix} x(l) \\ y(l) \end{bmatrix} = \begin{bmatrix} \int \cos\theta(l)dl \\ \int \sin\theta(l)dl \end{bmatrix} \tag{3}$$

Figure 1 presents the curve with the geometrical quantities used in 1-3.

In the paper there were applied the polynomial transition curves for which the diagram of the function $\kappa(l)$ in the interval <0, $L$> is the central symmetry towards the point $\boldsymbol{C}$ of the coordinates ($L$/2, ($\kappa_1$+$\kappa_2$)/2). The parameter $l$ is the position of a given point along the curvature, $L$ is the total length of the curve but $\kappa_1$ and $\kappa_2$ are the initial and terminal curvatures of the curve.

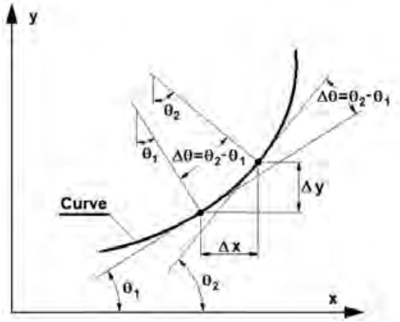


Fig. 1. Geometrical quantities of the curve

Figure 2 presents the courses of curvature function $\kappa(l)$ in the interval < 0, *L*>.

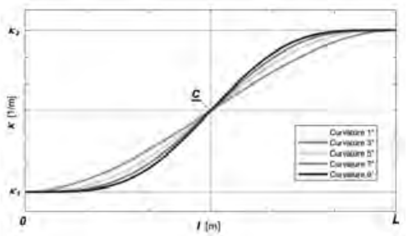


Fig 2. The exemplary function $\kappa(l)$ being a central symmetry towards the point ***C***

The polynomial describing the curvature for the analysed transition curves has the form.

$$\kappa(l) = a_0 + (\kappa_2 - \kappa_1)\sum_{k=1}^{9} a_k l^k \tag{4}$$

The polynomial coefficients are calculated using the boundary conditions. The first two boundary conditions for the analysed curvatures are: $\kappa(0) = \kappa_1$, $\kappa(L) = \kappa_2$. These conditions are sufficient for determination of coefficients for the linear curvature.

For the curvature $\kappa(l)$ defined by the degree of polynomial $k \geq 3$ the other conditions assume the form: $\frac{\mathrm{d}^i\kappa}{\mathrm{d}l^i}(0) = 0$ and $\frac{\mathrm{d}^i\kappa}{\mathrm{d}l^i}(L) = 0$ for $i=\{1,2,\ldots,(k-1)/2\}$. The angle tangent to the curve can be calculated from (2). The polynomial defining the angle tangent to the curve can be presented in the form:

$$\theta(l) = a_0 + a_1 l + (\kappa_2 - \kappa_1)\sum_{k=2}^{10} a_k l^k \tag{5}$$

The paper is confined to the transition curves whose curvature is described by the linear function as well as the third, fifth, seventh and ninth degree polynomials. Table 1 presents the relations for the coefficients of polynomials defining the curvature $\kappa(l)$ and Table 2 those for the coefficients of polynomials determining the angle tangent to the curve $\theta(l)$ for the single transition curve of the length *L*.

Table 1. The relations for the coefficients of polynomials describing the curvature $\kappa(l)$

| Polynomial degree | Polynomial coefficients describing the curvature | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $k$ | $a_0$ | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ | $a_6$ | $a_7$ | $a_8$ | $a_9$ |
| 1 | $\kappa_1$ | $1/L$ | - | - | - | - | - | - | - | - |
| 3 | $\kappa_1$ | - | $3/L^2$ | $-2/L^3$ | - | - | - | - | - | - |
| 5 | $\kappa_1$ | - | - | $10/L^3$ | $-15/L^4$ | $6/L^5$ | - | - | - | - |
| 7 | $\kappa_1$ | - | - | - | $35/L^4$ | $-84/L^5$ | $70/L^6$ | $-20/L^7$ | - | - |
| 9 | $\kappa_1$ | - | - | - | - | $126/L^5$ | $-420/L^6$ | $540/L^7$ | $-315/L^8$ | $70/L^9$ |

Table 2. The relations for the coefficients of polynomials describing the angle tangent to the curve $\theta(l)$

| Polynomial degree | Polynomial coefficients describing the tangent angle | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $k$ | $a_0$ | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ | $a_6$ | $a_7$ | $a_8$ | $a_9$ | $a_{10}$ |
| 1 | $\theta_b$ | $\kappa_1$ | $1/2L$ | - | - | - | - | - | - | - | - |
| 3 | $\theta_b$ | $\kappa_1$ | - | $1/L^2$ | $-1/2L^3$ | - | - | - | - | - | - |
| 5 | $\theta_b$ | $\kappa_1$ | - | - | $5/2L^3$ | $-3/L^4$ | $1/L^5$ | - | - | - | - |
| 7 | $\theta_b$ | $\kappa_1$ | - | - | - | $7/L^4$ | $-14/L^5$ | $10/L^6$ | $-5/2L^7$ | - | - |
| 9 | $\theta_b$ | $\kappa_1$ | - | - | - | - | $21/L^5$ | $-60/L^6$ | $135/2L^7$ | $-35/L^8$ | $7/L^9$ |

## PLANNING OF MOVEMENT TRAJECTORY

In the paper the kinematic quantities of the movement trajectory during the turn of an agriculture machine on the headland were analysed (Fig. 3). The trajectory is composed of two transition curves ***BT*** and ***TE***. The total length of the transition curve is $2L$. The curvature in the initial point of trajectory ***B*** equals $\kappa$=0, in the tangent point ***T*** being half of the total path length it is equal to the maximal value $\kappa= \kappa_{max}=1/R$ (the circumference radius $R$ can be minimal radius of agriculture machine turn). However, in the terminal point ***E***, similar to the initial point, it is $\kappa$=0. The angle between the tangents in points ***B*** and ***E*** is $\alpha=\pi$ but the angle tangent to the curve in the point of tangency ***T*** is $\theta=\pi/2$.

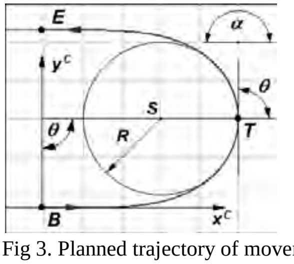

Fig 3. Planned trajectory of movement of an agriculture machine on the headland

The initial data are the coordinates of the centre ***S*** in the global coordinate system and the radius $R$. The constant velocity along the whole length of movement trajectory - $v_{max}$, angle of tangent to the curve $\theta=\pi/2$, curvature in the initial and final points $\kappa$=0 as well as the curvature in the half of the whole movement trajectory $\kappa_{max}=1/R$ are assumed. The beginning of coordinate system connected with the transition curve is in the initial point of the transition curve but the axis $x^C$ is on the tangent to the transition curve. The preliminary calculations are used for determination of the length of a single transition curve $L=2\theta/\kappa_{max}$. The coordinates of the terminal point of a single transition curve ***T*** in the coordinate system connected with the curve are calculated from the relation (3) but those of the initial point ***B*** in the global coordinate system are calculated based on Fig. 3. The displacement is calculated in the local coordinate system connected with the transition curve and them transformation into the base coordinate system is made. The courses of velocity, acceleration and jerk are determined as the first, second and third derivatives in relation to the displacement time.

## RESULTS OF THE SIMULATION

The figure presents the courses of kinematic quantities for the movement trajectory under consideration. The simulation was made for $v_{max}$=2π m/s, $R$=6m, $x_S$=10m, $y_S$=9m.

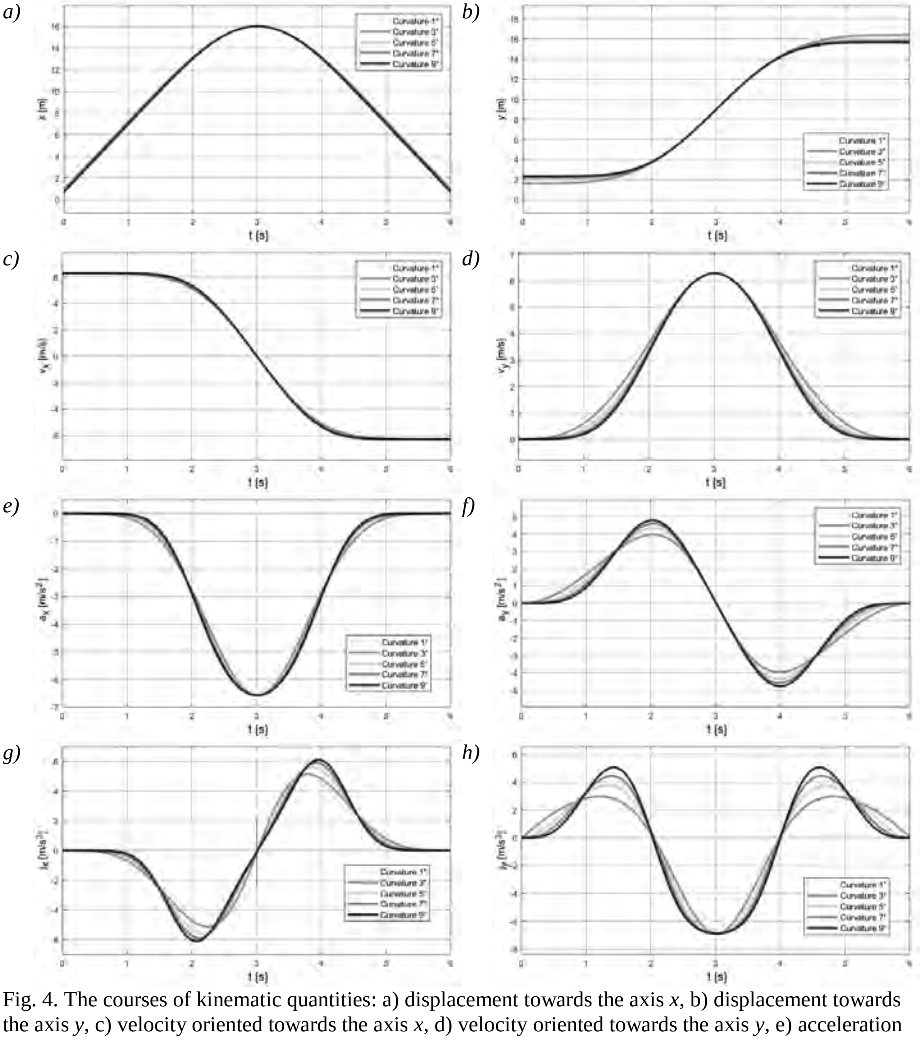


Fig. 4. The courses of kinematic quantities: a) displacement towards the axis *x*, b) displacement towards the axis *y*, c) velocity oriented towards the axis *x*, d) velocity oriented towards the axis *y*, e) acceleration oriented towards the axis *x*, f) acceleration oriented towards the axis *y*, g) jerk oriented towards the axis *x*, h) jerk oriented towards the axis *y*

The courses of displacement along the axis *x* for the individual transition curves are comparable (Fig. 4a). Slightly greater differences in the courses are obtained for the coordinate *y*, particularly in the initial and final periods of movement (Fig. 4b). The velocity and acceleration courses are similar. However, smaller changes are obtained for the curves whose curvature is determined by a lower degree polynomial (Fig. 4c to 4f).

The greatest differences are observed in the course of jerk for the transition curve whose curvature is described by the linear function (the first degree curvature). However, some discontinuities of the course (Fig. 4g) as well as non-zero values for the initial and final periods of time (Fig. 4h) were observed.

## CONCLUSIONS

The step course of standard acceleration during transition from the rectilinear movement into that along the arc of circle can lead to additional dynamic loads as well as vibrations and as a result, to lower accuracy of positioning. The transition curves whose curvature is determined by the linear function as well as the third, fifth, seventh and ninth degree polynomials, were proposed for realization of turn manoeuvre on the headland. The simulation tests showed that the courses of displacement, velocity and acceleration are continuous in the whole range of movement but the course of jerk is continuous for the transition curves whose curvature is determined by polynomials. For the transition curve whose curvature is determined by the linear function, the jerk course is discontinuous.

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# 2.5. THEORETICAL SUBSTANTIATION OF THE PARAMETERS OF A COMBINED COULTER OF THE GRAIN DRILL

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## ABSTRACT

Uniform distribution of seeds by depth is the most important parameter of grain drills. There are theoretically investigated and substantiated the design and kinematic parameters of the new combined double-disc wedge-shaped coulter that combines the advantages of the double-disc and the wedge-shaped coulters and can be successfully used on soils with the presence of plant residues. On the basis of the developed mathematical model of the movement of this coulter in the soil, a necessity is theoretically substantiated to use a spring of certain elasticity to ensure the drilling stability of seeds to the preset depth within the agrotechnological tolerance. Dependence is obtained for the calculation of a rational spring elasticity, which takes into account the geometrical parameters of the coulter design.

## INTRODUCTION

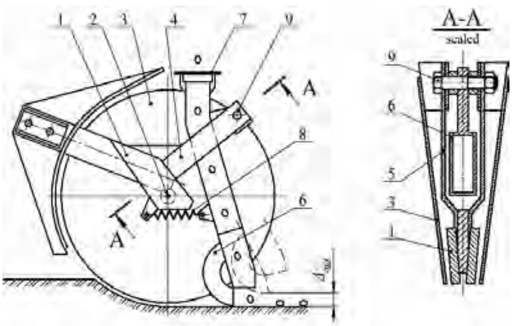
As one of the basic ways how to increase the efficiency of production of grain growing products may be regarded elaboration of the ways for raising the efficiency of aggregates and decreasing the costs for the execution of technological operations (Bulgakov *et al.,* 2017). The grain drilling quality significantly affects a high yield (Adamchuk, 2016; Barwicki *et al.,* 2012; Valainis *et al.,* 2014). A correct selection of coulters can provide the necessary uniformity on the seed distribution at the required depth. In grain drilling under production conditions and in the selective and seed-growing practice, seeders with double-disc coulters are used, which do not ensure the drilling stability of seeds by depth, especially at elevated speeds of drilling. The wedge-shaped coulters place seeds more evenly at the preset depth, on a solid seed bed; yet they are used less often since they, unlike the disk coulters, require careful soil preparation. The common depth of planting the seeds of wheat, rye, oats, barley in the light soils is 4.5...6.0 cm, in the medium wet soils 2.5...4.5 cm, in the heavy soils 2.0...4.0 cm, in the zone of the wind erosion 6...8 cm. The number of seeds that are sown to the given depth should be at least 80% (Vasilchenko, 2011).

One of the most efficient designs is the design of a combined double-disc wedge-shaped coulter. Yet the development of an efficient design requires a detailed theoretical study of the process of its operation and determination of the relationship between the design and the technological parameters of the double-disc coulter. There are a lot of works devoted to the theoretical and experimental study of coulters (Shmat and Reznichenko, 2006; Saxton, 2007). However, such investigations are not enough to study the work of the combined coulters (Lapshin, 2012). In addition, investigation of the combined coulters just in the selective seeders presupposes a number of specific tasks (Shaykhov, 2011).

The purpose of this paper is a research and development of theoretical foundations for the mechanical and technological substantiation of the design and kinematic parameters of the new combined coulter of the seeder.

## MATERIAL AND METHOD

The task to improve the design of the combined double-disc coulter is solved in such a way that two flat discs and the coulter body, located between them, are installed in the structure, and a wedge-shaped part with a flared end and a tip is attached to the body between the discs. The installed wedge-shaped part of the coulter between the discs by attaching it to the body, using a hinged suspension and a spring, allows the tip of the wedge-shaped part of the coulter to move along the prepared furrow, previously opened by the discs, compacting the bottom of the seed furrow, without the seeds contacting the rotating surfaces of the discs, which excludes bringing the seeds with the soil to the upper part of the furrow, increasing the stability of the depth and seed placing. Combination of the advantages of the double-disc and the wedge-shaped coulters is embodied in a patent for the design of a combined coulter (Lapshin, 2012; Shaykhov, 2011). The articulated suspension of the accordingly improved design of the combined double-disc wedge-shaped coulter is attached to a holder, connected with the coulter body, and it consists of two jaws that create an empty space in which the wedge-shaped part is inserted so that the axis of the articulated suspension of the wedge-shaped part is located in its rear side as viewed in the direction of the coulter movement; and the projection of the axis to the bottom of the furrow with the seeds coincides with the contact zone of the lower part of the wedge-shaped part and the bottom of the furrow with the seeds. The design and technological scheme of the new combined coulter is shown in Fig. 1. A general view of the coulter assembly with a combined double-disc wedge-shaped coulter is shown in Fig. 2.




a) b)

Fig. 1. The design and technological scheme of the combined coulter: a – side view; b – section A-A: 1 – body; 2 – axis; 3 – disc; 4 – holder; 5 – side plate; 6 – cylindrical seed drill tube; 7 – connecting element; 8 – spring; 9 – articulated suspension


Fig. 2. A general view of the combined coulter: 1 – disc; 2 – tip; 3 – seed drill tube; 4 – seed coverer (seed placer); 5 – packer roller; 6 – seed depth adjuster

The combined coulter (Fig. 1) consists of a body 1 in which two flat discs 3 are mounted with a possibility of rotation on axles 2 with an angle forward in the direction of the coulter movement. Between the discs 3, there is a holder 4 connected to the body, which consists of two jaws 5. In the empty space, formed by the jaws 5, a wedge-shaped part of the combined coulter is placed, which has a cylindrical seed drill tube 6 and a tip 7; and it is attached to the body 1 by a spring 8, and to the jaws of the holder 4 by means of an articulated suspension 9, which is located at the rear side of the wedge-shaped part as viewed in the direction of the coulter movement. The empty space formed by the jaws 5 houses the wedge-shaped part of the combined coulter with a cylindrical seed drill tube 6 and a tip 7; and it is attached to the body 1 by a spring 8, and to the jaws of the holder 4 by means of an articulated suspension 9, which is located relative at the rear side of the wedge-shaped part as viewed in the direction of the coulter movement. Installation of the wedge-shaped part of the coulter between the discs by attaching it to the body, using a hinged suspension and a spring, allows one to move along the prepared furrow, previously opened by the discs, compacting the bottom of the seed furrow, without the seeds contacting the surfaces of the rotating discs, which excludes bringing the seeds together with the soil to the upper part of the furrow, increasing the seeding depth stability.

During the study there were used methods of mathematical simulation, mathematics, theoretical mechanics, as well as the methods of compiling programs and numerical calculations on a PC (Silva *et al.*, 2018; Bulgakov *et al.*, 2016; Sysuev at al. 2016). Calculations of the coulter design with preset geometric parameters were carried out according to the developed program of numerical calculations on a PC in the MathCAD environment. To ensure the drilling depth stability of the seeds and to determine the parameters of the combined double-disc wedge-shaped coulter for mathematical description of its movement in the soil, analysis of the patterns of forces acting upon it during its movement was performed without taking into account the forces of inertia. A design scheme and a methodology for the calculation of the spring elasticity were developed to ensure maximum deviation of the seed drilling depth within the agrotechnical tolerance.

Let us regard the design of the new coulter as a balanced system, and the corresponding equivalent scheme, shown in Fig. 3.

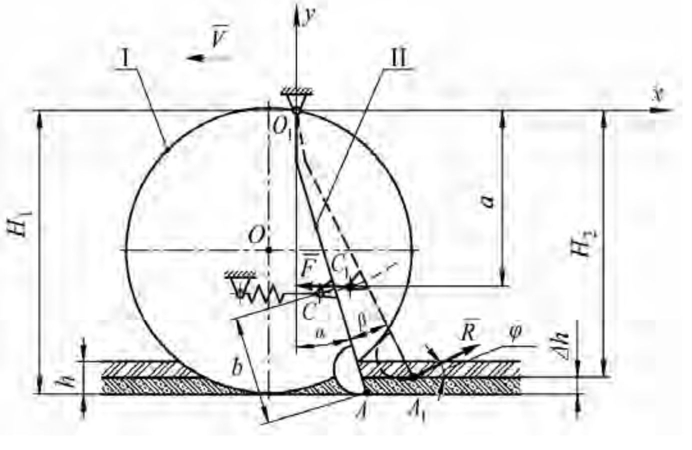


Fig. 3. An equivalent scheme of a combined double-disc wedge-shaped coulter of a selection seeder:
I – disc part; II – wedge-shaped part

Let us designate on the equivalent scheme (Fig. 3) the main structural dimensions and force parameters of the elements of the combined coulter moving in the soil at a certain depth: $H_1$ – the distance from the axis of the articulated suspension to the bottom of the seed furrow; $H_2$ – the drilling depth at maximum deviation; $a$, $b$ – the design parameters of the coulter; $\alpha$ – the initial deviation angle of the wedge-shaped coulter from the vertical; $\beta$ – the deviation angle of the wedge-shaped coulter and, accordingly, of the movement of the seeds during drilling; $R$ – the soil resistance force; $\varphi$ – the deviation angle of the direction of the soil resistance force from the horizontal; $\Delta h$ – a change in the drilling depth; $F$ – the elasticity force of the spring. Here the distance from the axis of the articulated suspension to the bottom of the furrow $H_1$ is selected, based on the ratio:

$$H_1\left(1-\cos\beta_{\max}\right)=\Delta h<\Delta_{agr}. \quad (1)$$

where: $\beta_{\max}$ – the maximum deviation angle of the wedge-shaped part of the coulter from the axis of the articulated suspension; $\Delta_{agr}$ – the value of the agrotechnical tolerance for an amount of seeds worked into the soil.

**RESULTS**

The equilibrium equation at the maximum drilling deviation in the form of equality to zero of the moments of forces acting upon the system, relative to point O of the hinged suspension (Fig. 3), will have the form:

$$\begin{aligned}&-Fa\cos\beta+R\sin\varphi\left[a\sin\beta+b\sin\left(\alpha+\beta\right)\right]+\\&+R\cos\varphi\left[a\cos\beta+b\cos\left(\alpha+\beta\right)\right]=0.\end{aligned} \quad (2)$$

From the equilibrium equation (2) we obtain an expression for finding the spring elasticity force:

$$F=\frac{R\left\{\sin\varphi\left[a\sin\beta+b\sin\left(\alpha+\beta\right)\right]+\cos\varphi\left[a\cos\beta+b\cos\left(\alpha+\beta\right)\right]\right\}}{a\cos\beta} \quad (3)$$

At a small angle of rotation $\beta$ the magnitude of the tensile force of the spring can be taken equal to:

$$\Delta x=a\sin\beta. \quad (4)$$

Next we find a relationship between the magnitude of the tensile force of the spring $\Delta x$ and deviation $\Delta h$ of the travel depth of the tip of the wedge-shaped part of the combined coulter in the soil.

Since:

$$\Delta h=H_1-H_2. \quad (5)$$

$$H_1=a+b\cos\alpha, \quad (6)$$

$$H_2=a+b\cos\left(\alpha+\beta\right), \quad (7)$$

deviation $\Delta h$ of the travel depth will be equal to:

$$\Delta h=b\cos\alpha-b\cos\left(\alpha+\beta\right). \quad (8)$$

Defining further:

$$\cos\left(\alpha+\beta\right)=\cos\alpha-\frac{\Delta h}{b}. \quad (9)$$

$$\alpha+\beta=\arccos\left(\cos\alpha-\frac{\Delta h}{b}\right). \quad (10)$$

From expression (10) we find the deviation angle $\beta$ of the movement of the seeds:

$$\beta=\arccos\left(\cos\alpha-\frac{\Delta h}{b}\right)-\alpha. \quad (11)$$

Substituting into formula (11) value $\Delta h = \Delta_{agr}$ of the allowed deviation of the drilling depth of the seeds and taking into account the agrotechnical tolerance, as well the value of parameters *b* and *α*, we obtain the value of the maximum allowed deviation angle $\beta_{\max}$ :

$$\beta_{\max} = \arccos\left(\cos\alpha - \frac{\Delta_{agr}}{b}\right) - \alpha . \tag{12}$$

Substituting expression (12) into expression (4), we obtain the value of the maximum tension of the spring:

$$\Delta x_{\max} = a \cdot \sin\beta_{\max} , \tag{13}$$

or:

$$\Delta x_{max} = a \cdot \sin\left[\arccos\left(\cos\alpha - \frac{\Delta_{agr}}{b}\right) - \alpha\right]. \tag{14}$$

Considering expressions (3) and (14), it is possible to calculate the spring elasticity *k* at which the deviation will be within the agrotechnical tolerance:

$$k = \frac{F}{\Delta x_{\max}} = \frac{F}{a \cdot \sin\left[\arccos\left(\cos\alpha - \frac{\Delta_{agr}}{b}\right) - \alpha\right]}, \tag{15}$$

Or, considering expression (3):

$$k = \frac{\left\{\sin\varphi\left[a\sin\beta + b\sin(\alpha+\beta)\right] + \cos\varphi\left[a\cos\beta + b\cos(\alpha+\beta)\right]\right\}R}{a^2\cos\beta \cdot \sin\left[\arccos\left(\cos\alpha - \frac{\Delta_{agr}}{b}\right) - \alpha\right]}. \tag{16}$$

The results of calculations for expression (16) on the PC, using a program developed in the MathCAD environment, indicate that, the geometric parameters of the coulter being $a$ = 120 mm, $b$ = 220 mm, $\alpha$ = 15°, $\beta$ = 10°, the maximum spring tension should be $\Delta x_{\max}$ = 14 mm. On the basis of calculations performed on the PC, a graph of the dependence of the spring elasticity *k* upon the soil resistance reaction $R$ a graph has also been constructed (Fig. 4). As one can see from the data in the graph, this dependence is of a linear nature.

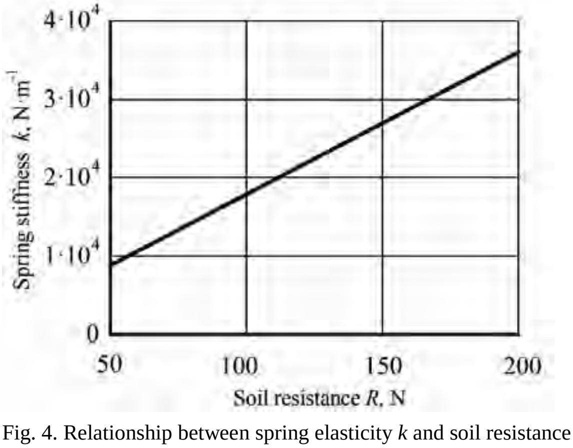



Fig. 4. Relationship between spring elasticity *k* and soil resistance $R$

From the graph of Fig. 4 it is also evident that, in order to overcome the resistance force *R* of the soil, which is within the range of 50...200 N, at angle $\varphi = 45°$ of the soil friction along the tip of the wedge-shaped coulter, the spring elasticity $k$ must be within the range of $9.04 \cdot 10^3 ... 3.60 \cdot 10^4$ N·m$^{-1}$.

## CONCLUSIONS

1. A theoretical substantiation is made of the parameters of a combined double-disc wedge-shaped coulter, and a new mathematical model is obtained for the calculation of rational spring elasticity to overcome the soil resistance forces acting upon the wedge-shaped part of the combined coulter.
2. Numerical calculations of the obtained mathematical model, carried out on a PC in the MathCAD environment, showed that the spring elasticity $k$ should be within the range of $9.04 \cdot 10^3 \ldots 3.60 \cdot 10^4$ N·m$^{-1}$.

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## 2.6. SPATIAL VARIABILITY OF HYPERSPECTRAL INDICATORS IN RELATION TO CULTIVATION METHODS – STUDY WITH THE USE OF A GYROCOPTER-MOUNTED REMOTE SENSING SYSTEM

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**Keywords:** precision agriculture, gyrocopter, remote sensing, hyperspectral imaging, decision support system

### ABSTRACT
The authors tested the condition of cultivated plants by means of aerial hyperspectral imaging using HySpex cameras (VNIR spectrum 400-1000 nm, SWIR spectrum 1000-2500 nm) mounted on a gyrocopter. Results were collected in test fields prepared using two tillage systems (conservation tillage and conventional tillage with ploughing) and two options of nitrogen fertilisation: following the principles of good agrotechnical practice and without fertilisation. The vegetation indices collected this way were confirmed to provide adequate input for the plant condition evaluation. A long-term analysis of spatial variability of these indices helps validate the cultivation methods and determine the relationship between the plant condition, the selection of agrotechnical treatment, and the natural conditions of growth. Therefore, the gyrocopter-based remote sensing system for the measurement of vegetation indices proved its applicability in farm advisory systems.

### INTRODUCTION
Precision agriculture is necessary for sustainable intensification of cultivation (Samborski *et al*. 2018). Introducing the rules of precision agriculture into a modern farm can provide an increase in crop yields, e.g. of 3.7% using 7% less artificial fertilisers (Hobbs *et al*. 2008). Assessing the local properties of soil and plant is essential to diagnose changes in plant condition and, at the same time, the basis of precise application of pesticides, biological agents, and fertilisers.

Multispectral or hyperspectral image analysis is widely adopted in agricultural science. For instance, it was applied to differentiate healthy and diseased areas on the leaves (Samborski *et al*. 2018, Strachan *et al*. 2002). Dammer *et a*l. (2015) applied NDVI (Normalised Difference Vegetation Index) to distinguish between wheat varieties with varying levels of resistance to *Fusarium spp*. Han *et al.* (2005) obtained images from the UAS system for evaluation of the growth status of winter wheat. In crop monitoring, aerial imaging has an advantage over collecting data by means of small-scale satellite remote-sensing as well as by sensors mounted on ground-operating machines: the high-resolution images taken from a relatively small height and at favourable atmospheric conditions provide a good insight into details and, at the same time, the general overview of the cultivated area (Bzowska-Bakalarz *et al*. 2017, Lan *et al*. 2010). For this reason, data from aerial images are easy to correlate with the yields and, at the same time, they facilitate interpretation of local changes in the state of the vegetation like local outbreaks of weeds (Gomez-Candon *et al*. 2014).

The paper presents the results of the first stage of a project to develop a decision support system (DSS) that, based on aerial hyperspectral image analysis, was to identify the condition of crops and their requirements for irrigation, fertilization, and plant protection measures in the context of precision agriculture. This stage consisted in elaborating a remote sensing tool for monitoring vegetation and testing it in field conditions. The paper presents the tool and selected results of its testing.

## OBJECTIVES AND METHODOLOGY

The data collection tool of the DSS was a set of two hyperspectral scanners by HySpex, mounted on an ultralight gyrocopter (Taurus by Aviation Artur Trendak) (Fig. 1, Fig. 2). The VNIR (visible and near-infrared) scanner registered electromagnetic radiation in the range from 400 to 1000 nm in 176 channels. The SWIR (short-wavelength infrared) scanner served the range from 1000 nm to 2500 nm in 288 channels. Resolution of images depended on the operating altitude. In this case, at the altitude of 400 m, the spatial resolutions of VNIR and SWIR were, respectively, 25 cm and 50 cm.

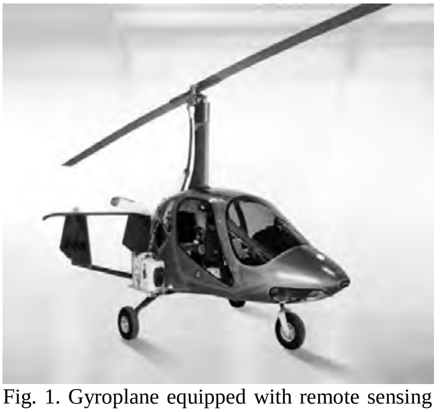

Fig. 1. Gyroplane equipped with remote sensing system for crop monitoring (photo by courtesy of Aviation Artur Trendak).

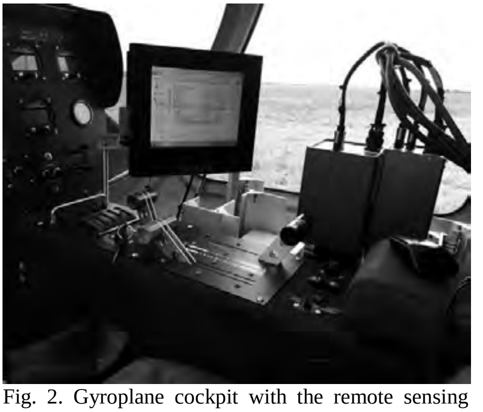

Fig. 2. Gyroplane cockpit with the remote sensing system.

The tool was tested, among others, in the experiment to assess the effect of tillage methods on the condition of winter wheat in fields located in Rogów near Zamość (North-Eastern Poland). The paper presents selected results of this test.

The object of analysis was a set of test plots of winter wheat subject to various combinations of tillage (conventional tillage with ploughing and conservation tillage), nitrogen fertilization, and protection against fungi (Fig. 3). This way, some test plots were treated according to the principles of good agricultural practices (tests fields no. 3, 4 and 11, 12) and some with intentional errors (without fertilization and protection against fungal diseases). The condition of plants, assessed at two selected stages of growth) was then assessed in ground tests, and the results were juxtaposed with the differences in hyperspectral images of the plots.

The soil in the area in question was Haplic Luvisol with particle size distribution corresponding to silt loam: sand 8.2%, silt 72.8, clay 19.0%. Particle size distribution was measured by laser diffraction using Mastersizer 2000 with the dispersion unit Hydro G (by Malvern Panalytical). The following set was used in the measurement: pump speed 700 rpm, stirrer speed 1750 rpm, ultrasounds maximum power in 3 min, RI of the soil 1.52 and AC of the sample 0.1 (Bieganowski *et al*., 2018).

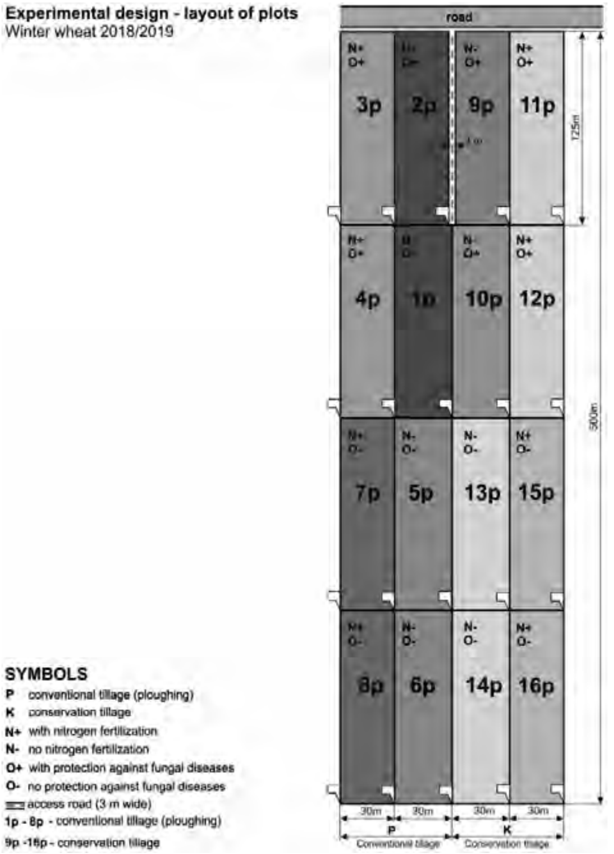

Fig.3. Plan of the experiment – arrangement of test plots and combinations of treatment (winter wheat).

## RESULTS

The condition of crops was monitored through all growth stages until harvest. The results presented in this paper were captured on 8th May 2019 (BBCH principal growth stage 3: stem elongation, code 31-32 – 1-2 nodes) and on 7$^{th}$ June 2019 (BBCH principal growth stage 6: flowering, code 61 – the beginning of flowering). Raw scans were subject to the process of radiometric, geometric and atmospheric correction and the image converted to the form of a cartometric orthophoto map. The images were used to calculate a set of vegetation condition indicators. This presentation is limited to the Normalized Difference Vegetation Index (NDVI). Figures 4 and 5 show the distribution of NDVI for both analysed growth stages. Figure 6 shows the digital terrain model of the area.

At both stages of wheat growth, and regardless of tillage methods (conventional or conservation), NDVI was lower (so the condition of plants was poorer) in the unfertilized strip (plots no. 1p, 2p, 5p, 6p, 9p, 10p, 13p, 14p). However, in the middle of unfertilized plots 5p and 13p, the vegetation condition was better (NDVI of 0.91-0.919) than in the plots prepared according to the principles of good agrotechnical practice; this was visible especially in the flowering phase. The terrain elevation (fig. 6) explains this observation: plots 7p, 5p, 13p, and 15p were situated lower, which contributed to advantageous inflow of ammonium hydroxide from the neighbouring plots.

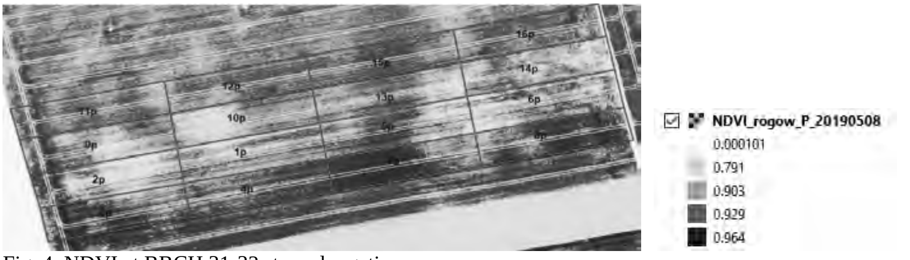

Fig. 4. NDVI at BBCH 31-32 stem elongation.

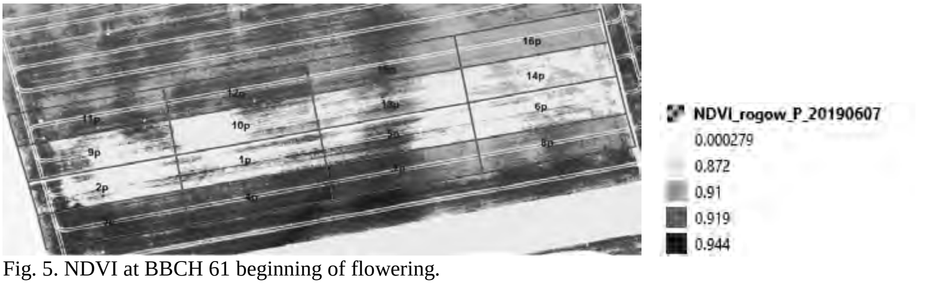

Fig. 5. NDVI at BBCH 61 beginning of flowering.

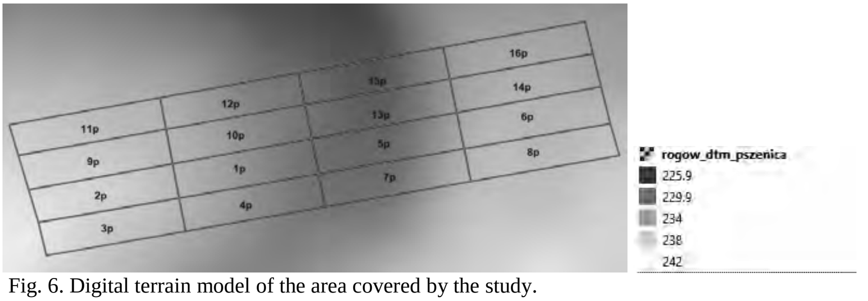

Fig. 6. Digital terrain model of the area covered by the study.

Figure 7 presents the relationship between the actual grain yield (measured in each plot at harvest) with NDVI assessed in May (significant Pearson correlation coefficient 0.8836) and June (significant Pearson correlation coefficient 0.8775). The results confirm that NDVI is a good predictor of the yield. However, no significant correlation was observed in plots subject to nitrogen fertilization regardless of the type of tillage (plots no. 7, 8, 15, 16): the yield was poor though the condition of plants in May and June was good. The preliminary analysis of the results allows concluding that the combination of soil factors and the shape of the terrain was the reason.

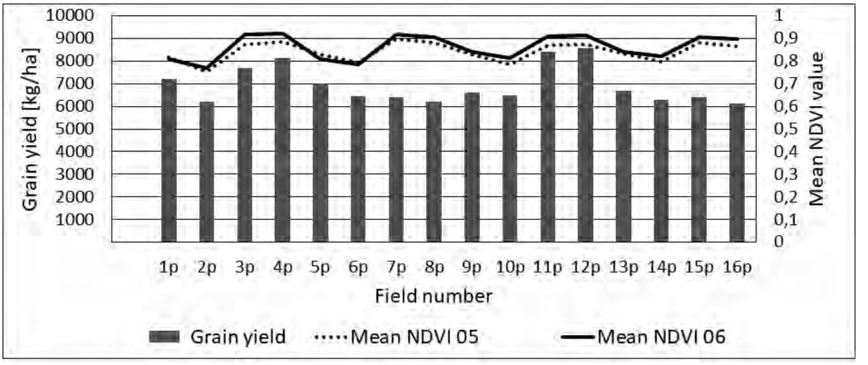


Fig. 7. The dependence of the yield amounts on NDVI indicators

## CONCLUSIONS

The study provided grounds to recommend NDVI for evaluation of plant condition. Other hyperspectral indicators (Red Edge NDVI, RVI, etc.) also showed clear differences in distribution between the plots with and without fertilization. Vegetation condition was highly dependent on the terrain relief: in the lower-lying plots, due to the possibility of the nitrogen fertilizer outflow from the higher-lying testing fields (ammonium hydroxide), the plants' condition was better – despite the lack of direct fertilizing.

The analysis of time-lapse aerial images – and thus changes in the spatial variability of the vegetation indicators – is used to verify the farming methods and identify plant health in relation to the type of agrotechnical procedures and the natural conditions of growth.

The results demonstrate that a spectral recording module mounted on a gyrocopter facilitates precise representation of the soil/plants' state and indicating the areas where particular agrotechnical procedures are necessary. It is thus fit for purpose as an element of the farm advisory systems and may become a diagnostic tool in sustainable agriculture.


## ACKNOWLEDGEMENT

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# 2.7. SPRAY MONITOR - A CONCEPT OF SPRAYING PARAMETERS OPTIMIZATION TAKING INTO ACCOUNT APPLICATION CONDITIONS

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**Keywords:** precision agriculture, process management, spraying characteristics, working parameters, online control

## ABSTRACT
The effectiveness of pesticide application depends on many factors. The PPP application must be conducted in different scenarios and conditions (local weather, crop characteristics/stage, tank mix properties). A monitoring system is required for adequate online optimization of local working parameters. For efficient use of locally adjusted technology, according to standards and requirements, an elaboration of dedicated control system is needed. A concept and prototype were created for just such an application. It includes control of the flow rate, pressure and temperature of the working liquid, ambient temperature and relative humidity.

## INTRODUCTION

The biological efficacy of the tank mix with plant protection products (PPP), as well as the balance of spray losses (ground, aerial drift, volatilization) depends significantly on the spraying quality. Test methods and standards contain requirements for registering specific parameters and information regarding performed tests and experiments. The published results of many complicated, labour-intensive and costly studies (field and laboratory), do not contain comprehensive information about the conditions of their implementation (weather, equipment and setting of sprayer operating parameters).

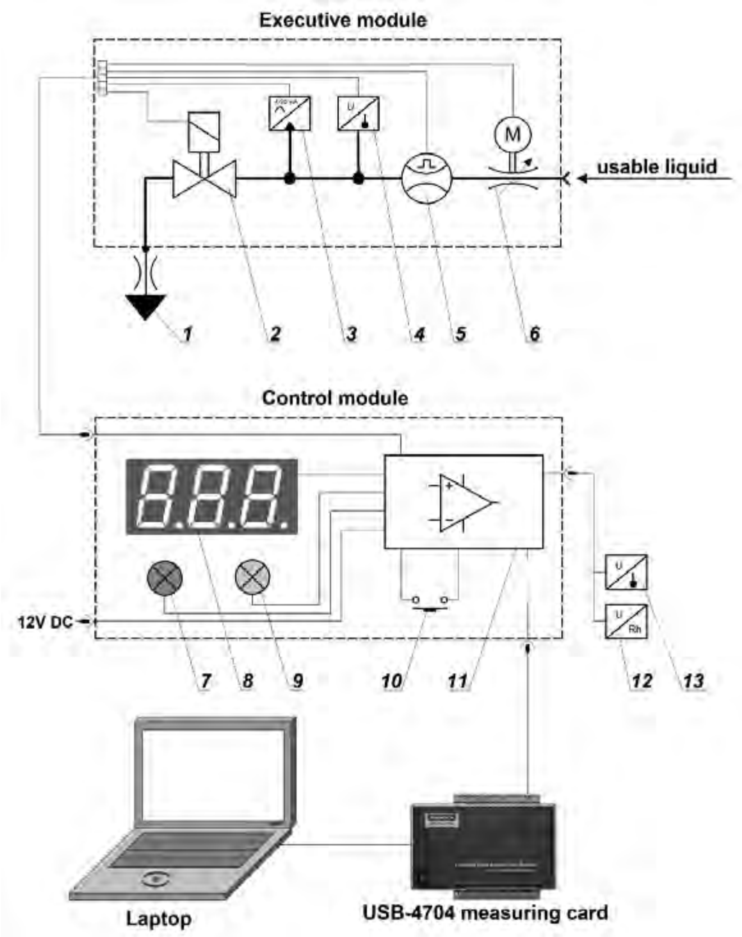
On one hand, this prevents an in-depth comparison of different scientists' studies, on other, it impoverishes the possibility of inferring the impact of unregistered parameters. This drawback could be reduced by the editors of scientific journals by the obligating the publication authors to deliver all important parameters of the conducted PPP application. From the research experience of the authors of this article, and from lack of some important information about the methods of testing noticed in the available publications, a concept has been created that is useful for easy monitoring of constant and variable parameters. The importance of individual parameters: ambient and tank mix temperature, relative air humidity, wind speed, physical properties of the tank mix, atomizer design, working pressure and forward speed, droplet size spectrum characteristics is reported by many works e.g.: Hewitt (1997), Womac *et al.,* (1999), Butler Ellis *et al.,* (2002), Langman & Pedryc (2008), Hoffmann *et al.,* (2011), Czaczyk (2012, 2014), Dorr *et al.,* (2013), Vulgarakis Minov *et al.,* (2013), Matthews *et al.,* (2014). The experiment methods e.g. Doble *et al.,* (1985), Giles *et al.,* (2002), Miller & Tuck (2005), Southcombe *et al.,* (2007), Lodwik & Pietrzyk (2013, 2018), Havens *et al.* (2018) and standards e.g. ANSI/ASAE (2009), ISO 25358 (2018) contain requirements for registering specific parameters and information regarding performed tests and experiments.

It is very important (especially during research studies in real conditions) to know the information "*in situ*". It makes it possible to compare the results with others, and also online optimize of the working parameters (e.g. in “future intelligent sprayer”).

The purpose of this work was to make a prototype according to the developed concept.

## MATERIALS, METHODS AND RESULTS

### *The concept*




*Legend:*
*1 – Tested nozzle*
*2 – Electromagnetic shut-off valve TeeJet e-ChemSaver (control voltage 12 V)*
*3 – Pressure sensor of spray liquid KELLER (measurement range 0-10 bar)*
*4 – Temperature sensor of spray liquid MCP 9700 (measurement range -40-125°C)*
*5 – Flow sensor of spray liquid V8189 (measurement range 0.25-6.5 l min$^{-1}$)*
*6 – Throttle valve controlled by a DC motor*
*7 – LED control (red) signalling the state in which the measured flow exceeds the permissible deviation from the nominal value*
*8 – Display of the measured flow value*
*9 – LED (green) signalling the state in which the measured flow does not exceed the permissible value*
*10 – START / STOP button for manual control of the measuring process*
*11 – Interface matching the form and levels of measurement signals*
*12 – Ambient humidity sensor HIH-4000-010 (measurement range 0-100%)*
*13 – Ambient temperature sensor MCP 9700 (measurement range -40-125°C)*
Fig. 1. Scheme of concept for settings of tested parameters and result recording (source - J. Pietrzyk).

### *The Spray Monitor prototype*

As a result of team work, a prototype of the system was created that met the assumptions of the concept of "Spray Monitor" (Fig. 2).

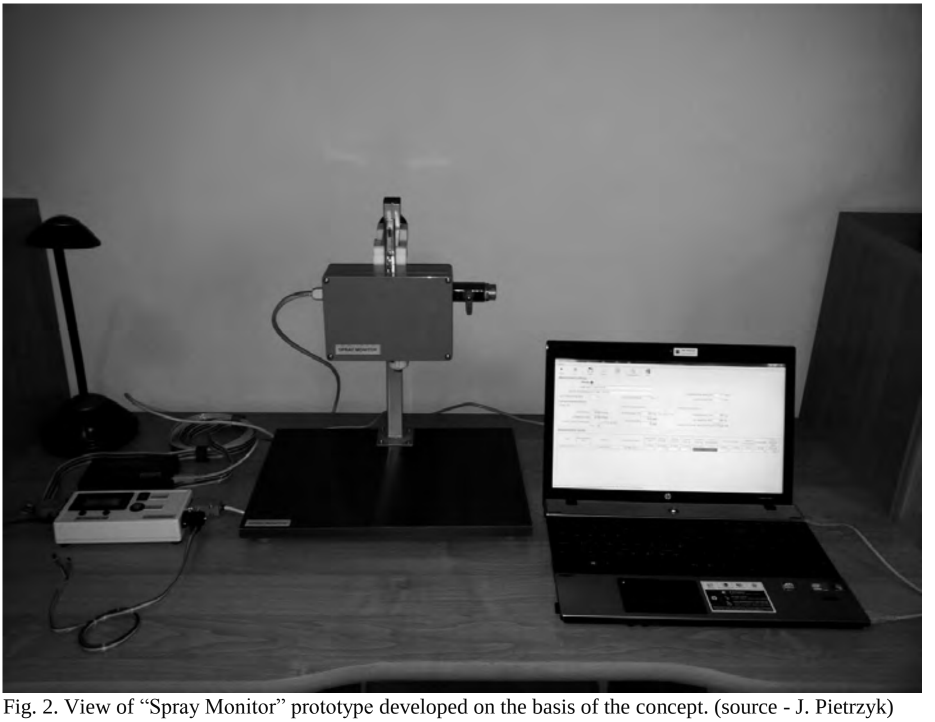


Fig. 2. View of “Spray Monitor” prototype developed on the basis of the concept. (source - J. Pietrzyk)

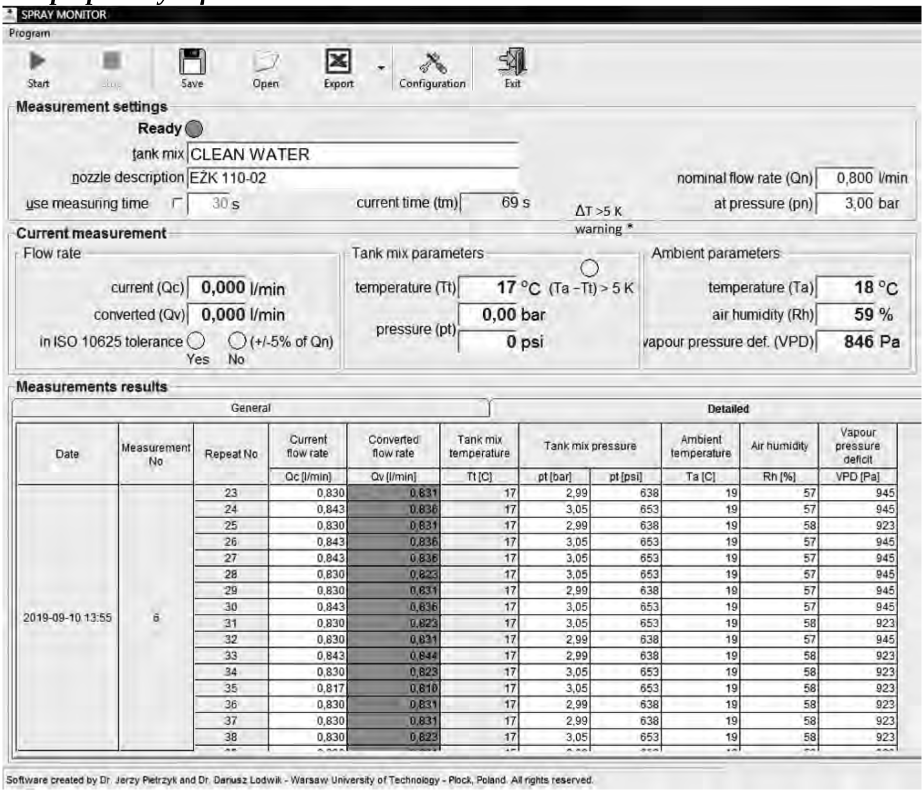
The Spray Monitor can be operated from a laptop or manually. Configuration of the device (reading frequency, measurement time, measured parameters, used materials, language, units, description of stored data) was carried out by proprietary laptop software.

Testing methods and standards contain tolerances and requirements for registering specific parameters and required information regarding the performed tests and experiments. The proprietary software includes tolerances of ±5% $Q_n$ (nominal) flow rate according ISO 10625 (2005) and provides numerical and colour (green/red) interpretation of the received readings (on the laptop and on the control module (Fig. 1.) with LED (7 & 9). Also the difference of temperatures exceeding 5 K (ºC) (between ambient air and working liquid) ($\Delta T > 5$ K) was signalized with the red – Fig. 3 – marked with * in the yellow frame). Additionally relative humidity and atmospheric pressure were controlled to determine the vapour pressure deficit – VPD (Pa).

To support the spray monitor prototype, a proprietary application was developed (Visual Basic 6.0 Professional) to control and then store the tested parameters.

Single readings of all parameters are collected every 0.5 s. For the measurement time, e.g. 30 s, there are 60 readings (of each parameter). The final result is the arithmetic mean of the single readings, and is saved in txt file format.

***The proprietary software***




| Date | Measurement No | Repeat No | Current flow rate Qc [l/min] | Converted flow rate Qv [l/min] | Tank mix temperature Tt [C] | Tank mix pressure pt [bar] | Tank mix pressure pt [psi] | Ambient temperature Ta [C] | Air humidity Rh [%] | Vapour pressure deficit VPD [Pa] |
|---|---|---|---|---|---|---|---|---|---|---|
| 2019-09-10 13:55 | 6 | 23 | 0,830 | 0,831 | 17 | 2,99 | 638 | 19 | 57 | 945 |
| | | 24 | 0,843 | 0,836 | 17 | 3,05 | 653 | 19 | 57 | 945 |
| | | 25 | 0,830 | 0,831 | 17 | 2,99 | 638 | 19 | 58 | 923 |
| | | 26 | 0,843 | 0,836 | 17 | 3,05 | 653 | 19 | 57 | 945 |
| | | 27 | 0,843 | 0,836 | 17 | 3,05 | 653 | 19 | 57 | 945 |
| | | 28 | 0,830 | 0,823 | 17 | 3,05 | 653 | 19 | 57 | 945 |
| | | 29 | 0,830 | 0,831 | 17 | 2,99 | 638 | 19 | 57 | 945 |
| | | 30 | 0,843 | 0,836 | 17 | 3,05 | 653 | 19 | 57 | 945 |
| | | 31 | 0,830 | 0,823 | 17 | 3,05 | 653 | 19 | 58 | 923 |
| | | 32 | 0,830 | 0,831 | 17 | 2,99 | 638 | 19 | 57 | 945 |
| | | 33 | 0,843 | 0,844 | 17 | 2,99 | 638 | 19 | 58 | 923 |
| | | 34 | 0,830 | 0,823 | 17 | 3,05 | 653 | 19 | 58 | 923 |
| | | 35 | 0,817 | 0,810 | 17 | 3,05 | 653 | 19 | 58 | 923 |
| | | 36 | 0,830 | 0,831 | 17 | 2,99 | 638 | 19 | 58 | 923 |
| | | 37 | 0,830 | 0,831 | 17 | 2,99 | 638 | 19 | 58 | 923 |
| | | 38 | 0,830 | 0,823 | 17 | 3,05 | 653 | 19 | 58 | 923 |

Fig. 3. View of application for settings of tested parameters and result recording. (source - J. Pietrzyk)

## CONCLUSIONS

The technologies in precision agriculture require adaptation of new available techniques and setting solutions for the equipment used. The created prototype is used to monitor and record required parameters during spraying process. It includes the control of flow rate and working pressure for tested nozzles in the range of up to 6.5 l $min^{-1}$.

The "Spray Monitor" is the author's idea and can be used to monitor and record parameters important for conducting tests on: liquid cross distribution, droplet size spectrum measurements, drift potential determination, spraying quality and different studies on the evaluation of PPP efficacy (and during registration studies).

According to this concept, it is possible to develop and install on serially produced sprayers a system enabling online control of the spray quality during variable spraying conditions (changeable scenarios). It would be also advisable to use such systems on experimental sprayers in scientific studies.

The use of the developed system allows significant reduction of the adjustment time of the required spraying parameters. At the same time, the amount of use the needed test liquid is reduced, which may include toxic ingredients.

Introduction of such control and steering system to agricultural practice allows increasing efficacy of PPP application, food/forage safety as well as reduction of the environment pollution.

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## 2.8. SENSOR-BASED DETECTION OF DISEASES IN FIELD CROPS

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**Keywords**: crop protection, image analyses, stripe rust, winter wheat

## ABSTRACT

For saving fungicides it should be kept in mind that diseases are often not equally distributed in the field; they rather occur in patches. Consequently, the application of fungicides is not necessary within disease-free areas. Aspects for a future target-orientated fungicide spraying according to disease occurrence are the increasing resistance of the fungi and future restrictions in availability of antifungal agents because of environmental concerns. For this approach it is important to know the location and the size of disease patches. As example presented in this paper, yellow (stripe) rust in winter wheat are chosen. Within the project "FungiDetect", financed by the German Federal Ministry of Food and Agriculture, sensors with different modes of action were tested to detect this harmful disease occurring in winter wheat. This paper discusses the state of art in precise target-orientated fungicide application, first results, and future perspectives in yellow rust detection.

## INTRODUCTION

In precise fungicide application the target of the spray liquid is the infected crop. In contrast, the manufacturer of a pesticide gives a dosage instruction on the product label uniformly on a "per hectare" basis for the whole field.

The approach of a precise variable rate fungicide application started developing nearly 20 years ago at the ATB. Since there are no sensor-based technologies on the market for the automatic detection of diseases, an alternative method has been developed. Because soil, nutrient, and water conditions within a field are mostly not equal distributed, the vegetation of the cultivated crop can differ on a small scale in heterogeneous fields. Hence, crop biomass and crop surface to be sprinkled by the spray mixture are also different. Areas with poor growing are ripening of up to 1 month earlier compared to well growing areas (Dammer 2005). In these areas the crop tissue must not be saved as long as in well growing field areas.

As a first sensor generation a mechanical sensor was measuring biomass and crop surface of cereals while driving. The CROP-METER sensor measurements were correlated with crop surface and biomass. Crop surface can be determined by the Leaf Area Index (LAI) which quantifies the surface of the crop per area of ground ($m^2$ $m^{-2}$). A direct destructive measurement or the use of hand-held optical instruments cannot be used for a dense sampling in the field e.g. along a narrow grid (Stroppiana *et al.*, 2006). Also, by a deterministic model using crop height and the number of tillers per $m^{-2}$ (Dammer *et al.*, 2008) only an estimation about the width (min / max) of the LAI within the field can be obtained for example in cereal fields. The same problem occurs if above-ground biomass is sampled destructively by manual cutting. With the CROP-METER sensor this two plant parameters could be sampled on the go while driving. With this sensor a field sprayer was controlled in real time. In 11 farmers cereal fields on average 22% (min.7%, max.38%) fungicide savings (Dammer and Ehlert 2006) compared to uniform spraying were obtained. While operating, this sensor was in contact with the crop canopy. This causes some problems (e.g., damage of the device, if the driver was not carefully in reversing at the end of the field). Optical non-contact sensors do not have this disadvantage. As a second sensor generation a multispectral camera sensor (red, infrared, and green wavelength) was developed by the ATB to discriminate between green crop and background (soil or dead plant material). The highest difference in reflection can be measured in the infrared (IR) and red (R) wave band. Green crop contains chlorophyll and thus absorbs red-light. The reflectance curve for soil and plant material is almost constant. Based on a multispectral camera the Normalized Difference Vegetation Index NDVI=(IR-R)/(IR+R) is calculated and convenient to describe the green coverage level. In precise fungicide spraying only the green living crop tissue has to be protected against the disease. In contrast to one-dimensional spectrometric sensors, which are recording an intensity signal from the whole sensed area including soil death and vigour crop tissue (main disadvantage), a camera sensor delivers spatially resolved intensity data. Based on the image data collected while driving the coverage level was calculated with different image analyses steps. The coverage level was used to adapt the spray volume in a precise variable rate fungicide spraying. In trials conducted by the ATB in 5 farmers cereal fields from 2014 to 2016 by using this non-contact camera sensor on average 22 % (min. 1 %, max 45 %) fungicide savings (Tackenberg *et al*. 2016, 2017) compared to uniform spraying were obtained..

In the approach of fungicide application according to Leaf Area Index or biomass the whole field is sprayed with the fungicide. But to spray the whole field only makes sense if, for example, the whole field is infected with the disease. Aspects for a future target-orientated fungicide spraying according to disease occurrence are the increase of resistance of the fungi against the fungicide product and the decreasing degree in the availability of antifungal agents because of environmental concerns of the society. For this approach of fungicide application according to the areas in the field, which are infected by the disease, it is important to know the location and the size of disease patches. In this paper first results of a field trial for detecting yellow (stripe) rust (*Puccinia striiformis* West. f. sp. *tritici*) in winter wheat are presented.

## MATERIAL AND METHODS

Within the research project "FungiDetect" financed by the German Federal Ministry of Food and Agriculture a trial of 15 plots with two treatments (7 plots stripe rust infected and 8 plots fungicide treated healthy) were conducted. A mobile multisensory system was developed to scan the area in certain time intervals (Fig. 1).

An unmanned-arial system (UAS) with a Sony Alpha 6000 camera (16 mm lens, flight height: 15 m, 80% overlapping, resolution on ground: 3,7 mm) was used to detect first disease patches. Orthophotos were generated using the software Metashape (Agisoft).


Fig. 1. Tractor with RGB camera, multispectral camera, ultrasonic sensor (from left to right on the gallows) and optoelectronic vertical sensor inside the crop canopy (left on the back three-point linkage) while test run

A widely used technology in disease detection is image analysis. Often in research multispectral cameras are used to distinguish between healthy and diseased areas on plant leaves. Franke and Menz (2007) used the NDVI to measure the infection of wheat plants with powdery mildew (*Blumeria graminis* f. sp. *tritici*) and leaf rust (*Puccinia recondita* Rob. ex Desm. f. sp. *tritici*). Dammer *et al.*, (2011) used also the NDVI to differentiate between wheat varieties with different resistance levels against head blight (*Fusarium* spp.). Therefore, among others in the trials a multispectral camera sensor using the red and infrared wavelength with real-time image analysis was used.

**RESULTS**

In the orthophoto generated from the UAS-images the infected plots were clearly visible 64 days after the artificial infection of Uredospore-suspension (Fig. 2). The healthy plots were greener. After zooming in, two infected patches in one plot were clearly visible already 49 days after infection (image not shown here).

Yellow rust causes a reduction of the chlorophyll content and a senescence of the leaves. The green coverage level and the NDVI from the multispectral camera were used to characterize the health status. Box-Whisker-Plots of the NDVI und the coverage level in dependence of the measuring date (Fig. 3) show that both parameters of the healthy plots were higher (greener) in comparison to the diseased plots. The differences increased over time.

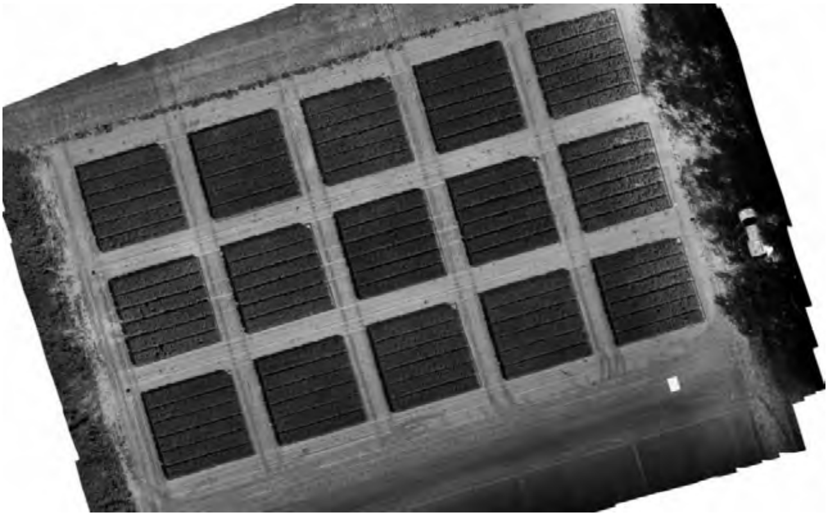

Fig. 2. Orthofoto of the experimental site 2018, 64 days after artificial infection, early milk ripeness of winter wheat, red bordered: infected plots

A significance (median are outside the box of the other treatment and vice versa) occurred not before 54 days (NDVI) and 56 days (coverage level) after infection.

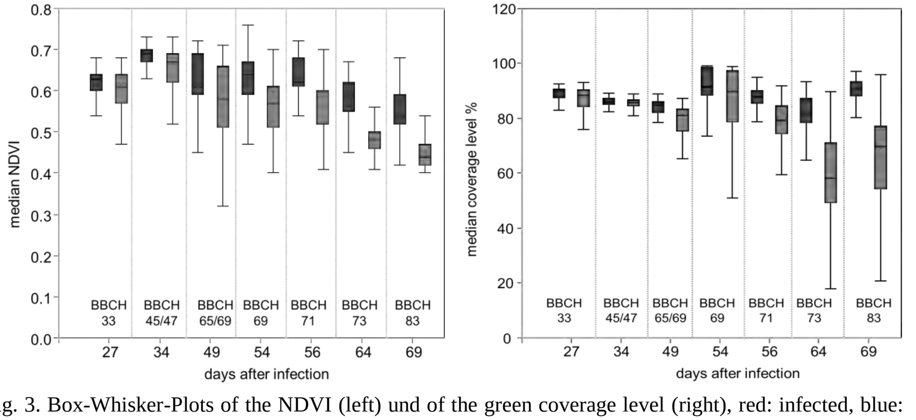


Fig. 3. Box-Whisker-Plots of the NDVI (left) und of the green coverage level (right), red: infected, blue: healthy

For the distinct evaluation of the cause of the symptoms image analysis of the proximal images of the RGB camera were performed. The MSER-detector (maximally stable extremal regions) was used to discriminate the rust symptoms from the background. Two thresholds were set: for eccentricity > 0.995 and for the area of clustered pixels >1000px and <=2500px. As result the detected yellow rust symptoms are green (Fig. 4).

Fig. 4. Classified RGB image, green ellipsoids: yellow rust symptoms

## CONCLUSIONS

UAS-monitoring of a cereal field is useful for the detection of diseased crop patches infected with yellow rust. The infestation threshold for spraying or not spraying against yellow rust declared by the governmental agency is the appearance of the disease patches in the cereal crop. These patches can also be caused by other factors like nutrient deficiency, water stress etc. Consequently, ground truthing is necessary. This is also the case, if the NDVI or coverage level differences from the multispectral camera sensor are used to detect chlorophyll deficiency of the crop canopy. If symptoms were detected the farmer has to spray immediately to prevent an outbreak of the disease. This can be overcome by evaluating the oldest leaves at which the first symptoms use to occur. These leaves are not visible from above the canopy. Therefore, a new optoelectronic vertical sensor (see Fig. 5) was developed to measure the reflectance inside the crop canopy. As mentioned above, healthy crop tissue reflects the infrared light and absorbs the red light.


Fig. 5. Additional red and infrared LED-lighting at a vertical rod

The reflection of dead crop tissue is nearly constant. By calculating indices from these two wavelength ranges and setting a threshold afterwards, healthy tissue can be separated from dead tissue in dependence of the distance from ground level. The main problem inside the canopy is, however, the low illumination. Therefore, as the latest innovation additional LED-lighting was adapted to the vertical rod. The data analysis from the vertical sensor is still in progress.

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## 2.9. COMPUTER COLOUR ANALYSIS OF CONVECTIVE DRIED CARROT

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**Keywords:** convective drying, carrot, colour, sustainable agriculture

## ABSTRACT

The production of safe, high-quality food is an important element of sustainable agriculture. Colour is one of the inseparable and basic parameters used in the assessment of food products and raw materials and is an important measure of quality assessment. The paper presents an analysis of the colour change of convective dried carrot at three drying air temperatures: 40, 60 and 80°C. The colour of carrot was analysed in the RGB and CIE Lab systems. The values of R and G discriminant decreased after drying carrot, while the B value increased. The *L* value after drying carrot has decreased which means darkening of the material, while the parameter ***a*** has increased, which confirms the browning of the material after drying.

## INTRODUCTION

Vegetables and fruits are one of the main components of the human diet, they are a source of vitamins, minerals and fibre. The seasonal nature of crops means that their availability outside harvesting periods is associated with the establishment of appropriate storage and processing facilities. The most known methods of processing agricultural products are: freezing, drying, fixing by heating, concentration, pickling, acidification, salting and combinations of these methods. They allow the products to be preserved while maintaining their smell, taste, colour and nutritional value. Fruits and vegetables can also be processed into syrups, juices, concentrates and purees.

Carrot is one of the most commonly grown vegetables in Poland (Table 1), in 2019 its yield is estimated at 670 thousand tonnes (a decrease compared to 2018 and 2017 year).

Table 1 Production of ground vegetables and tomatoes in Poland

| Vegetable | Production in 2017 [thousand tons] | Production in 2018 [thousand tons] |
|---|---|---|
| cabbage | 1000 | 913 |
| cauliflower | 238 | 219 |
| onion | 667 | 562 |
| **carrot** | **827** | **726** |
| beetroot | 336 | 298 |
| tomato | 249 | 252 |
| cucumber | 255 | 245 |

Source: GUS, 2017; GUS, 2018

Drying is one of the oldest methods of food preservation, it allows to easily and quickly fix raw materials of plant origin (Lewicki, 2006). Dried products are healthy because they are not subjected to high temperatures during drying, such as during cooking or frying (Krokida, 2003).

Many factors influence the convective drying process. One of them is the temperature of the drying medium. Higher temperature shortens the drying time (Skorupska, 2005; Szarycz *et al*., 2011). Temperature also changes the colour. The increase of temperature and longer drying time cause that the colour of the dried material is darker (Biller *et al*., 2005; Sharma & Prasad, 2001; Sumnu *et al*., 2005). Colour is one of the inseparable and basic parameters used in the assessment of food products and raw materials and is an important measure of quality assessment. Measurements of colour can be made by sensory or instrumental methods. Sensory methods use the human sense of vision, but the values thus obtained are non-objective and imprecise values (Jaros *et al*., 2019).

The exact methods of determining the colour are instrumental methods that determine the colour characteristics in the selected system based on digital image analysis. Currently, there are many devices that allow colour measurements. They are, among others: digital camera, scanner and colorimeter. Biller (2005) has stated that: "Colour is a vector (spatial) feature described by three vectors (indicators): tone, saturation and brightness." There are different systems for determining colour, the most commonly used is the RGB model, the XYZ system and the CIE Lab system.

The RGB system describes colours using additive synthesis, i.e. combining light beams. It consists of three basic colours, i.e. red, green and blue. Individual letters in the system name are derived from colour names in English; R-red, G-green, B-blue and they take values from 0 to 1 (as fractional numbers) or, from 0 to 255 (as integers) (Michalski, 2015). Black has the parameters [0,0,0] and it is the initial colour in this system, while white is the superposition of red, green and blue and it has the parameters [255, 255, 255] (Pastuszak, 2000). The CIE XYZ system is a development of CIE RGB system. The CIE Lab system is the most approximate system to the human eye in receiving colours. The *L* parameter is used to describe the colour brightness; the higher the value, the lighter the colour, while parameter *a* describes the colour deviation towards red - for positive values, or green - for negative values. The last parameter in this model is *b*, which characterizes the colour deviation towards yellow, assuming positive or blue (negative values) (Michalski, 2015). The values of parameter *L* can be in the range of 0 (black) to 100 (white), while *a* and *b* can be ± 120 (Kazimierska, 2014).

The colour change of plant materials, and thus also vegetables, at the stage of their preparation for processing, may be an indicator of the quality of their processing. The colour change may also occur in the heat treatment process and its range may be an indication of the quality of the produced product. The products darken during drying. The causes of browning of vegetables may be due to enzymatic or non-enzymatic reactions. In the study decided to examine how the colour of carrot changes during convective drying.

The aim of the work was to use the instrumental method in assessing the colour of discriminants from the digital image of slices carrot, fresh and convective dried at various temperatures of drying air in a chamber dryer.

## EXPERIMENTAL DESIGN

The research methods included drying protocol, image acquisition and determining colour characteristics.

Carrot in the form of slices 3 mm thickness were convective dried in a chamber drier at three air temperatures: 40, 60 and 80° C.

The image acquisition stand consisted of a Canon CanoScan 5600 flatbed scanner and a computer with ImageJ program installed. Scanning took place at 300 dpi in two stages, before and after drying carrot. The images were saved in bmp format in the computer's memory, and then the RGB colour parameters were read in ImageJ program. Then RGB colour components were made linear using inverse sRGB companding. From chromaticity coordinates of sRGB components and its reference white 3×3 RGB to XYZ conversion matrix was calculated and finally CIE Lab colour coordinates were obtained using reference white corresponding to 2° standard observer and standard illuminant D65. No chromatic adaptation was used since sRGB is also relative to D65 reference white. The conversion of colour models was conducted using the norm (Schanda, 2007).

**RESULTS**

The colour change of the material dried to a moisture content of about 50%, compared to the standard, i.e. fresh carrot slices immediately after cutting, was analysed.

The values of colour discriminant in the RGB system were read in the ImageJ program for images obtained from the scanner. Figure 1 shows the RGB parameters of fresh and dried carrot for three drying air temperatures. For fresh carrot, the RGB colour characteristics ranged respectively: R 247-254 (on average 252), G 130-152 (on average 144), and B 17-34 (on average 26), depending on the sample.

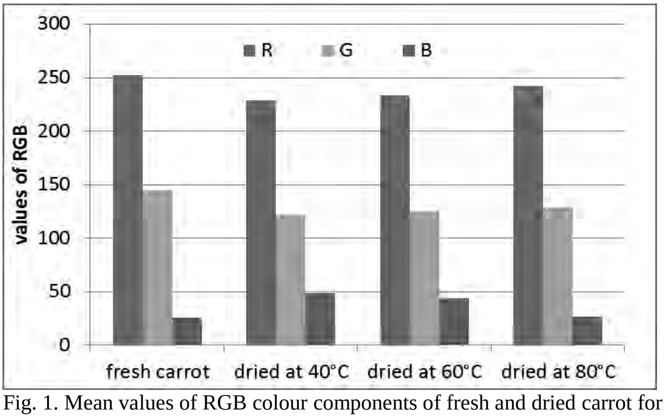


Fig. 1. Mean values of RGB colour components of fresh and dried carrot for different the temperature of the drying agent

After drying carrot, a slight decrease in the colour index R was observed, to 228 at temperature 40°C, 233 at temperature 60°C and 241 at temperature 80°C, which gives a decrease respectively of 4, 7 and 9%. The colour of G parameter had a similar tendency, its values decreased to 121 at temperature 40°C (which is decrease of 16%), 124 at temperature60°C (decrease of 14%) and 128 at temperature 80°C (decrease of 11%). It can be seen that the higher the drying temperature, the smaller decrease of values R and G, only 4% for the R colour component and 11% for G at temperature 80°C. The value of B parameter after drying carrot increased, the most at a temperature of 40°C by 85% (from 26 to 48), while at temperature 80°C only by 1%.

The next step of work was analysing the colour parameters in the CIE Lab system. The RGB values were converted into the CIE Lab system and the results are presented in the bar charts (Figures 2-4).

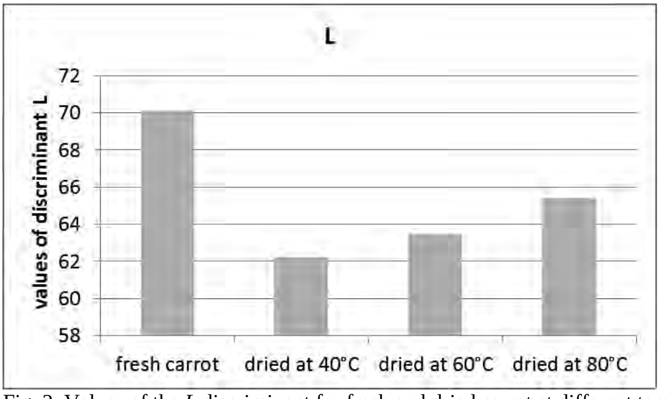

Fig. 2. Values of the *L* discriminant for fresh and dried carrot at different temperatures of the drying agent

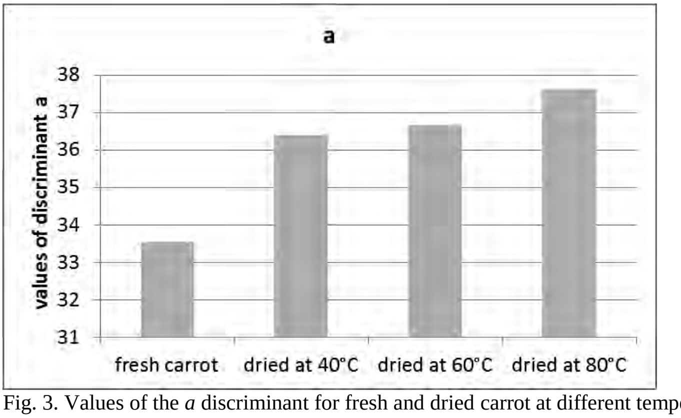

Fig. 3. Values of the *a* discriminant for fresh and dried carrot at different temperatures of the drying agent

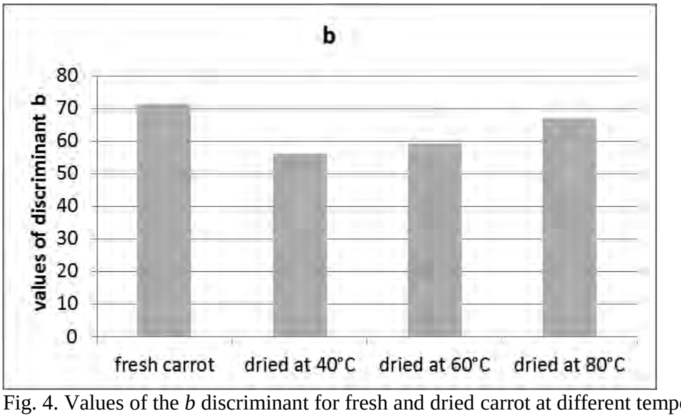

Fig. 4. Values of the *b* discriminant for fresh and dried carrot at different temperatures of the drying agent

The values of the *L* and *b* discriminants after dried carrot decreased, while *a* value increased.

The value of the *L* discriminant of dried carrot decreased from 7 to 11% in relation to fresh one, depending on the drying temperature, which indicates that dried carrot is darker. Interestingly, the higher the drying temperature, the higher the *L* parameter value, which means a lighter carrot colour. The value of *a* discriminant increased by about 9-12% in relation to fresh carrot, which suggests change of colour tone towards more red. The largest change was observed for the *b* discriminant, at the lowest temperature of the drying air, it was a decrease of 22%, i.e. the colour changed to more yellow, which confirms the light browning of the carrot after drying.

## CONLUSIONS

The instrumental method of assessing the colour characteristics of the digital image of carrot slices was used in the work. Changing the colour of vegetables, at the stage of their preparation for processing, can be an indicator of their processing quality, and producing of good quality food is one element of sustainable agriculture.

Comparing the results of measuring the colour of fresh and convective dried carrot, a slight decrease in the value of the R and G colour components was found after drying at each temperature of drying air. The slices of carrot after drying were less red and the colour had a cooler shade. Value of parameter L characterizing the brightness of the material for each drying air temperature was lower than for fresh carrot, and the smallest decrease was observed at the highest drying temperature. At temperature 80°C, the values of most colour discriminants in both systems: the RGB and CIE Lab, differed the least, although a caramelization effect was expected to be identified, but it was not observed. Perhaps the high temperature, but the relatively short exposure time to the dried material caused the smallest difference in the brightness of fresh and dried carrot.

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# 2.10. RESEARCHES OF THE DISTRIBUTOR OF THE COMBINED TILL-PLANT OUTFIT FOR SOWING OF THE SMALL-SEED CROPS

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**Keywords:** combined till-plant outfit, plate distributor, design parameters, distribution density, small seed crops

**ABSTRACT**
The article presents theoretical and experimental investigations of a plate distributor design parameters of the combined till-plant outfit for sowing of small-seed crops. Analytical expressions are presented to calculate the scattering band of the seed material, the density of seed distribution on the soil surface, and the number of seeds per designated area sown by a single distributor. The design parameters of the plate distributor are substantiated, namely: the velocity of the air-seed mixture $V_{asm}$, the angle of opening of the lower plate of the distributor β and the height of the distributor location $N_D$ on the till-plant outfit, which ensures a uniform distribution of seeds of the small-seed crops on the area of sowing.
On the basis of analytical calculations, the size of the scattering area $x_{sa}$, the density of seed distribution along the width and direction of movement of the till-plant outfit $f(x, y)$, depending on the velocity of the air-seed mixture $V_{asm}$ and the design parameters of the plate distributor (the opening angles of the lower plate of the distributor and the height of its location $H_D$ on the till-plant outfit, were determined.

## INTRODUCTION

Mechanical engineers and enterprises of Ukraine and leading countries of the world offer technical support for sowing small seed crops, which is constantly developing and improving. Effective tools in this direction are combined till-plant outfits with various configurations of distributors, which provide sowing of small-seed crops simultaneously with tillage.
According to analysis of expert findings the existing distributors do not fully ensure the uniformity of seeding.

## ANALYSIS OF RESEARCHES

The presented investigations are focused on optimization of parameters and modes of operation of distributors of the plate type and arrangement of their location along the width of the tillage module with the accepted conditions: unchanging parameters – diameter of the distributor ($d$) and angle of installation of the distributor (φ); variables – the velocity of the air-seed mixture ($V_{asm}$), the distributor opening angle (β) and the height of location of the distributor on the till-plant outfit ($N_D$).
The scattering area during travelling is characterized by the distance of seed rebound $x_f$ after falling on the lower plate of the distributor (Peretyatko A. V., 2006, Olkhovsky I. I. 1970, Goryunov D.V. 1959, Kirov A. A. 1984, Rud A.V. 2009, Ulenbeck J., Ford J. 1965, Buzenkov G. M., Ma S. A. 1976).
To determine the size of the scattering band of seeds of small-seed crops without taking into account the air resistance (Fig. 1) we use a calculation technique based on the formulas of the impact theory (Pavelchuk Yu.F. 2009, Deikun V. A. 2012, Yablonsky A. A. 1966, Targ S. M. 1986).

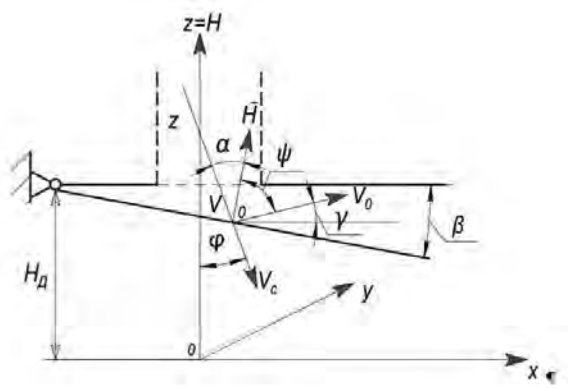

Fig. 1 Calculated scheme of the seeds travelling in the plate distributor

The distance of the rebound of the seeds $x_f$ after falling on the lower plate of the distributor is determined by the expression:

$$x_f = \frac{V_0 \cdot cos\gamma \cdot \left(V_0 \cdot sin\gamma + \sqrt{V_0{}^2 \cdot sin^2\gamma + 2 \cdot g \cdot \mathrm{H}_{\mathbf{D}}}\right)}{g}, \quad (1)$$

where $V_0$ is the speed of the seeds acquired after hitting on the lower plate of the distributor, m / s

$$V_0 = \frac{k \cdot V_c \cdot \cos\alpha}{\cos\psi}; \quad (2)$$

• $V_c$ – the speed of the seeds falling on the plate from the seed spout the condition of a free movement (neglecting the friction of the seeds against the wall of the seed spout), m / s,

$$V_c = \sqrt{V_{\boldsymbol{ac}}^2 \quad \cdot \cos^2\varphi + 2 \cdot g \cdot H_D}\ ; \quad (3)$$

• γ – the angle between the initial velocity vector $\overline{\mathrm{V}}_0$ and the axis *Ox*, degrees

$$\gamma = {}^{\pi}/_{2} - (\beta_\theta + \psi); \quad (4)$$

• $\psi$ – rebound angle (between velocity vector $\overline{\boldsymbol{V}}_0$ and normal to the plate at the point of falling of the seed on it), degrees

$$\psi = arctg\left(\tfrac{1}{k} \cdot tg(\beta_\theta + \varphi)\right); \quad (5)$$

• α – the angle of falling, degrees

$$\alpha = \beta_\theta + \varphi; \quad (6)$$

• $\varphi$ – the angle of the seed coming out from the seed spout, degrees

• $\beta_\theta$ – the angle of inclination of the lower plate of the distributor relative to the horizontal plane for these seeds

$$\beta_\theta = arctg(cos\,\theta \cdot tg\beta); \quad (7)$$

• $\theta$ – the seed bounce angle in the horizontal plane *xOy* relative to the direction of the machine-tractor unit travelling, degrees, $k$ – recovery factor (loss of the mechanical energy of the seeds during the impact), $N_D$, – the height of the distributor installation above the soil surface m, $V_{asm}$ – initial velocity of the air-seed mixture, given by the blower m / s, β – the angle of inclination of the plate to the ground, degree; *Vu* – the speed of the machine-tractor unit travelling m / s.

The calculation of the flight distance of the seeds makes it possible to determine the area of scattering (sown area) (Fig. 2) and, accordingly, the density of seed distribution on the soil surface, which we assume is close to the density of normal distribution according to the Gaussian law:

$$f_n(x,y) = f_{nx}(x)\cdot f_{ny}(y) = \frac{1}{\sigma_x\sqrt{2\pi}}exp\left(-\frac{(x-m_x)^2}{2\sigma_x^2}\right)\cdot\frac{1}{\sigma_y\sqrt{2\pi}}exp\left(-\frac{\left(y-m_y\right)^2}{2\sigma_y^2}\right) =$$

$$= \frac{1}{2\pi\sigma_x\sigma_y}exp\left(-\left(\frac{(x-m_x)^2}{2\sigma_x^2}+\frac{\left(y-m_y\right)^2}{2\sigma_y^2}\right)\right), \qquad (8)$$

where $m_x$, $m_y$ is the mathematical expectation and $\sigma_x\sigma_y$ is the root mean square deviation of the normally distributed random variables in the coordinates x, y.

The amount of seeds ($K_{ni}$) that hit the elemental region $S_{ri}$ in the coordinates x, y when normally distributed is calculated by the equation:

$$\boldsymbol{K}_{\mathbf{ni}} = \boldsymbol{K}\cdot\frac{1}{2\pi\sigma_x\sigma_y}\iint_{S_{r_i}} exp\left(-\left(\frac{(x-\hat{m}_x)^2}{2\sigma_x^2}+\frac{\left(y-\hat{m}_y\right)^2}{2\sigma_y^2}\right)\right)dxdy, \qquad (9)$$

where *K* – is the number of seeds according to the established seeding rate, *pcs / m²*.

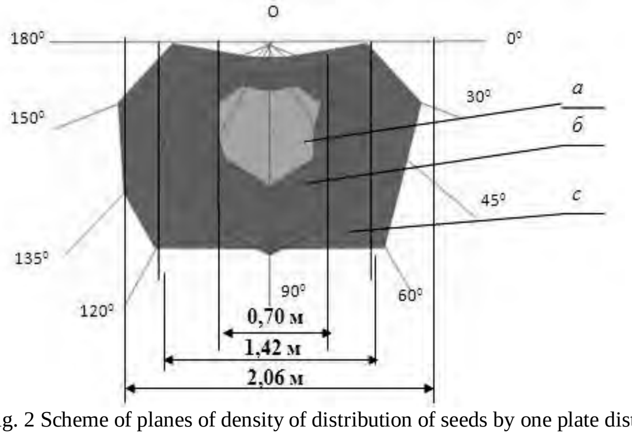


Fig. 2 Scheme of planes of density of distribution of seeds by one plate distributor at the height of its installation $N_D$ = 0,54 m, air-seed mixture velocity $V_{asm}$ = 12 m / s and angles of opening: a) *β = 50*, b) *β = 110*, *c*) *β = 17⁰*

In order to test the theoretical assumptions an experimental setup with a plate distributor was developed, which carried out a series of experiments, on the basis of which statistical arrays of seed distribution data on the cells of the tray were obtained and corresponding charts were constructed.

The nature and shape of the distribution drawings obtained by experimental studies confirm the theoretical data that the best seed distribution in the cells of the tray (S = 0,33 m$^2$) is determined by the set parameters: opening angle β = 5$^0$, air-seed mixture velocity $V_{asm}$ = 12 m / s and height of the distributor installation $H_D$ = 0.54 m.

The above laws indicate that at the rate of 20 kg / ha the uniform distribution of seeds is satisfactory in zone 1, an area of 0.12 m$^2$ and unsatisfactory in zones 2, 3, each with an area of 0.1050 m$^2$. To ensure a uniform distribution of seeds throughout the area simulation was performed with the overlapping of the sowing area under different variants of the distance between the distributors (Fig. 3).

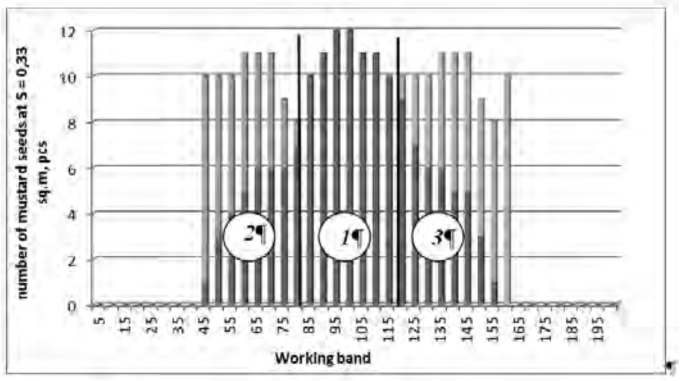


Fig. 3 Scheme of achievement of the set density of seeds with overlapping of the sowing areas: *1 - sown area with one distributor; 2.3 - sown area with overlapping adjacent distributors*

The minimum value of the coefficient of variation ν = 49.3 % fixed at the 8 steps of displacement of adjacent distribution patterns, which corresponds to the distance between the distributors $L_p$ = 0.5 meters and is provided by rational parameters: the opening angle β = $5^0$, the airflow velocity $V_{asm}$ = 12 m/s and the height of the installation of the distributor $N_D$ = 0.54 m.

## CONCLUSIONS

On the basis of analytical calculations, the size of the scattering area $x_f$, the density of seed distribution along the width and direction of movement of the machine-tractor unit *f (x, y)* taking into account the velocity of the air-seed mixture $V_{asm}$ and the design parameters of the plate distributor were determined: the angles of opening of the lower plate of the distributor $\beta$ and the height of its location $H_D$ on the unit.

According to the results of the theoretical and experimental investigations the design parameters of the plate distributor (opening angle β = $5^0$, air velocity $V_{asm}$ = 12 m / s, height of the distributor location $N_D$ = 0.54 m and the distance between the distributors $L_p$ = 0.5 m) of the combined till-plant outfit for sowing of small-seed crops are determined.

These parameters were confirmed by the experimental researches with uneven distribution ν = 49.3% and a uniformity increase of 20.2% of the small-seed crop distribution was achieved.

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# 2.11. THE USE OF ELECTRICAL CONDUCTIVITY SENSOR ON THE GO TO PREDICT CLAY CONTENT IN THE SOIL OF BELGIUM

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**Keywords:** sensor, conductivity, texture, clay

## ABSTRACT

This study aims to validate the exploitation of electro-conductivity data for the evaluation of clay contents. During this work, the conductivity was measured by electrical resistivity tomography using the Veris. The repeatability, the limits of use as well as the influence of the speed of the quad on the measurements were evaluated. Several factors likely to bias the conductivity measurement have been studied. In addition, the calibration to convert the electrical conductivity into clay or useful water portion amount is sometimes not applicable to the entire agricultural parcel in the case of strong heterogeneities. Since this is mainly due to a memory effect of the soil, resulting from previous parcels differing from the current ones, a historical approach was adopted in order to take this heterogeneity into account. These results are therefore more than encouraging for the characterisation of highly heterogeneous soils in precision agriculture.

## INTRODUCTION

Soil management is a significant factor in the context of sustainable agriculture, but also in optimising the yield potential of a parcel of land. Obtaining fundamental information such as soil texture, which affects other soil properties like structure, porosity, hydrological regime etc., is essential to this management. (Gobat, *et al.*, 2010). The proportion of clay influences the water retention capacity, the hydraulic properties of the soil (Frenkel, *et al*., 1978) ; (Bresler, *et al*., 1984) ; (Jabro, 1992) and the cation exchange capacity (CEC) (Gasser, 1975). Clay also affects fertility through the formation of the clay-humus complex (Davey, 1990). In Belgium, too high a percentage of clay can reduce permeability and deep drainage, leading to saturated soils in wet conditions and lower yields (Triantafilis, *et al*., 2003).

The only existing way to create an intra-parcel map of the clay percentage is to carry out sampling according to a specified mesh size, and complete particle size analyses in the laboratory. This method is highly laborious and expensive.

There are, however, mounted sensors that provide continuous measurement of the soil properties based on the conductivity or electrical resistivity of the soil. It has been proved that electrical conductivity (EC) is affected by several soil properties such as clay, salinity, moisture and organic matter (Lund, *et al*., 1999). Sudduth, *et al*. (2003) found positives correlation between the EC and clay, silt or CEC over the first 30 cm and concludes that the use of EC measured at 0-30 by VERIS provides a reasonable prediction of these parameters. The objective of this study was to assess the possibility of mapping the clay percentage of the 0-30 cm layer using EC measurements, and to analyse the possible influence of other factors on the observed correlation.

## EQUIPMENT AND METHOD

### *Area studied*

Parcels belonging to the Apligeer association, located in Wallonia, were scanned using the conductivity meter to map the percentage of clay. On the basis of the orthophotoplans of previous years, certain features could be identified as storage areas or passageways, along with former subdivisions of the parcels. Because the distinctive features are likely to create artefacts in the EC measurements, it was decided that the parcels should be subdivided into sub-parcels according to the parcel history and to exclude storage areas or uncultivated areas.

Because the distinctive features revealed in the various parcels are likely to create artefacts in the EC measurements, it was decided that the parcels should be subdivided into sub-parcels according to the parcel history and to exclude storage areas or uncultivated areas. The sub-parcels were labelled by adding a lower-case letter (Table 1).

Table 1. Description of the parcels

| Parcel No. | Sub Parcel No. | Area [ha] | Subdivision criteria |
|---|---|---|---|
| P2 | P2a | 11.32 | P2 without storage area (harvest, manure) |
| P3 | P3a | 20.30 | P3 without storage area (harvest, manure) |
| P5 | P5a | 17.1 | P5 without storage area (manure) |
| P6 | P6a | 14.82 | P6 without former football field |
| P7 | P7a | 2.34 | Former parcel 1 (re-parcelling before 2000) |
| P7 | P7b | 1 | Former parcel 2 (re-parcelling before 2000) |
| P7 | P7c | 0.5 | Former parcel 3 (re-parcelling before 2000) |
| P7 | P7d | 1.53 | Former parcel 4 (re-parcelling before 2000) |
| P8 | P8a | 30.85 | Former parcel 1 without storage area (harvest, manure) and without passageway |

### *Electrical conductivity (EC)*

The conductivity meter used is the Q2800 (Veris Technologies Inc. Salina, Kansas USA) towed by a quad bike. This device measures the EC over two depths simultaneously: 0-30 cm and 0-90 cm. The data is georeferenced by a Garmin antenna with EGNOS differential correction in the WGS84 geographic coordinate system. The system has an accuracy of +/- 30 cm. The acquisition frequency is 1 Hz. The quad bike moves forward at a speed of between 16 and 25 km/hour. The spacing between two measuring routes is 5 to 9 metres. The direction of movement was always parallel to the seeding lines.

### *Processing of data*

The raw data is exported in .txt format. The data is pre-processed in order to eliminate values deemed to be outliers. Values are considered to be outliers if they have no physical meaning, if they are the result of misplacement, or if their behaviour is markedly distinct from neighbouring measurements (Planchon, 2005) (Cerioli & Riani, 1999). This may be explained by poor conditions of use, poor reception of the GNSS signal (e.g. effect of reflection of waves near woodland) or the presence of local artefacts. Outliers were eliminated by simple observation of the set of data, and for the local artefacts, by a statistical method based on the Z-score (Cheadle, 2003)

### *Interpolation of data*

EC measurements carried out in storage and work areas are considered to belong to a different statistical population since the measurements are too greatly affected by external factors. This is illustrated by a breakdown similar to a bimodal distribution of measurements. These measurements are therefore eliminated from the dataset. On the other hand, since the distribution of the EC measurement populations was very close in the subdivided parcels, it was decided that they could be considered as a single population. In addition to this, depending on the parcels, the data was sometimes withdrawn from the trend and a logarithmic or Box-cox type transformation performed[1] in order to follow the normal distribution required for the use of the chosen interpolation method. The data is then interpolated according to a 1m grid, using the ordinary kriging interpolation method by means of a semi-variogram approximation by composition of an exponential nugget model. Interpolation is carried out using the ArcGis 10.6 Geostatical Analyst tool (Esri, Redlands, Callifornia, USA).

### *Sampling of soils*

Soil sampling was carried out according to areas of heterogeneity of the parcels detected using the Veris Q2800. A sample involves collection of several soil cores within a radius of 5 metres around a central point. This point constitutes the coordinates of an accurate conductivity measurement. The number of samples varies depending on the subparcel (table 2).

Table 2. Number of samples per subdivision

| | P2a | P3a | P5a | P6a | P7a | P7b | P7c | P7d | P8a |
|---|---|---|---|---|---|---|---|---|---|
| No. of samples | 9 | 10 | 11 | 11 | 6 | 3 | / | 2 | 11 |

The samples are then analysed in the laboratory to determine, among other things, the grain size according to ISO standard 17892-4. These analyses enable determination of the various grain size categories (clay, silt and sand). Other factors were analysed, such as the various nutrients ($Ca^{2+}$, P, $K^{+}$, $Mg^{2+}$), pH and organic carbon.

### *Statistical analysis*

A linear regression analysis was carried out between the EC measured by the Veris Q2800 and the percentage of clay determined on soil samples in the lab. The EC measurement used for the correlation and the coefficient of determination[2] is the mean of the values obtained by kriging for the same area as that of the samples. This enabled a comparison of identical areas.

## RESULTS AND DISCUSSION

### *Processing of data*

The number of outliers varies greatly from one parcel to another (from 1.62 to 4.54%). The percentage of values eliminated is between 3.09% and 6.17%, irrespective of the number of measurements carried out.

### *Electrical conductivity (EC)*

Table 3 indicates the number of measured values of EC, the maximum and minimum values and the mean and median for each parcel. Parcels P2, P3, P5 and P8 have very high values and differ widely from the mean. Moreover, the mean and median values are close, which shows that there is only a small proportion of extreme values.

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[1]The Box-cox function, like the logarithm, enables data to be standardised by modifying the differences (heteroscedasticity) between values. The difference between this and the logarithm is that it has a factor that makes it possible to adjust the normalisation of data.

[2]The coefficient of determination ($R^2$) is an indicator of the quality of the linear regression. When $R^2$ is 1, the regression is considered excellent. If it is 0, it is considered poor.

Table 1. Statistics of the EC measurements of different parcels

| | P2 | P3 | P5 | P6 | P7 | P8 |
|---|---|---|---|---|---|---|
| No. of value | 3552 | 6541 | 6103 | 6450 | 1761 | 7069 |
| Max [mS/m] | 241.2 | 165.1 | 96.9 | 46.5 | 41.6 | 135.1 |
| Min [mS/m] | 14.5 | 12.5 | 4 | 4.5 | 6.3 | 10.8 |
| Mean [mS/m] | 29.53 | 29.8 | 23.29 | 25.55 | 24.5 | 23.59 |
| Median [mS/m] | 28.8 | 28.7 | 22.9 | 25.3 | 24.5 | 22.4 |

Table 2 shows the same statistics for the redefined parcels. The maximum values are much lower for parcels P2a, P3a, P5a, and P8a. The original and redefined parcels have identical minimum values. This shows that the storage areas and passageways are associated with very high EC values, which can be a result of soil compaction[1] during repeated movements of agricultural machinery or the anomalously high levels of minerals transferred following storage of organic material.

Table 2. EC measurement statistics for parcels without storage areas or passageways

| | P2a | P3a | P5a | P6a | P7 | P8a |
|---|---|---|---|---|---|---|
| No. of value | 3442 | 6290 | 5972 | 6052 | 1761 | 6781 |
| Max [mS/m] | 51.5 | 55.2 | 44.2 | 46.5 | 41.6 | 56 |
| Min [mS/m] | 14.5 | 12.5 | 4 | 4.5 | 6.3 | 10.8 |
| Mean [mS/m] | 28.7 | 28.88 | 23.02 | 25.4 | 24.5 | 22.68 |
| Median [mS/m] | 28.7 | 28.5 | 22.8 | 25.2 | 24.5 | 22.2 |

***Interpolation of data***

Table 3 shows the kriging parameters and indicators of the prediction quality of these for the original parcels. The N/S ratio is the proportion of the variance of measurements, which is due to independent errors and thus comparable to noise. The greater the N/S ratio, the more significant the noise portion. The range is the distance from which the spatial autocorrelation between two measurements is considered to be zero (Gringarten & Deutsch, 2001). The prediction quality is assessed by means of two estimators: the MSE and the RMSSE. The mean standardised error (MSE) is a kriging prediction quality indicator. The closer its value is to 0, the lower the prediction bias and the more accurate the model. The root mean square standardised error (RMSSE) makes it possible to determine the accuracy of the applied model. The closer the RMSSE value is to 1, the more accurate the model (Esri, 2016).

Table 3. Parameters and kriging indicators for original parcels

| | P2 | P3 | P5 | P6 | P7 | P8 |
|---|---|---|---|---|---|---|
| N/S | 0.181 | 0.273 | 0.212 | 0.418 | 0.378 | 0.113 |
| Range [m] | 24.67 | 105.05 | 139.22 | 102.99 | 83.07 | 147.17 |
| RMSSE | 0.786 | 0.781 | 0.911 | 0.922 | 0.883 | 0.897 |
| MSE | 0.028 | 0.038 | 0.014 | 0.004 | 0.001 | 0.014 |

Removal of the storage areas and passageways areas further increases the prediction quality of the model used for kriging (Table 6). The subdivided parcels are not considered in this table because the model used is the same as for the original parcel, which is why the values assigned to the P7 remain unchanged.

[1]Soil compaction was not quantified in this study.

Table 6. Parameters and kriging indicators for redefined parcels

| | P2a | P3a | P5a | P6a | P7 | P8a |
|---|---|---|---|---|---|---|
| N/S | 0.191 | 0.205 | 0.191 | 0.366 | 0.378 | 0.116 |
| Range [m] | 24.47 | 126.31 | 127.09 | 126.868 | 83.07 | 161.64 |
| RMSSE | 0.831 | 0.876 | 0.971 | 0.928 | 0.883 | 0.961 |
| MSE | 0.002 | 0.01 | 0.0002 | 0.003 | 0.001 | 0.008 |

### *Soil samples*

The parcels show an intra-parcellar heterogeneity as regards the percentage of clay (Table 7). Parcel P5 has the most heterogeneous clay content (13.18%) while parcel P2 is the least heterogeneous (5.93%). The clay values for the samples in the storage areas or passageways are within the same range of values as the rest of the parcel. This confirms that high EC values are affected by other factors, and not just clay. For redefined parcels, the variability of the clay percentage does not depend on the former parcel.

Table 7. Overall results of sampling of clay content per parcel (%)

| | P2 | P3 | P4 | P5 | P6 | P7 | P8 |
|---|---|---|---|---|---|---|---|
| No. of sample | 10 | 11 | 14 | 12 | 12 | 12 | 12 |
| Min [%] | 21.02 | 17.78 | 17.4 | 17.4 | 20.2 | 18.6 | 17.2 |
| Max [%] | 26.95 | 26.34 | 28.5 | 30.58 | 26.31 | 26.9 | 26.22 |
| Mean [%] | 24.35 | 22.24 | 22.44 | 22 | 23.75 | 23 | 22.61 |
| Median [%] | 25.06 | 23.62 | 22.8 | 21.6 | 24 | 23.5 | 24.26 |

As for the other factors analysed by sampling, they are within the same range of values except for calcium and/or potassium, which have higher values in the storage areas in the case of the P2, P3 and P5 parcels.

### *Statistical analyses*

The coefficients of correlation are presented in Table 8 and Table 9. A comparison of the calculated values shows the increase in accuracy of prediction of the clay content of the soil over the first 30 cm due to the detection of distinctive features of the parcel. The coefficients of correlation and determination are much greater when the parcel history is taken into account.

Table 8. Coefficients of correlation (R) and determination ($R^2$) between clay content and soil EC at 30cm

| | P2 | P3 | P5 | P6 | P7 | P8 |
|---|---|---|---|---|---|---|
| R | 0.216 | 0.255 | 0.504 | 0.828 | 0.724 | 0.794 |
| $R^2$ | 0.047 | 0.065 | 0.254 | 0.686 | 0.524 | 0.631 |

Table 9. Coefficients of correlation (R) and determination ($R^2$) between clay content and soil EC at 30 cm after subdivision

| | P2a | P3 | P5a | P6a | P7a | P8 |
|---|---|---|---|---|---|---|
| R | 0.840 | 0.875 | 0.9 | 0.91 | 0.915 | 0.904 |
| $R^2$ | 0.705 | 0.765 | 0.811 | 0.828 | 0.838 | 0.818 |

## CONCLUSION

This study shows that the conductivity meter can provide a satisfactory estimation of the clay content of the soil in the first 30 cm, taking the historical deployment of the parcel into account. This study is based on the assumption that, for a parcel having undergone spatially homogeneous agricultural operations for several years, the factors affecting the EC, such as salinity, structure and water content, are stable or do not vary enough to influence the EC. When the former plot is not identical, it is therefore possible to isolate the effect of the clay content on the EC by establishing a relationship specific to each sub-parcel. The estimation of clay content by sub-parcel, considered to be homogeneous in terms of texture, salinity and water content, is thus more accurate than attempting to obtain a relationship specific to the parcel as a whole. It should be noted that, in instances where annual changes are made to the parcel the phenomenon does not appear to be problematic, since agricultural practices do not sufficiently affect the parameters of the EC. It has also been demonstrated that the clay-conductivity relationship does not apply in the storage areas and passageways. This could be due to the structural conditions of the soil, the presence of a plough pan or a locally significant saline concentration. To assess the clay content of these areas, it appears that more samples need to be taken and that the areas should be considered separate from the parcels. If these areas are of no interest to the farmer, such measures are irrelevant.

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# 2.12. A NEW SYSTEM FOR AERIAL TREATMENT AGAINST EUROPEAN CORN BORER: ASSESSING THE QUALITY OF APPLICATION OF A BIOLOGICAL PLANT PROTECTION PRODUCT

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**Keywords**: *Ostrinia nubilalis, Trichogramma evanescens,* application an unmanned aerial vehicle, biological plant protection

## ABSTRACT

The paper presents an innovative construction of an agricultural aviation system consisting of three carriers: a) a purpose-built unmanned aircraft for application of biological plant treatment substances, equipped with dedicated applicators and fit to carry other equipment if necessary, with two options of propulsion: electrical and hybrid, b) a mobile platform based on a car that serves as a carrier of a computer-based control system for the aircrafts, a battery charging and replacement system, a storage of the plant treatment formulations, additionally serving as a take-off and landing deck for the aircrafts, c) another unmanned aircraft to collect images for the preparation of orthophoto maps of the terrain. The system was intended for biological control of the European corn borer (*Ostrinia nubilalis*) with the possibility of using it in precision agriculture. Dosage of the biological formulation can be adjusted according to the flight speed. Field tests proved that the system uniformly distributes the biological formulation across the treated area.

## INTRODUCTION

One of the most destructive pests of maize is the European corn borer (*Ostrinia nubilalis* Hbn., Lepidoptera, Crambidae). The scale of yield loss is considerable: in Poland, it is on average 20-30% or even up to 80%, depending on weather (Bereś, 2010; Bzowska-Bakalarz *et al.*, 2015). Moreover, damage caused directly by the corn borer larvae in the maize stalks and ears contributes to the spread of infections by e.g. *Fusarium verticillioides*, resulting in contamination of the grain with mycotoxins (Bereś, 2010; Weber and Kita, 2017).

In accordance with the requirements of integrated plant protection and the principles of sustainable agriculture, maize farmers resort to biological methods of reducing the population of *O. nubilalis.* Egg parasitoids of Lepidoptera, especially *Trichogramma brassicae* (Albert *et al.*, 2008) and *T. evanescens* (Oztemiz, 2009), are considered efficient natural enemies of the corn borer. Various biopreparations containing *Trichogramma* are in use, designed for manual or machine application, including aerial spraying (Bereś, 2010; Bzowska-Bakalarz *et al.*, 2015).

Aerial introduction of Trichogramma is an established method of fighting the corn borer in Czechia, a country of the largest maize plantations in Europe (Pniak *et al.*, 2014). In Poland, aerial application is practiced by means of ultralight gyroplanes (Bzowska-Bakalarz *et al*, 2015). Due to their manoeuvrability at low speed and low altitude, and ability to take-off and land in short grass airstrips (meadows), these aircrafts proved suitable in the case of medium-sized and fragmented plantations of complex shapes: they enable precise application of the plant protection product and provide a good trade-off between output (up to 80 he per 40 minutes of flight) and cost.

Recently, unmanned aerial vehicles (UAVs) are tested for applications in precision farming. UAVs have become popular tools in crop monitoring (Gomez *et al.*, 2014, Yanbo *et al.*, 2013). However, they are increasingly recognized as efficient carriers of spraying systems, especially in biological pest management operations (Zhang and Kovacs, 2012; Li *et al.*, 2013; Beitzen-Heineke, 2015; Rangel, 2016, Shulin *et al.*, 2018). This clearly points to the need to design unmanned platforms that meet the requirements of precision farming and use geospatial techniques and remote sensing in combination with systems for the application of plant protection products and fertilizers.

## OBJECTIVES AND METHODOLGY

The aim of the project was to develop an innovative UAV-based system for plant protection that meets the requirements of precision farming, with a special emphasis on biological protection against *Ostrinia nubilalis* using a particular plant protection product, TrichoLet® containing two species: *Trichogramma evanescens* and *T. brassicae* in the form of fine granules.

The components of the system were: an UAV carrier of the plant protection product application system, an application system itself, an imaging UAV, and a mobile control centre. The carrier, AGRODRON, was an originally designed and constructed hexacopter, battery-powered (Fig. 1) or hybrid-powered (Fig. 2). Its arms were designed as completely detachable (to facilitate transport in a relatively small box), and easy to reassemble in one "click" that provides a sturdy structural joint and a reliable connection of the wiring.

Fig. 1. Battery-powered AGRODRON

Fig 2. Hybrid-powered AGRODRON

Fig. 3. Imaging UAV

Fig 4. Example orthophoto map produced on the basis of images taken by the imaging UAV

The purpose of the fixed-wing imaging UAV (Fig. 3), battery-powered, was to provide input for preparing orthophotos for precise mapping of the area needed to plan the flight route (Fig. 4).

The plant protection product application system comprised two containers connected with gravity flow spreaders with dosing discs rotating with adjustable speed to control the dosage; they were mounted on the carrier by means of booms (Fig. 5).

The mobile control centre (Fig. 6) on board of a road vehicle was to control and monitor all functions of AGRODRON and its spreading system. Apart from being a carrier of the whole system, it served as a take-off and landing platform for both UAVs. It was equipped with a battery charging station and a climate control storage chamber for the biological formulations.

Fig. 5. Plant protection product applicator

Fig 6. Mobile control centre

The UAVs were designed to be remote-controlled in take-off, landing, and emergencies, whereas the actual precise farming operations were automatically controlled by the control centre.

**RESULTS**

The project deliverables were designs of individual components of the system, technical documentation, and prototypes. The interaction between the prototype system's components was assessed in outdoor operations, in conditions resembling the target environment.

The carrier's (AGRODRON) automatic control system was tested for precision. Inside a square of 50 m side, with flight speeds of 10 km/h and 30km/h, and at wind speed below 4 m/s, the automatic flight control proved more accurate than manual remote control: deviations from the assumed flight path were smaller, from 0.2 m to 2 m, depending on weather conditions. This was considered to assure a satisfactory quality of application; the design assumptions in this respect were fulfilled. The strength of AGRODRON's detachable arms was examined in a static bend test.

To assess the UAV's performance, a number of tests were conducted to check the flight stability (ability to maintain ground speed and altitude) under various wind speeds in a natural environment. By windless conditions, as well as by steady wind up to 5 m/s, the automatic flight controller proved capable of maintaining stable flight; at greater wind speeds (10 m/s with gusts up to 18 m/s), the UAV was able to fly but the drift was too great to consider any aerial operations.

Performance tests of the battery powered AGRODRON were conducted under the payload of 5 kg assumed in the design specification. The complete assembly (the carrier and the loaded application system) of a gross weight of 20 kg, with a fully charged battery, at wind speed not exceeding 4 m/s, was able to hover at the altitude of 5 m for 60 minutes. The flight was stable. The assembly was loaded successively with extra 2, 4, 8, and 10 kg. The stability of the flight did not change. The hover time decreased, accordingly, to 55, 45, 30, and 25 minutes.

The swath pattern was analysed to ensure an appropriate application rate (24 g/ha) recommended by the manufacturer of TrichoLet®. A series of test flights were conducted in windless conditions (Fig. 7), in a combination of two altitudes (3 and 5 m above the ground) and two flight speeds (20 and 30 km/h). The rotational speed of the spreaders' discs was adjusted according to the flight speed: at 20 km/h, the spreader was calibrated to ensure the total expenditure of both applicators of 5.42 g/min, whereas, at 30 km/h, the total expenditure was 8.39 g/min. Moreover, similar tests were carried out in crosswind and upwind flight at the height of 5 m, with the flight speed of 30 km/h and spreading output of 8.39 g/min, and the wind speed of 4 m/s (Fig. 8). All test combinations were performed in 3 repetitions.

The deposit was collected by means of a 10-cm-wide strip of a sticky tape laid on the ground at the right angle to the flight path. The strip was then divided into 1-m-long sections, numbered to the left and right from the axis of flight, and the grains were counted in each section to discover the swath pattern. Then the uniformity of particle distribution was assessed in each section of the tape. All test combinations were performed in 3 repetitions.

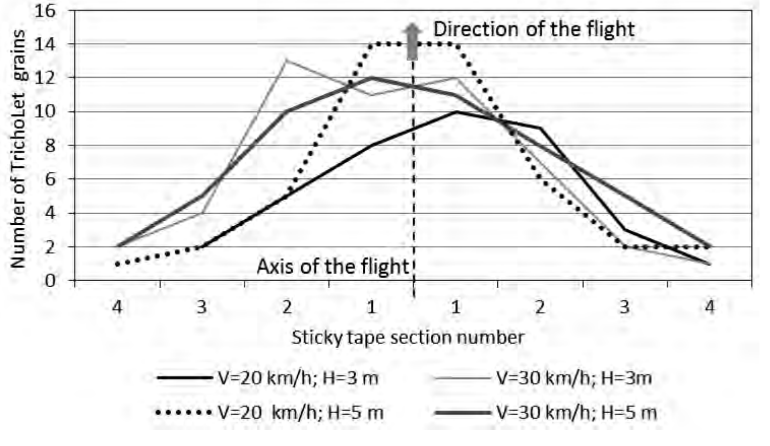


Fig. 7. Swath patterns in windless conditions (average from 3 repetitions)

Considering the results in windless conditions (Fig. 7), the flight at 5m above the ground provides better uniformity of the deposit and a wider swath. Additionally, greater speed (V2=30 km/h) adds to the uniformity of the spread pattern.

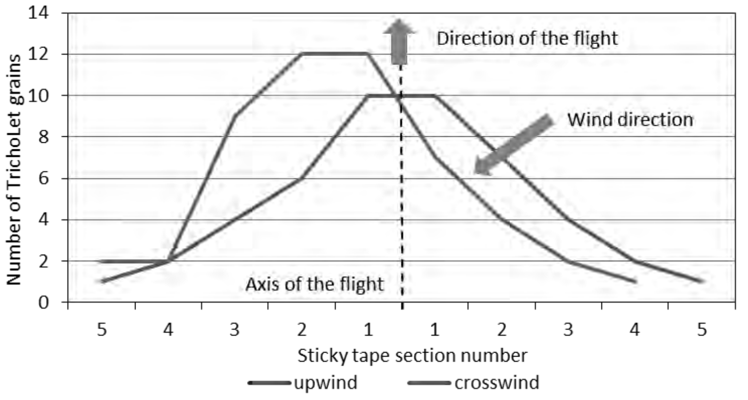


Fig. 8. Swath pattern in upwind and crosswind flight; wind speed not exceeding 4 m/s

As shown in Figure 8, in crosswind, the particles drifted by about 1 m from the axis of the flight. Considering the accuracy of the GPS-based positioning system of 0.5 m and, above all, the Trichogramma's ability to migrate within a radius of 5 m, the effect of wind up to 4 m/h on the operation's efficiency was negligible.

## CONCLUSIONS

The operating parameters of electric, electronic, and mechanical components of the UAV-based system for plant protection, designed for the application of the biological preparation against European corn borer, met the project prerequisites, i.e. the minimum acceptable flight time of the fully loaded carrier (AGRODRON) 30 min, operating ground speed of 30 km/h, and swath width ranging from 7 to 9 m. The distinguishing features of the proposed application system are: flight controlled with the use of real-time kinematic (RTK) positioning system, possibility of adjusting the dose of the plant protection product according to the flight speed, automatic flight control that allows for actual terrain relief (LiDAR-based terrain model), two options of propulsion of the spreading system's carrier (battery or hybrid engine), the possibility of expanding the load capacity up to 20kg, ease of disassembly for transport, and ease of reassembly. The plant protection product application system passed the tests on the quality of distribution, responding to dosage settings with accuracy and repeatability. Therefore, the system proved its fitness for the purpose of precise farming operations, such as biological protection of plantations of small size or in locations difficult to access by larger aircrafts.


## ACKNOWLEDGEMENT

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# 2.13. WINTER OIL SEED RAPE MONITORING WITH UNMANNED AERIAL VEHICLES

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**Keywords**: teledetection, precision farming, oil seed rape, drone, UAV, NDVI

## ABSTRACT
The results were presented of investigations into the impact of snow cover in a field with winter rape plants on the condition of the same cultivation in the spring period. In the investigations, the following drones were used: a fixed wing drone with an RGB camera and multicopter with a multispectral camera: Parrot Sequoia. Prior to commencing the investigations, zones on the map of the field were outlined with 100 %, 50 % and 0 % snow cover. The NDVI vegetation index was used to assess the condition of the vegetation. No significant changes were found in the condition of the vegetation in the cultivation of winter oil seed rape caused by diversified snow cover with the use of NDVI indexes.

## INTRODUCTION

Efficient management in modern farms requires instruments and machines to monitor cultivation and to enable quick response to any irregularities that might appear, such as pests, lack of the required level of minerals in soil and damage of plants caused by weather factors. Unmanned aerial vehicles may be used to support plant production management. When using drones to manage a farm with high precision, cultivation may be observed in the small zones of the field and flights can be performed on heights that are lower compared to when using manned aerial vehicles (Huang *et al.,* 2013). Owing to their advantages, drones can provide a fast, accurate, all seasonal and even many years source of qualitative information on the health of the plants and the condition of the crop. Both multirotor drones and fixed wing drones can be used to monitor cultivation. Cultivation from seed sprouting can be monitored with their aid (Liu *et al.,* 2017) and the yield can be predicted based on monitoring in the growth phase halfway through the season (Fathipoor *et al.,* 2019, Wang *et al.,* 2019).
The latest developments related to unmanned aerial vehicles which are equipped with seed sowing installations, installations for the spreading of chemical agents and plant spraying and with multi-spectral cameras prove to be useful agricultural tools and machinery as well as robots in precision agriculture. Attempts are made to sow forest areas (Novikov and Ersson, 2019), to sow rice on plots (Li *et al.,* 2016) and to sow rye seeds (Chojnacki and Berner, 2018) with the use of drones. Unmanned aerial vehicles are becoming aerial sprayers (Berner and Chojnacki, 2017), which may successfully perform plant protection treatments also in vineyards (Sarri *et al.,* 2019).
To analyse cultivation, drones are equipped with multi-spectral optical sensors, which register high resolution images in electromagnetic spectrum parts in visible and in near infrared, in this manner enabling the calculation of vegetation indexes. The Normalized Difference Vegetation Index (NDVI), which makes it possible to assess the productivity and classification of vegetation, is most frequently used (Assmann *et al.,* 2019). Depending on the stage of the growth and development of plants, the type of information sought and equipment available – the width of the light spectrum band registered by cameras, vegetation indexes that are different from NDVI are also used: from the simplest ones to the most advanced ones and specific for agriculture (Candiago

*et al.*, 2015, Wójtowicz *et al.*, 2016). The data acquired from sensors is processed with the use of dedicated software, and with an appropriate agronomic interpretation, this constitutes an important tool for application in precision agriculture (Zhang and Kovacs, 2012, Mazur and Chojnacki 2018, Mazur and Chojnacki, 2017).

The use of laser light and the LiDAR scanner in an analysis of cultivation constitutes another manner to detect cultivation both in an assessment of biomass and nitrogen (Eitel *et al.,* 2014), while the price of the equipment is a high limitation to this method for its common use in agriculture. The method with the use of the laser scanner is treated rather as a method to improve optical detection.

Rasmussen *at al*. (2016) claim that consumer class cameras mounted on UAV, when used appropriately, constitute a simple and cheap alternative to advanced and expensive hyper-spectral sensors and laser scanners, which may commonly be used in farm management by farmers. The following needs to be taken into consideration: angular variation in reflectance (bidirectional reflectance), stitching and ambient light fluctuations.

**The purpose of the investigations** was an attempt to use drones with a multispectral camera and the NDVI index to assess any possible losses in plants in the cultivation of winter rape caused by snow cover remaining on the field. First of all, it also was the attempt to establish whether by using this method such losses can be stated and assessed.

## MATERIALS AND METHOD

A field with winter rape of an area of ca. 160 ha situated in north-west Poland (53O39'01.52 "N, 15O41'29,46" E) was assessed. It was monitored in November 2016 and in March 2017. For remote vegetation sensing, Parrot Sequoia multispectral camera dedicated to small UAV has been used. It is four band, global shutter camera with wavelengths: Green - 550 nm, Red 660 nm, Red Edge - 735 nm, Near infrared - 790 nm, with ambient light sensor (four bands as well) and IMU recording camera to earth angles and GNSS (Global Navigation Satellite Systems) receiver with automatic, time or distance triggering and geo tagging, (see Figure 1).

Fig. 1. Parrot Sequoia multispectral camera (source: authors)

Camera has been installed on Agrodron X4 - quadcopter with Pixhawk autopilot system. Mission plan with needed camera over- and sidelap (80 %) on 300 m AGL has been prepared to cover researched area. For RGB mapping, Sony camera ILCE 5000 with 18 MPix resolution has been used. Camera was installed on fixed wing drone FX–79 with 2-meter span delta wing. Sony ILCE 5000 was triggering by Pixhawk autopilot under uploaded mission plan. Used with DGPS (Differential Global Positioning System) and GNSS receiver, picture triggering positions have been recorded in log file used further in preparing mosaic. Parameters of flights are shown in table 1.

On 22 November 2016, a flight was performed with the use of an Agrodron X4 drone with a Parrot Sequoia multi-spectral camera to generate a digital map of NDVI indexes for rape cultivation. NDVI indexes accepted to generate the maps were determined for each pixel on the map based on the photographs obtained. On 15 December, a flight was performed with an FX–79 drone with an RGB Sony ILCE camera to obtain a map of snow cover remaining after snow precipitations in the previous week. It was assessed that ca. 30 % of the area of the field examined was covered with snow. 24 zones of interest, including ca. 100%, 50% and 0% snow covers, were selected on the grounds of the snow cover map. Figure 2 presents the map generated from the photographs obtained including the zones marked.

Table 1. An overview of the drones and equipment used for raids

| Platform | Multicopter | Fixed Wing |
|---|---|---|
| Camera | Parrot Sequoia, multispectral | Sony ILCE 5000, RGB |
| Survey aim | Vegetation indices | Snow cover |
| Flights per one survey to cover whole field | 3 x 20 minutes | 1x30 minutes |
| Flights heights | 300 m AGL | 300 m AGL |
| Number of pictures/survey | 2488 | 315 |
| Map resolution | 30.72 cm/pix | 6.43 cm/pix |

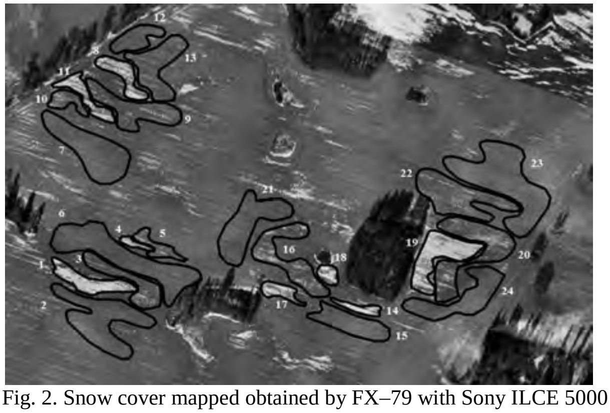

Fig. 2. Snow cover mapped obtained by FX–79 with Sony ILCE 5000 camera and zones-of-interest

These zones underwent further investigations in connection with the predicted changes in the condition of the plants between December and March. For this purpose, on 26 March 2017, a flight was again performed with a multi-spectral camera over the cultivation and, based on the material obtained, a new map of NDVI indexes was generated while determining the value of the index for each pixel on the map (Fig. 3).

## RESULTS AND DISCUSSION

In order to establish whether the snow cover had a significant impact on changes in the vegetation, in this case on a decrease of plant biomass in the zones covered with snow, the average NDVI values were calculated within 24 zones that had previously been marked based on the NDVI values determined from the flights performed in November and March. The results are presented in Table 2. The NDVI results obtained from the November and March flights and determined for the 24 zones underwent an analysis of variance, and the average values of the indexes were determined for 100 %, 50 % and 0 % snow cover. The smallest significant difference - LSD, was calculated for the results obtained. The results of the calculations are presented in Fig. 4.

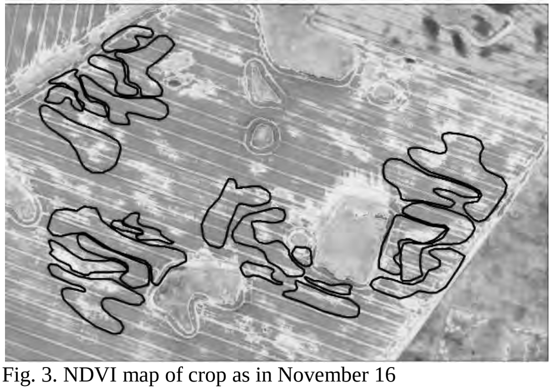
Fig. 3. NDVI map of crop as in November 16

Table 2. Overview of NDVI zone values

| LP | Snow cover | Zone area [ha] | NDVI mean November 2016 | NDVI mean March 2017 |
|---|---|---|---|---|
| 1 | 100% | 0.408 | 0.762 | 0.653 |
| 2 | 0% | 1.064 | 0.775 | 0.648 |
| 3 | 50% | 0.459 | 0.787 | 0.628 |
| 4 | 100% | 0.069 | 0.772 | 0.640 |
| 5 | 50% | 0.198 | 0.779 | 0.646 |
| 6 | 0% | 1.296 | 0.778 | 0.634 |
| 7 | 0% | 0.963 | 0.780 | 0.679 |
| 8 | 100% | 0.279 | 0.777 | 0.646 |
| 9 | 50% | 0.672 | 0.789 | 0.649 |
| 10 | 50% | 0.186 | 0.784 | 0.668 |
| 11 | 100% | 0.307 | 0.779 | 0.663 |
| 12 | 0% | 0.309 | 0.777 | 0.649 |
| 13 | 50% | 0.655 | 0.784 | 0.671 |
| 14 | 100% | 0.121 | 0.776 | 0.654 |
| 15 | 0% | 0.509 | 0.778 | 0.642 |
| 16 | 50% | 0.712 | 0.781 | 0.659 |
| 17 | 100% | 0.170 | 0.765 | 0.629 |
| 18 | 100% | 0.117 | 0.759 | 0.633 |
| 19 | 100% | 0.658 | 0.765 | 0.576 |
| 20 | 50% | 0.923 | 0.775 | 0.612 |
| 21 | 0% | 0.723 | 0.763 | 0.585 |
| 22 | 50% | 0.878 | 0.779 | 0.613 |
| 23 | 0% | 1.462 | 0.774 | 0.612 |
| 24 | 0% | 0.807 | 0.783 | 0.649 |

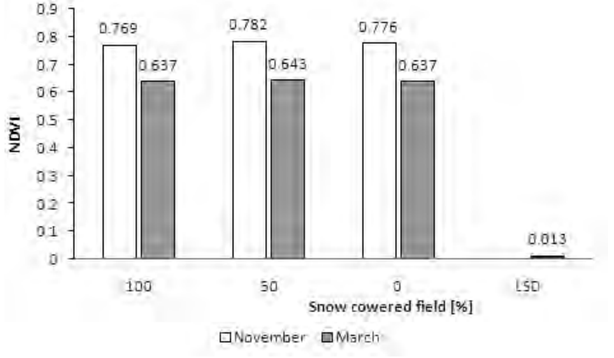

Fig. 4. Average NDVI indexes for zones with 100 %, 50 % and 0 % snow covers performed before snow precipitations: in November and March

## CONCLUSION

A comparison of the average values of NDVI indexes for the field zones with 100 %, 50 % and 0 % snow covers obtained from the flights over winter rape fields performed with a drone with a multi-spectral camera mounted on it before snow precipitations: in November, with NDVI indexes in the same zones with those from flights performed in March did not exhibit any significant differences that would point to the influence of the snow cover on changes in the vegetation.

No other methods to assess the influence of the snow cover on the field on changes in the vegetation were used from the investigations performed with a drone including optical sensors with the determination of NDVI indexes. Therefore, it was not possible to verify whether in reality such losses did occur. It was accepted that there was loss to the vegetation as this was not demonstrated using the method with the NDVI index.

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## 2.14. DEVELOPMENT OF AN EXPLANATORY AND PREDICTIVE MODEL OF THE INTRA-PLOT VARIABILITY OF YIELD IN WALLOON WHEAT

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**Keywords:** crop modelling, wheat yield predictive, explanatory yield, intra-plot yield variability

## ABSTRACT

Following the development of precision farming, the number of sensors equipped on all machines is constantly growing up in the agricultural world. The collected information's are mainly used for specific purposes: inputs modulation (fertilizers, pesticides or pH correctors), soil working depth, guidance, biomass evaluation, etc. This study is a part of the CRA-W VISA project and aims to remobilize the information**'s** already present to explain and predict the yield variability at the intra-plot scale. Several model types were examined to finally retain the regression tree analysis method belonging to Machine Learning concept. The model is currently based on the observations of three Walloons fields, which have been followed during 3 years for the wheat cultivation. Following the first encouraging results, the data collection will be continued and the number of monitored fields will be increased. Furthermore, this will provide information's for more varied weather events and to potentially extend the methodology to other crop types.

## INTRODUCTION

Numerous smart farming applications are currently emerging and offering solutions to optimise yields. However, they are based on a single agronomic strategy, e.g. pH correction, input of organic matter, adjustment of seeding density or supply of fertilisers and water, or soil tillage (Wolfert, Ge, Verdouw, & Bogaardt, 2017). Whereas crop development is not affected by just one parameter at a time, but by a combination of factors that can vary according to the pedoclimatic conditions.

Some agricultural factors, such as exposure to the sun, temperature, rainfall and topography, which cannot be changed by means of agronomic strategies and are not generally considered in smart farming applications, should also be included.

The objective of this study is to assess whether the information collected by current smart farming technologies, supplemented by other available information, can be used to explain and predict the yield variability on an intra-plot scale in the cultivation of wheat in the Walloon Region.

One longer term use would be to prioritise relevant agricultural strategies according to their impact on yield. This would make it possible to choose smart farming applications that have a real impact on the agronomic parameters that limit yield.

## EQUIPMENT AND METHODS

### *Areas studied*

3 land plots located in a silty region have been monitored since 2016 (Visa Project, Table *1*). As part of this study, plots P2 and P3 were chosen because of their significant spatial heterogeneity in terms of yield, pH, clay content, humus content, and electrical conductivity of the soil. Plot P1 shows no significant heterogeneity, i.e. the measurement variations are very close to the precision of our various probes. Its main purpose is to act as a control for this study.

Table 1. Plots (Visa Project)

| Plot No. | Location | Year | Area [ha] | Comments |
|---|---|---|---|---|
| P1 | Gembloux | 2018 | 4.7 | Homogeneous |
| P2 | Ernage | 2018 | 5.5 | Rectangular plot whose long borders have undergone shifts over time. |
| P3 | Rèves | 2016<br>2017 | 21.9 | Sudden variations in pH, humus content and soil structure due to land consolidation. Presence of a thalweg. |

### *Collection and choice of data*

The data collected are presented in Table 2 and were chosen so as to take into account soil, topography, meteorological conditions and development of the crop biomass. Moreover, such data are extensively used in precision farming, most of which does not require any activities beyond those already included in the agricultural working calendar. The meteorological data are obtained from the Pameseb weather station network, and the normalised difference vegetation index (NDVI) satellite data are obtained from the CNES Theia[1]. The skid measurements are obtained from the GéoCAN project *(Defays, 2017)* , which enables the tractor CAN Bus to provide a reading during ploughing and the data to be recorded by a datalogger.

Table 2. Variables used for modelling

| Name [unit] | Description | Acquisition sources |
|---|---|---|
| EC30 [mS/m]<br>EC90 [mS/m] | Electrical conductivity of the soil at a depth of 30 and 90 cm | Veris EC mapping |
| pH | pH of the soi to a depth of 10 cm [2] | Veris Soil pH Managers |
| Humus content [%] | Percentage mass of humus to a depth of 5 cm [2] | Veris OpticMapper |
| Yield [kg/ha] | Yield measured during harvest | Yield Master Pro |
| Radiance [Wh/m2] | Number of Wh detected between March and July | MNT 1m Wallonia[3] |
| Concavity | Defines whether the topography profile is concave (+), linear (0) or convex (-) | MNT 1m Wallonia |
| Slope [%] | Slope of topography | MNT 1m Wallonia |
| Skid [%] | Estimation of soil cohesion by wheel slippage during ploughing | Vector GL2010 |
| Seed density [grains/ha] | Conversion of electrical conductivity into seed density after calibration by sampling[2] | Veris EC mapping |
| Quantity of N on 3rd input [kg/ha] | Biomass index converted to nitrogen guidance | Yara N-Sensor ™ ALS: N supply |
| NDVI | Biomass status index calculated on an average monthly basis between March and July | Sentinel 2 |
| Temperature [°c] | Average monthly temperature measured between March and July | Pameseb network |
| Rainfall [mm] | Total monthly rainfall measured between March and July | Pameseb network |

[1] Centre national d'études spatiales français (French space agency).
[2] Calibrated using samples collected and analysed by the Requasud laboratory network.
[3] The 1m DTM is a digital terrain model obtained from Lidar measurements taken by the Walloon Public Service between 12/12/2012 and 09/03/2014.

### *Pre-processing of data*

ArcMap software is used for the interpolation and management of geo-localised data. The remaining operations were carried out via Matlab software using the Statistics toolbox.

First, all data were cleaned[4] to remove any potential errors/artefacts (Planchon, 2005). The trend was then identified, and the residuals normalised. The normalised residuals were interpolated using the ordinary kriging method, and then the normalisation inverse and addition of the trend was applied to the areas obtained (Kravchenko, 2003). In order to obtain a dataset that provides an estimate of each variable for each square metre making up the plots, the resolution of the interpolations was aligned to that of the DTM (1m resolution). Since satellite measurements have a resolution of 10x10m and cover areas outside the plots, all data located within 10m of the border of the plots were subsequently removed.

To avoid the effect of units and magnitudes in the modelling stage, all data are standardised, i.e. the data are divided by their variance after removing the means. This stage is completed according to the regional means and variances observed[5] during the 3 years in which the trial took place. For the meteorological data, the average and variance were estimated from the Belgian seasonal norms.

Due to the interactions among the variables used, there is a strong correlation between them and the information they contain is highly redundant. The greater the number of variables, the greater the risk of producing a model that can only be considered valid for the data used in its design (overfitting). A reduction in the number of variables using a Principal Component Analysis (PCA) is therefore applied in order to recalculate new variables independent of each other. These can then be used in the modelling (Jolliffe & Cadima, 2016).

Finally, the data are separated into 2 data sets, a “learning” set containing 75% randomly selected data, and a “validation” set containing the remaining 25%. The distribution across learning and validation sets is arbitrary, and cross-validation methods have been excluded due to the considerable size of the data set. The models are built on the learning set and validated on the validation set.

### *Choice and evaluation of selected models*

Based on a literature review, several types of models were selected to explain and model the yield of wheat crops on an intra-plot scale. These were chosen according to their speed of execution, their ability to process large data sets, their ability to assess the significance of each variable, and their adaptability to different variables in the event of the model being extended to other types of crops.

The selected models were compared based on the coefficient of determination ($R^2$), the root mean squared error (RMSE), and the sensitivity to measurement errors. The first 2 criteria were evaluated for the learning and validation sets. The sensitivity analysis was only performed on the validation set. It compares the response differential between the predicted yield and the predicted yield when a bias is added to the variables For this purpose, positive and negative biases of 1, 5, 10, 15, 20, 25 and 30% were applied to the variables obtained from the PCA, so that all possible combinations of variations of

[4] Data cleaning is carried out via an algorithm based on spatial autocorrelation.

[5] The area that enables an assessment of means and variances is therefore much larger than the area of the plots monitored for this trial.

variables were tested. Since the data obtained from the PCA consists of linear combinations of source data, this greatly reduces the number of combinations tested, while ensuring that the greatest response to an imposed bias is observed.

## RESULTS

### *Pre-processing of data*

After interpolation, the dataset consists of 481,203 observations, of which 8.14% belong to P1, 8.66% to P2, 41.6% to P3 of 2016 and 41.6% to P3 of 2017.

The PCA made it possible to reduce the number of variables from 25 to 6 main components, retaining 83.79% of the variance in the starting data. Starting from the fifth main component, the explained variance is only 3.54%, which proves that the percentage gain in explanation of variance is no longer justified compared with the increase in the number of variables.

### *Choice and evaluation of selected models*

The literature review led to the selection of 3 methods: multivariate polynomial regression of degree 3 (MPR) (Breiman & Friedman, 1997), multivariate polynomial regression of degree 3 following application of a zoning algorithm (MPR-C), and a regression tree analysis method (RTA) (Prasad, Iverson, & Liaw, 2006). These 3 models were optimised using the least squares method (Markovsky & Van Huffel, 2007).

In the case of the MPR-C, the zoning is carried out by means of the K-means algorithm (Saxena, *et al.*, 2017) (Chiericati, *et al.*, 2007). Zoning is applied on the variables EC30, EC90, pH, humus content, radiance, concavity, slope and skid, just before application of the PCA. This made it possible to define 5 zones per plot (Fig.1.). The spatial autocorrelation of the different variables used is important in the case of the P2 and P3 plots, since the algorithm forms distinct zones without knowledge of the spatialization of the data. Conversely, the zones appear to be randomly allocated in the P1 plots. This is largely because the observed variations in the variables used in the zoning of P1 are small and very close to the instrumental uncertainty of the probes used. Their variations are therefore mainly due to the noise found in the measurements, which means that the zoning algorithm cannot correctly distinguish between zones with identical behaviour. A second interesting point in the case of P3 is that the borders of the zones were stable between 2016 and 2017. This means that these variables, or at least their measurements, were stable over the two-year period.

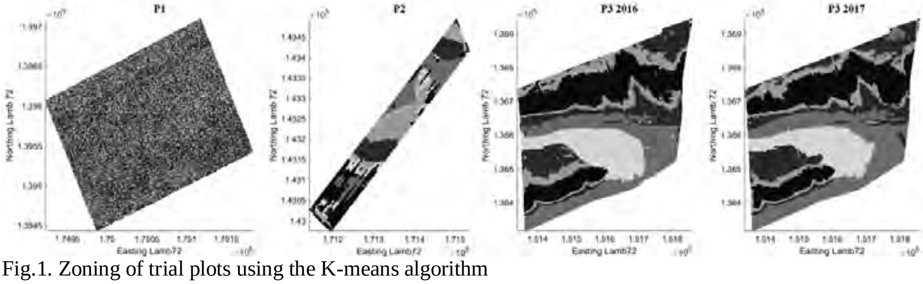

Fig.1. Zoning of trial plots using the K-means algorithm

The R² and RMSE were calculated (Table 3), and the high R² values tell us that the 3 models tested provided a good estimate of the distribution of data. In other words, when low yield is observed, low yield is predicted. As for the RMSE, it provides an indication of the accuracy of predictions by estimating the expected error. Moreover, a difference in

RMSE between validation and learning sets can highlight a case of overfitting (Hawkins, 2003). The increase in RMSE between learning and validation sets is relatively low for the MPR and the MPR-C (0.7% and 0.53%), while it is 51.46% in the case of the RTA, suggesting a case of overfitting in the latter.

Table 3. RMSE and $R^2$ for the MPR, MPR-C and RTA. The L columns refer to the learning set and V to the validation set.

| | MPR | | MPR-C | | RTA | |
|---|---|---|---|---|---|---|
| | L | V | L | V | L | V |
| $R^2$ | 0.928 | 0.928 | 0.958 | 0.958 | 0.995 | 0.988 |
| RMSE [kg] | 589.734 | 592.869 | 449.839 | 452.981 | 158.379 | 239.873 |

The results of the sensitivity analysis are set out in Table . For the 3 models tested, the MPR-C seems to be the most sensitive to the variations introduced, since a variation of 5%, can reduce the $R^2$ to 0 depending on the variables, while the RTA and MPR are still above 0.85. The difference between the MPR and the RTA only arises from variations greater than 10%, where the $R^2$ of the RTA decreases slower than that of the MPR. The RTA is less sensitive and therefore more robust against measurement errors.

Table 4. Sensitivity analysis for the $R^2$ index for MPR, MPR-C and RTA (Mean: $R^2$, Min: $R^2$ minimum and Max: $R^2$ maximum)

| | | 1% | 5% | 10% | 15% | 20% | 25% | 30% |
|---|---|---|---|---|---|---|---|---|
| | Min | 0.934 | 0.894 | 0.655 | 0.252 | 0.04 | 0.001 | 0 |
| MPR | Max | 0.936 | 0.935 | 0.935 | 0.935 | 0.934 | 0.934 | 0.934 |
| | Mean | 0.935 | 0.916 | 0.814 | 0.626 | 0.381 | 0.219 | 0.23 |
| | Min | 0.889 | 0.005 | 0 | 0 | 0 | 0 | 0 |
| MPR-C | Max | 0.964 | 0.964 | 0.962 | 0.957 | 0.948 | 0.936 | 0.924 |
| | Mean | 0.938 | 0.515 | 0.25 | 0.162 | 0.14 | 0.11 | 0.093 |
| | Min | 0.969 | 0.88 | 0.602 | 0.597 | 0.579 | 0.268 | 0 |
| RTA | Max | 0.995 | 0.992 | 0.985 | 0.975 | 0.964 | 0.952 | 0.943 |
| | Mean | 0.979 | 0.917 | 0.809 | 0.785 | 0.756 | 0.618 | 0.495 |

## CONCLUSION

Following evaluation of the models, the RTA showed greater precision and greater robustness in relation to the variations in parameters. It does present a case of overfitting, but this could be corrected by means of additional data sets during validation. This would make it possible to show whether MPR and MPR-C are also affected by this problem. For this purpose, the number of plots monitored will be increased to include a greater number of pedoclimatic conditions and enrich the model. As well, this will provide further understanding in relation to different weather conditions compared with those of the period 2016 to 2018.

A major obstacle encountered in elaborating this type of model is the acquisition of data. A large number of probes and acquisition/validation chains must be set up to obtain all required information, to characterise all the variables, and to access satellite images of a satisfactory quality and suitable frequency. If not all these measures can be deployed, it would be interesting to develop a method to fill any data gaps and estimate how these affect the predictions.

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# 2.15. OSCILLATION THEORY OF THE FREE ENDS OF THE SPIRAL SEPARATOR FOR A POTATO HEAP

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**Keywords:** potato heap, tuber, cleaning spiral, differential equation, oscillation, deformation, distributed load

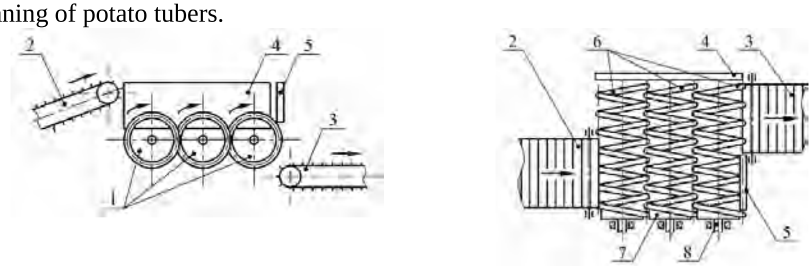
## ABSTRACT

The existing cleaning elements of the potato heap used in modern potato harvesters have several disadvantages. Since the harvesting of potatoes often occurs in the soil of high humidity and plasticity, the cleaning elements often occur stuck in the separation gaps with moist soil and plant residues. This significantly reduces the ability of the potato heap cleaners to ensure the cleaning quality of tubers from the soil impurities and plant residues. A new spiral separator has been developed that is capable of self-cleaning from the stuck soil during the operation. It is also efficient in capturing and removal of the soil and plant residues from the separator. This work shows theoretical studies on bending oscillations of the cantilever spiral separator for a potato heap. In the analysis, analytical expressions describing the deflection and oscillations of the cleaning spiral when performing the technological process have been obtained. The analysis consists of deriving a partial differential equation of transverse oscillations of a cantilever cleaning spiral.

## INTRODUCTION

One of the main requirements for the harvesting of potatoes is the providing of quality cleaning of potato heap from soil and vegetable impurities, as well as the cleaning of the tubers themselves from stuck soil, reducing their damage and losses (Karwowski 1982, Petrov 1984, Bulgakov *et al*. 2002a, b).

However, the existing cleaning working bodies of the potato heap used on modern potato harvesters do not sufficiently meet the above requirements (Bulgakov *et al.* 2017, 2019a). Since the harvesting of potatoes often occurs in the soil of high humidity and plasticity, in the existing cleaning working bodies is often observed stuck of the separation gaps with sticky moist soil and plant residues, which significantly reduces the ability of potato heap cleaners to remove impurities and therefore the quality of cleaning of potato tubers.




a b

Fig. 1. Spiral cleaner of potato heap dug from soil:
a – side view; b – top view: 1 – cleaning spirals; 2 – feed conveyor; 3 – unloading conveyor; 4 – face protective screen; 5 – side protective screen; 6 – free ends of spirals; 7 – hubs; 8 – drive shafts

We have developed a new spiral separator for potato heap, capable of self-cleaning from stuck soil during its operation, as well as the effective capture of soil and plant impurities and their removal beyond the separator (Bulgakov *et al.* 2001, 2019b). The structural and technological scheme of this separator is shown in Fig. 1.

A distinctive feature of the design of this cleaner is that the process of destruction of potato pile dug from the soil, its separation into different components and removal of soil impurities and plant residues through the cleaning zone occurs on successively installed three cleaning spirals 1. The spirals 1 with their ends are mounted as cantilever on the hubs 7, which are mounted on the drive shafts 8, providing them with rotational motions in one direction with a certain angular speed of rotation. The second (free) ends of 6 spirals 1 under the action of variable load capable of oscillatory motions in the longitudinal-vertical plane. The delivery of heap of potato tubers dug out of the soil is carried out by the feed conveyor 2, and the removal of the cleaned potato tubers from spirals 1 is carried out by the unloading conveyor 3. To prevent the loss of potato tubers during the technological process of cleaning them from soil impurities and plant residues around the spirals 1 installed face 4 and side 5 protective screens of rectangular shape. Cleaning, console-mounted cleaning spirals 1 are installed with a mutual overlap, which ensures their self-purification from moist, stuck soil.

Effective self-cleaning is due to the oscillatory motions of the working spiral springs 1, which results in a variable deformation of the cleaning spirals 1 itself, namely their longitudinal extension and transverse bending. This leads to the fact that the distance between the neighbouring coils of spirals 1, that is, their pitch, changes all the time, which helps tear the soil stuck in the intercoil space and sift it down beyond the separator. Thus, in this separator of potato heap is occur not only self-cleaning of the cleaning working bodies (cleaning spirals 1), but also intensive separation of soil impurities and plant residues through the gaps between the coils of spirals 1, as well as between the spirals 1.

## MATERIAL AND METHODS

Improving the quality of cleaning of potato tubers by a spiral separator of potato heap by justification the design and kinematic parameters of working cleaning spirals on the basis of analytical study of transverse bending oscillations of the cantilever cleaning spiral with ensuring that the do not fall outside the separator during the technological process.

The researches were carried out with using the methods of higher mathematics, theoretical mechanics, in particular the theory of oscillations, and methods of compiling programs for numerical calculations of differential equations on PC (Chelomey 1981, 1989, Dolgov 1996).

## RESULTS

Since the oscillatory movement of cantilever cleaning spirals plays an important role in the technological process of cleaning potato tubers from soil and vegetable impurities, it is necessary first of all to analytically investigate the indicated oscillatory process.

This requires, first of all, to build a mathematical model of the oscillatory process of spirals under the action of variable load.

First of all, we construct an equivalent oscillation scheme of a cantilever mounted on the drive shaft of a spiral, which rotates and is under the influence of an external load caused by the potato heap that is on it (Fig. 2).

The equivalent scheme (Fig. 2) shows the cleaning spiral in two positions: in the non-deformed state, when its longitudinal axis coincides with the axis $Oz$, and in the deformed state, when its longitudinal axis undergoes a bending action under the variable distributed load which indicated by $\tilde{q}(z,t)$. This load is due to the continuously flowing potato heap from the loading conveyor to the surface of the cleaning spirals. This scheme shows $S$ – the pitch of a non-deformed spiral, which has a constant value along the entire length of the spiral, and also shows $S(z,t)$ – the pitch of a spiral that has undergone deformation under the action of external loading. This pitch of the deformed spiral is variable along the length of the spiral itself and depends on the time due to the oscillatory motion of the spiral. The deflection of the longitudinal axis of the spiral, indicated $W(z,t)$, is also variable along its axis ($z$ coordinate) and depends on the time (parameter $t$) as a result of the oscillatory motion of the spiral. $R$ – is the radius of the spiral. $\omega$ – the angular velocity of rotation of the spiral around its longitudinal axis (the direction of rotation is shown by an arrow).

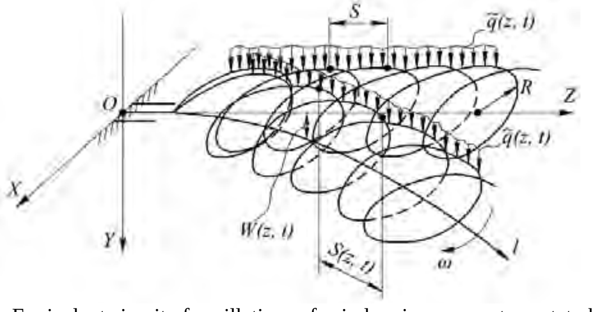



Fig. 2. Equivalent circuit of oscillations of spiral springs separator potato heap

Research of the transverse oscillations of the cantilever cleaning spiral will be carried out in an absolute coordinate system $OXYZ$, where the axis $OZ$ directed along the longitudinal axis of the non-deformed spiral, the axis $OY$ is directed down, and the axis $OX$ – perpendicular to the plane $OYZ$. We denote the longitudinal axis of the curved spiral by $Ol$.

Thus, there is every reason for theoretical consideration of the process of oscillation of the spiral of the cleaner of the potato heap, considering it as a spring rod, which is made in the form of a cylindrical spring with a radius $R$ with a pitch of winding $S$ and the angle $\gamma$ of rise of the helical line along the spiral axis.

To simplify the consideration in this case and, given the rigidity of the spiral, we replace the curved rod of the console with the given parameters.

In our case, in the first approximation, the bending oscillations of the spiral (conditional rod) can be described by the equation of this form (Chelomey 1981):

$$\frac{\partial^2}{\partial z^2}\left(E \cdot I_R \frac{\partial^2 W}{\partial z^2}\right) + \rho \cdot F \frac{\partial^2 W}{\partial t^2} = \tilde{q}(z,t), \tag{1}$$

where $W$ – deflection of the longitudinal axis of the spiral; $\tilde{q}(z,t)$ – distributed and time-varying load of the cleaning spiral with a potato heap; $\rho$ – density of the material of which the spiral is made; $F$ – the cross-sectional area of rod of the cleaning spiral; $E$ – young's module; $I_R$ – the given moment of inertia of a spiral.

The solution of differential equation (1) is the dependence of the bending of the console along the length for the case of natural and forced oscillation (Chelomey 1981).

After completing the necessary mathematical transformations, we give the general solution of differential equation (1) as the sum of functions:

$$W(z,t)=W^{*}(z,t)+\tilde{W}(z,t), \tag{2}$$

where: $W^{*}(z,t)$ – a general solution of a homogeneous differential equation, which has the following form:

$$\frac{\partial^2}{\partial z^2}\left(E\cdot I_R\frac{\partial^2 W}{\partial z^2}\right)+\rho\cdot F\frac{\partial^2 W}{\partial t^2}=0, \tag{3}$$

$\tilde{W}(z,t)$ – partial solution of the original differential equation with the right part.

Herewith, the initial and border conditions will be as follows:

at $z=0$, $t=0$:

$$W(z,t)=0\ , \qquad \frac{\partial^2 W}{\partial z^2}=0, \tag{4}$$

at $z=L$:

$$E\cdot I_R\frac{\partial^2 W}{\partial z^2}=0, \qquad \frac{\partial}{\partial z}\left(E\cdot I_R\frac{\partial^2 W}{\partial z^2}\right)=0. \tag{5}$$

The partial solution $\tilde{W}(z,t)$ is given in the form of the deflection dependence on the length of the cleaning spiral (Chelomey 1981). So, we have:

$$\tilde{W}(z,t)=\frac{q\cdot L^2\left(\frac{z^4}{L^2}-\frac{2z^3}{L}+6z^2\right)}{24E\cdot I_R}, \tag{6}$$

where: $L$ – the length of the spiral.

The general solution of the homogeneous differential equation (3), according to the Fourier method as the product of the function of the longitudinal coordinate $Z(z)$ of the function of time $T(t)$. That is:

$$W^{*}(z,t)=Z(z)\cdot T(t) \tag{7}$$

Suppose that the frequency of spiral own oscillations is $k$ times greater than the frequency of its rotation. In this $k$ – the multiplicity of oscillations. Then we can accept that:

$$T(t)=\cos(\omega k t) \tag{8}$$

The first multiplier of expression (7) is given in the form of special Krylov functions (Chelomey 1981):

$$Z(z)=AS(\lambda z)+BT(\lambda z)+CU(\lambda z)+DV(\lambda z), \tag{9}$$

where: $S(\lambda z)$, $T(\lambda z)$, $U(\lambda z)$ and $V(\lambda z)$ – special functions; $A$, $B$, $C$ and $D$ – constant that determined by the substitution of the general solution into border conditions; $\lambda$ – the spectrum of its own oscillation frequencies.

Then, considering expressions (2), (7), (8) and (9), the general solution of differential equation (1) will have the following form:

$$W=\left[AS(\lambda z)+BT(\lambda z)+CU(\lambda z)+DV(\lambda z)\right]\cdot\cos(\omega\cdot k\cdot t)+\frac{qL^2\left(\frac{z^4}{L^2}-\frac{2z^3}{L}+6z^2\right)}{24E\cdot I_R} \tag{10}$$

The solution of this differential equation (10) is a dependence that reflects the oscillation process of the cantilever spiral as a function of the design parameters of the spiral and the material properties (Timoshenko 1959). Since the coefficients for the Krylov function have numerical values in a certain spiral position, the solution of the equation is given in the form of graphical dependences (Fig. 4, 5) at the angular velocity of the spiral $\omega$ = 30 rad.·s$^{-1}$, material density (spring steel), from which a spiral is made of $\rho$ = 7700 kg·m$^{-3}$, the module of resilience $E = 2 \cdot 10^{11}$ Pa, the radius of the rod $r$ = 8.5 mm under the action of a evenly distributed load of 1000 N·m$^{-1}$ in moments of time: 1) 0 s; 2) 0.1 s; 3) 0.25 s.

As the graph in Fig. 3 shows, under the influence of the distributed load of the potato heap, the deflection of the spiral axis varies from 0 to 0.25 m.

To determine the change in the pitch of the winding in the process of oscillation of the spiral, consider the geometry of the bend of the spiral.

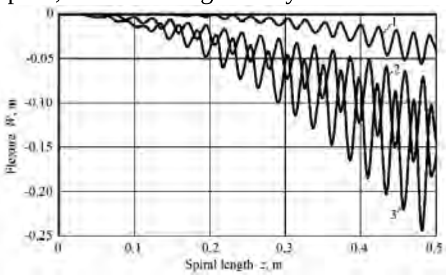



Fig. 3. Dependence of the total deflection of the spiral axis on the action of evenly distributed load

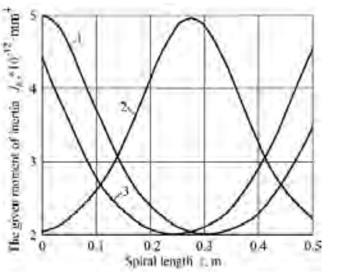



Fig. 4. Calculation scheme of bending of the cantilever resilience spiral

Let this longitudinal axis of the spiral, which is located along the axis $Oz$ and is in a non-bent state (Fig. 4). Between the coils $i$ and $i+1$, whose centres in the coordinate system $YOZ$ are given as $A_O(z_i;\ 0)$ and $B_O(z_{i+1};\ 0)$, the distance $A_OB_O = z_{i+1} - z_i = S$, where $S$ – winding pitch. At longitudinal elongation of the spring there is a movement of the centre of the $i$-th coil to a distance $A_OA_1 = \Delta_i$ and the centre $i+1$-th coil to a distance $B_OB_1 = \Delta_{i+1}$. Then the new coordinates of the centres of coils will be $A_1(z_i + \Delta_i;\ 0)$ and $B_1(z_{i+1} + \Delta_{i+1};\ 0)$ accordingly. Considering, that in the case of transverse bending, the bends of the $i$-th and $i+1$-th coils are $W_A$ and $W_B$ respectively, their centres will have coordinates $A(z_i + \Delta_i;\ W_A)$ and $B(z_{i+1} + \Delta_{i+1};\ W_B)$ respectively. The distance between points $A$ and $B$ will be determined as follows:

$$AB = \sqrt{(Y_B - Y_A)^2 + (Z_B - Z_A)^2} = \sqrt{(W_B - W_A)^2 + (S + \Delta_{i+1} - \Delta_i)^2} \tag{11}$$

The curve passing through points $A$ and $B$ describes the deflection of the longitudinal axis of the spiral. Draw a tangent to the curve at these points, then the angle between the tangent and the horizontal will be $\varphi_i$ and $\varphi_{i+1}$ accordingly, which determines the angle of rotation of the section relative to the initial position. The angle of rotation of the section is determined from the following expressions (Chelomey 1981):

$$\varphi_i = \arctan\frac{dW}{dz} \quad \text{at } z = Z_A; \qquad \varphi_{i+1} = \arctan\frac{dW}{dz} \quad \text{at } z = Z_B \tag{12}$$

Suppose that the normal drawn through points $A$ and $B$, intersect at the point $O_i$, then the distances from this point to points $A$ and $B$ – are the radii of curvature of the curve $AB$ at points $A$ and $B$, respectively.

Let us denote $O_iA = \rho_i$, $O_iB = \rho_{i+1}$. Then, according to Chelomey (1981), we have:

$$\rho_i = \frac{1}{\frac{d^2W}{dz^2}} \quad \text{at } z = Z_A, \qquad \rho_{i+1} = \frac{1}{\frac{d^2W}{dz^2}} \quad \text{at } z = Z_B \tag{13}$$

As can be seen from Fig. 4, the angle between the indicated radii of curvature is equal $\varphi_{i+1} - \varphi_i$.

If we extend the normal $O_iA$ and $O_iB$ on the value of the radius of the spiral $R = AC = BD$, we get the end points of deformation of the coil of the working (separating) surface on which the technological mass is. Then:

$$\begin{aligned} Y_D &= W_B - R\cos\varphi_{i+1}, & Y_C &= W_A - R\cos\varphi_i, \\ Z_D &= Z_B + R\sin\varphi_{i+1}, & Z_C &= Z_A + R\sin\varphi_i. \end{aligned} \tag{14}$$

The distance between points *C* and *D* determines the distance between the centres of neighbouring coils, that is the pitch between the coils after deformation of the spring.

Then the mentioned pitch will be equal:

$$CD = \sqrt{(\rho_i + R)^2 + (\rho_{i+1} + R)^2 - 2(\rho_i + R)(\rho_{i+1} + R)\cos(\varphi_{i+1} - \varphi_i)} \le [S_{\max}] \tag{15}$$

The obtained analytical dependences allow to simulate the dynamics of the cantilever working element (cleaning spiral) when performing the technological process at the selected design parameters and operating modes, based on the conditions (15) of the tubers do not from the separating surface under variable loading and taking into account changes in the moment of inertia of the resilient console in time and in length.

## CONCLUSIONS

A mathematical model of the oscillations of the cleaning elements of a spiral potato separator is developed, and a differential equation of the transverse bending vibrations of its cleaning spiral of the cantilever structure is compiled.

Dependences have been obtained to determine the variable pitch of the spiral bending at any given time and for any intercoil gap during a given oscillatory process.

Analytical expressions of the restriction on the maximum change of the pitch of the cleaning spiral during its oscillations have been obtained, with the condition that the potato tubers do not fall into the intercoil gap of the spiral, taking into account the design and kinematic parameters of the cleaning spiral.

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# 2.16. *PISUM SATIVUM* L. (PEA) YIELD MODELLING USING SENTINEL-2 NDVI MAPS

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**Keywords:** Sentinel-2, NDVI, Yield modelling, peas

## ABSTRACT
Accurately and affordably predict the production of a crop can be very helpful to achieve sustainable agriculture practices. With the increasing presence of new technologies in agricultural management, remote sensing data is being used more and more often for crop monitoring and yield forecast. This study determined the relation between Sentinel-2's derived NDVI and final production values for pea crops at maturity stage at Sorraia and Tejo's Valleys, Portugal. For the model, 37 parcels from the 2017 and 2018 campaigns were used. The results showed the average production of a pea crop parcel was directly proportional to the average NDVI values. The linear model achieved an $R^2$ of 0.72 and was considered statistically significant at $p<0.01$. Additionally, 15 parcels from the 2019 campaign were used as a validation set. The model revealed a tendency to overestimate yield values with an average error of 19%. Additional data, such as weed effect on production and NDVI values, is necessary in order to improve the model accuracy.

## INTRODUCTION

Crop yield forecast data can be an important factor, not only for producers and agri-food companies to allocate resources, improve their farm profitability and help pricing their goods, but also for insurance companies to set their crop insurance policies or to help decision makers on humanitarian actions and disaster responses (Xu & Katchova, 2019). The growing presence of new technologies in agricultural management, allows a quick, reliable and relevant data production for agri-business. Data derived from remote sources, such as satellites, airplanes or Unmanned Aerial Vehicles (UAV), is increasingly being used to monitor farms all around the globe (Jina, *et al.*, 2018). Among several remote data sources, European Space Agency's (ESA) Earth observation program Copernicus offers one of the best opportunities to freely use accurate, timely and easily accessible information for agriculture purposes.

## MATERIAL AND METHODS

By using ESA's Sentinel-2 satellite images, this research aimed at yield modelling pea crops (*Pisum sativum* L.) in Sorraia and Tejo's Valleys, in southern Portugal (Lat: 39.028601; Long: -8.860793). Initially, a total of 37 parcels, managed by the agri-food company DARDICO S.A., were chosen to develop the yield forecast model. From those, regarding the 2017 and 2018 campaigns, 13 and 24 parcels concerning the first and second year, respectively, totalized a crop area of 722.5 ha. Sowing occurred between mid-December and late January for the 2017 campaign and between early December and late February for the 2018 campaign. Additionally, 15 more parcels, regarding the 2019 campaign, were selected as the test data for the model.

With a total crop area of 330.2 ha, this parcels were sowed between late December and mid-February. In the study region, it is very common for farmers to rotate the crops between pea and corn, so from the last set of parcels (2019 campaign), 7 were already considered in the 2017 campaign set.

Information regarding final yield was obtain for each parcel, with an overall average of 7301.54 Kg/ha. Sentinel-2 images were used to generate 10 m spatial resolution Normalized Difference Vegetation Index (NDVI) maps of the region. The average NDVI value was retrieved for each parcel considering the maturity stage close to 90-110 days after sowing (Zając, Klimek-Kopyra, & Oleksy, 2013).

The study region is characterized by a Mediterranean climate with dry summers and rainy winters. However, 2017 was one of the driest years in 8 decades and 2018 presented an above average spring precipitation, especially in March (IPMA, 2019). All of the 52 parcels had active irrigation systems providing water to the crops if necessary.

**RESULTS**

The drier climate in 2017 was balanced by the water supply, allowing the crops to develop in good conditions. In 2018, the heavy rain of March flooded segments of some parcels, especially in slow drain soils, making it impossible for the crops to develop in those sites, which can explain the average NDVI and yield values decrease, comparing with 2017’s average values.

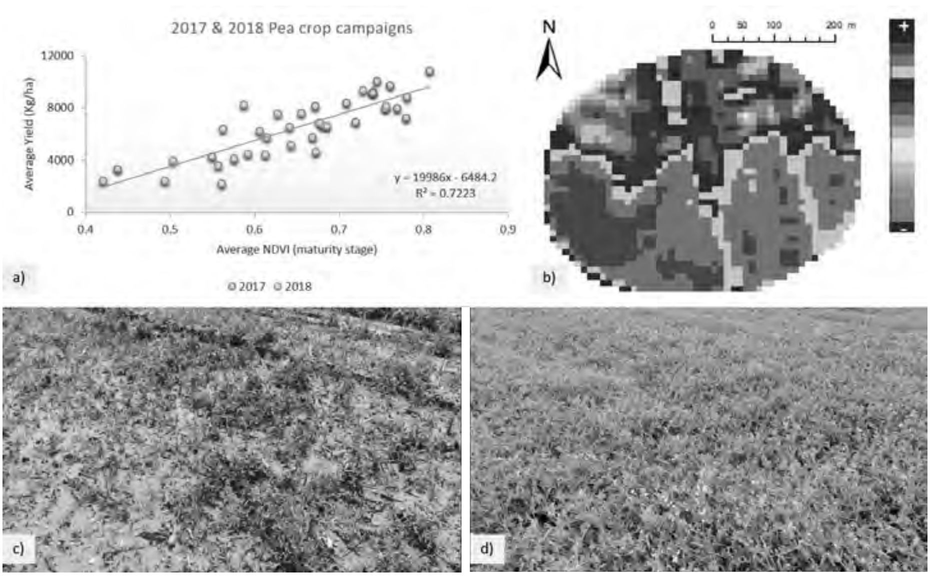
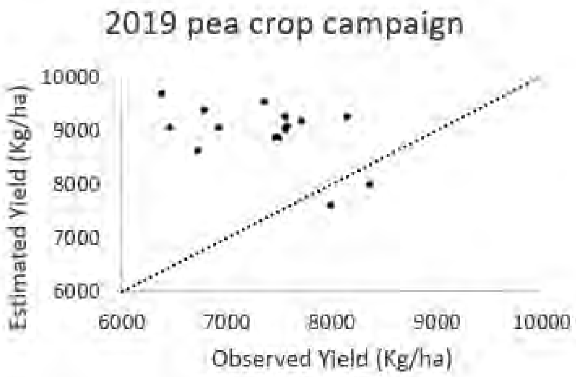



Fig. 1. a) Linear regression between average NDVI (maturity stage) and average yield (Kg/ha) for each of the 37 parcels of the 2017 and 2018 pea crop campaigns in Tejo and Sorraia Valleys, Portugal; b) NDVI map of a 2018 pea crop parcel at maturity stage; c) & d) Plant development in the lower (green) and higher (blue) NDVI regions portrayed in b).

In Fig. 1 it's possible to verify the positive relationship between the average NDVI at the maturity stage and the average yield. In general, average yield increases with higher average NDVI values. The fitted regression line achieved an $R^2$ of 0.7223 and can be considered statistically significant at $p<0.01$.

Using the 2019 campaign parcels as a validation set, it was possible to verify the model accuracy in predicting yield values.




| Average Observed Yield | Average Estimated Yield | Mean Absolute Error (MAE) |
|---|---|---|
| 7357.7 | 8974.1 | 1714.6 |

Fig. 2. Difference between Observed and Estimated Yield for the 15 parcels on the test data set and overall analysis of estimation error.

We can verify in Fig. 2 the tendency for the model to overestimate the yield values in comparison to the observed ones. The Mean Absolute Error (MAE) associated with the estimated values was over 1700 kg/ha, which represents an average error of 19%. We have to take into account that, similarly to the 2017 campaign, in 2019 there were no limitation in water supply or flooded areas due to water excess, so NDVI values and production were to be expected as high. Unlike 2018, the main limitation factor for production was not water, but probably related to another element or elements (soil, nutrients, sowing density, germination percentage, weeds, etc…).

## CONCLUSION

Sentinel-2 data, although not having a very high spatial resolution, appears to be suited for this type of modelling, for more considering the minimal work area of such crop types to be no less than 10x10m. By the results it seems evident the relation between NDVI and pea crop yield, however more data is necessary in order to improve the model. Nevertheless, using the model presented on Fig. 1, DARDICO S. A. agri-food factory can: i) predict, with some certainty and little effort, the overall pea production (in space and time) that will arrive to the factory and better organize the factory operational processes; ii) better manage Nitrogen fertilization due to the fact that the NDVI index is highly correlated with the plant nitrogen deficiency especially on rainy years when leguminous plants have difficulties in fixing nitrogen from the air; and iii) segment harvest between fields and intra-fields in order to obtain different pea quality and different product price.

Future developments include; i) the validation and/or adjustment of the model with future pea crop campaigns and different pea varieties; ii) the consideration of weed presence and their effect in NDVI and yield values; and iii) automatic segmentation of crop parcels in order to manage different pea qualities.


## ACKNOWLEDGEMENTS

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# 2.17. METHOD FOR TESTING RESISTANCE OF RYE TO ERGOT (*CLAVICEPS PURPUREA*) UNDER CONTROLLED INOCULATION

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**Key words**: ergot, rye, controlled infection, sustainable breeding process

## ABSTRACT

Ergot, caused by the fungus *Claviceps purpurea,* is a severe disease in rye (*Secale cereale* L.) leading to development purplish-black sclerotia in the cereal ear. Sclerotia can contain >30 mycotoxins, ergot alkaloids. The experiment involved 16 rye genotypes differing in the amount of pollen produced. Experiments in Poland were carried out in two places: in the Zybiszów Experimental Station for Testing Varieties and in the Kościelna Wieś Experimental Station. Similar experiments were carried out in Germany and Austria - in total in 10 locations.Most of the worldwide rye (*Secale cereale* L.) is produced in Europe. Germany and Poland are the largest producers within the EU..

## INTRODUCTION

Rye (*Secale cereale* L.) is a major staple crop in the Europe grown on 3.6 million hectares with a production of 11,2 million tons in 2017 (FAOSTAT 2017). About eighty percent of this amount is produced in Germany, Poland, and Austria. The other large producers in the EU are Spain and Denmark. In Germany, about 60% of the area is grown by hybrid cultivars, in Poland and Austria hybrids have an increasing importance Ergot, caused by *Claviceps purpurea* (Fr.) Tul., is a severe disease in rye (*Secale cereale* L.) and well-known since the early Middle Ages. The fungus replaces the seeds by a dark, purplish mycelial mass known as a sclerotium (Mielke 2000). The disease causes severe economic damage due to the contamination of grain with ergot sclerotia. They contain up to 30 ergot alkaloids with extremely deleterious effects on the central nervous systems of mammals including man ('ergotism'). The pattern of alkaloids and the amount of individual alkaloids are highly dependent on the location where they have grown (Miedaner *et al.*, 2010). Therefore, alkaloid contents cannot be estimated from the percentage of sclerotia in a rye sample and there are discussions within the EU to change the threshold levels to contents of individual alkaloids. For this, however, more information about the effect of sites, years and countries on alkaloid contents is urgently necessary. Agronomic practices and cultivar resistance, which is very important in sustainable agriculture are the only measures for reducing the risk of ergot infection. Because of the strict EU threshold levels, ergot-free rye grain has a high economic impact for the farmer, but also for breeding companies that have to offer less susceptible cultivars. A harmonized ergot infection test will be an important tool to guide the breeding process to a more sustainable direction. The aim of the research is to create a unified method for testing rye resistance to ergot and analysis of the amount of alkaloids in contaminated grain depending on the location, year and origin of the fungal isolate

## METHODS

In the project were carried four tasks:

- WP 1 Production of high-quality, homogeneous inoculum
- WP 2 Multi-environment field tests using a set of rye cultivars (set A)
- WP 3 Effect of amount of pollen on ergot infection by inoculating factorial crosses with a maximal range of pollen-fertility restoration (set B)
- WP 4 Determination of ergot alkaloids

The purpose of the WP 2 task in the 2017/18 season was to assess the susceptibility of commonly cultivated rye varieties and test hybrids in terms of their susceptibility to infestation with roundnose (*Claviceps purpurea*), causing ergot symptoms.
The experiment involved 16 rye genotypes (Elego, H_Pop, K_Hyb4, Conduct, H_Hyb4, D. Amber, H_Hyb3, Elias, H_Hyb2, K_Hyb1, K_Hyb2, H_Hyb5, D. Turkus, SE_09001_WR, K_Hyb3, D. Scand set in terms of the amount of pollen produced. Experiments in Poland were carried out in two places: at the Zybiszów Experimental Station for Testing Varieties and the Kościelna Wieś Experimental Station. Similar experiments were carried out in Germany and Austria - in total in 10 locations (Table 1). In tests, set A was subjected to controlled inoculation using three inoculates, from Germany, Austria and Poland. Inoculation took place for 3-4 consecutive days during the flowering of rye. The first inoculation was carried out on the day when 30% of the varieties reached the flowering stage. Anther was assessed using a 9-point scale, where 1 means no anthers, 3– presence of anthers, without pollen, 5 - anthers with low pollen count, 7 - anthers with medium pollen count, 9 - anthers with high pollen count (Fig. 1).


anther score 1


anther score 3


anther score 5


anther score 7


Anther score 9

Fig. 1. Point scale of dusting.

Rye ears from 1 m² of each experimental plot were collected manually just before harvest at the wax maturity stage. 500 grams of grain samples obtained from the harvested of each plot were used to determine the weight and percentage of ergot sclerotia in the rye.

## RESULTS AND CONCLUSIONS

Figures 2 - 4 show the results of the experiment for set A.
The more genotype produced pollen - the less ergot infection was recorded.

Table 1. Location and individual sets varieties and genotypes of rye in field experiments.

| Location/Country | Responsible unit | Research material (set) | | |
|---|---|---|---|---|
| | | SET A (N = 16) | SET B (N = 50) | SET C (N = 10) |
| Ob. Lindenhof (DE) | UHOH | X | X | X |
| Braunschweig (DE) | JKI | X | X | X |
| Wohlde (DE) | KWL | X | X | X |

| Location/Country | Responsible unit | Research material (set) | | |
|---|---|---|---|---|
| | | SET A (N = 16) | SET B (N = 50) | SET C (N = 10) |
| Petkus (DE) | KWL | X | X | - |
| Wulfsode (DE) | Hybro | X | X | - |
| Kleptow (DE) | Hybro | X | X | X |
| Edelhof (A) | SZ Edelhof | X | - | - |
| Hagenberg (A) | AGES | X | - | X |
| Koscielna Wieś (PL) | IOR - PIB | X | X | - |
| Zybiszów (PL) | IOR - PIB | X | X | - |

UHOH – University of Hohenheim, Stuttgart
JKI – Julius Kuhn Institute, Braunschweig
KWL, HYBRO, SZ Edelhof – breeding companies
AGES – Österreichische Agentur für Gesundheit und Ernährungssicherheit Gmb
HIOR – PIB – Institute of Plant Protection - National Research Institute

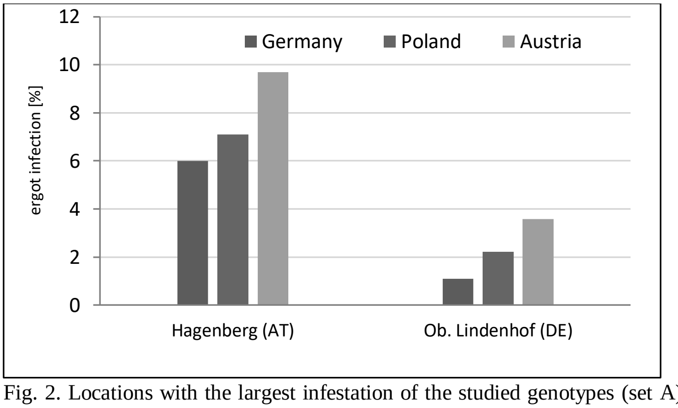


Fig. 2. Locations with the largest infestation of the studied genotypes (set A) by ergot depending on the origin of the inoculate.

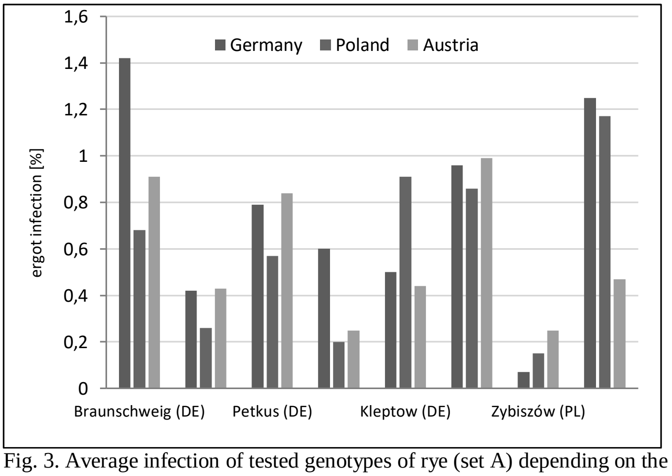


Fig. 3. Average infection of tested genotypes of rye (set A) depending on the origin of the inoculate.

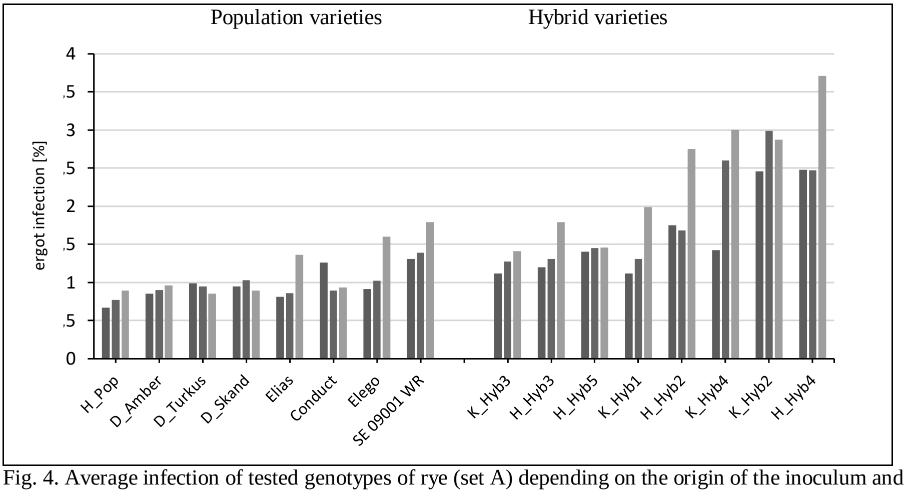


Fig. 4. Average infection of tested genotypes of rye (set A) depending on the origin of the inoculum and the type of variety (population, hybrid).

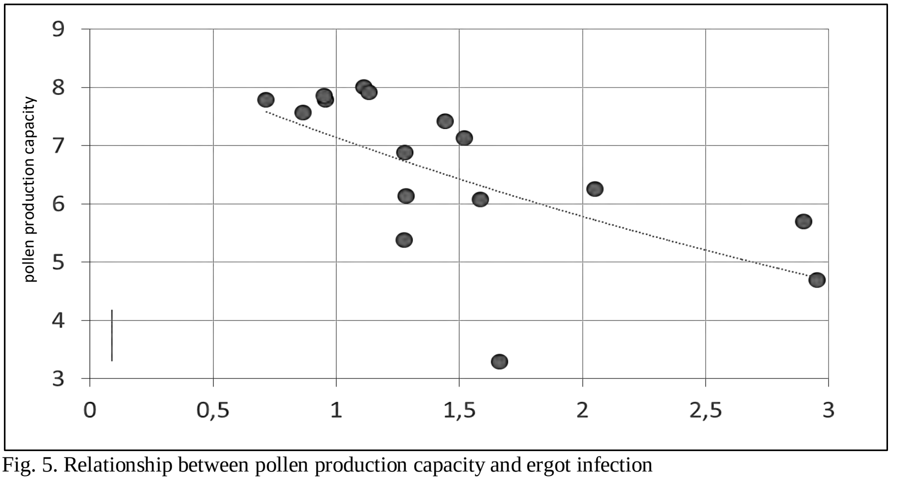


Fig. 5. Relationship between pollen production capacity and ergot infection

In Hagenberg (Austria) and Ob. Lindenhof (Germany) reported the highest rye ergot infection (Fig. 2). Higher infestation was reported in Braunschweig (Germany) and Edelhof (Austria) when an inoculum from Germany was used. After using an inoculum from Poland higher infection was recorded in Edelhof (Austria), Kościelna Wieś (Poland) and Kleptow (Germany). An isolate from Austria caused greater infection in Braunschweig (Germany) and Kościelna Wieś (Poland) (Fig. 3). In general, population varieties were less infested by ergot compared to hybrid varieties regardless of the origin of the inoculate (Fig. 4).

Figure 5 shows the results of the relationship between the amount of pollen production by individual rye varieties and the degree of ergot infection.

The effectiveness of inoculation in the analysed years of research varied depending on the location and origin of the inoculate. In the experiments wide differentiation in ergot infection on individual genotypes was observed. Ergot "honeydew" appeared on the ears of rye about 10 days after artificial inoculation. Differentiation of ergot infection in individual genotypes was observed. Differences in weather conditions during the growing season may have had a significant impact on ergot infection in individual genotypes in individual locations.

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# 2.18. MEASUREMENT OF THE SPRAY ANGLE FOR FLAT FAN NOZZLE USING DIFFERENT METHODS

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**Keywords**: pesticide application; nozzle performance; patternator; drop size distribution

## ABSTRACT
The spray angle of the flat fan nozzle is an important factor to ensure the uniformity of the spray distribution on the target surface. Measuring the spray angle is necessary before the calibration process of the sprayers because the changes in this angle due to different reasons will affect the setting of the sprayer boom for getting the uniform distribution. The aim of this study was to compare three methods of measuring the spray angle of the standard flat fan nozzle. These methods included: using captured images of the spray fan with the aid of image processing software, using the data collected from the spray distribution patternator, and using the data obtained by a laser diffraction device during the measurement of droplet size. The results showed that the first and third methods had the values of the spray angle close to its nominal value.

## INTRODUCTION
The spray angle of a nozzle refers to the angle confined between the outer edges of the spray fan produced from atomizing the liquid by the nozzle tip. The popular spray fan angles are 110°, 80° and 65°. According to (ISO 5681, 1992), the spray angle was defined as "the angle that is formed close to a spray nozzle by the edges of the spray", and the nominal spray angle as "spray angle obtained at a reference pressure so as to characterize a given type of nozzle". The spray angle, boom height and nozzle spacing, and their interaction affect the uniformity of spray coverage and deposition on the target. The spray angle should be taken into account when adjusting the boom height, using 110–120° spraying angles allow the operators to reduce the spraying height of the sprayers boom to less than 50cm for uniform distribution (Miller, Butler Ellis., Lane., O Sullivan., & Tuck., 2011). A positive correlation between the flow rate and spray angle was found by (Ghasemzadeh & Humburg, 2016), and the spray angle also has an influence on the droplet velocity (Miller, Tuck, Murphy, & Ferreira, 2008). Fritz & Hoffmann (2016) reported a higher breakup on the far edges of the spray fan due to the increase in the spray angle. Wang, Dorr, Khashehchi, & He (2015) found that a small size droplets were produced when using wider spray angle or when the liquid breakup during atomization take longer time, suggesting the need for further investigation to find a relationship between sheet thickness to length and spray angle. Miller, Butler Ellis., Lane., O Sullivan., & Tuck (2011) indicated that using nozzles with smaller spray angle (65°) resulted in an increase in the mean droplet size comparing with 110° nozzle angle, this also resulted in a shift for the droplet quality classification from fine (using 110° nozzle angle with 3 and 4 bar) to coarse (using 65° nozzle angle with 2 and 3 bar). The study also concluded that the risk of drift could be reduced when using nozzles with spray angle smaller than 110° in case the spraying with boom height more than 50 cm is necessary. The factors that influence the spray angle are the type and size of nozzle, and the spray pressure (Roşu, Căsăndroiu, Matache, Vlăduţ, & Pruteanu, 2018); (Laryea &

No, 2004). Generally, decreasing the spray pressure results in a decrease in spray angle (Zhang, Wang, & Thierstein, 1994); and increasing the pressure results in the opposite effect (Dorr, *et al.*, 2013). Bai (2014) reported a significant positive correlations of the spray pressure and the pre-orifice diameter on the spray angle, while the nozzle tip area effect was not significant.

Generally, there are different methods to measure the spray angle, it can be classified according to the measurement zone of the angle. The first is where the spray angle is measured near the nozzle tip. In this method, the spray angle can be measured directly by using a protractor (usually with the help of illuminating the spray fan and dark background) as mentioned in (Bateman, 2004); (Ghasemzadeh & Humburg, 2016), or it can be measured by capturing images of the spray fan and then by using a protractor with the images as mentioned in (Liljedahl, 1971); and Juslin, Antikainen, Merkku, & Yliruusi (1995) who used a geometric triangle and original size slides projected on the screen. It can be measured also with the assistance of image processing software after defining the spray angle between a two manually drawn lines of the two outer edges of the spray fan near the nozzle tip (Bai, 2014; Dorr, et al., 2013; Roşu, Căsăndroiu, Matache, Vlăduţ, & Pruteanu, 2018; Wang, Dorr, Khashehchi, & He, 2015; Zhang, Wang, & Thierstein, 1994) and Laryea & No (2004) who investigated pressure-swirl nozzle. The second method depends on the spray volume collected on the spray patternator tubes which they are positioned usually 50cm under the nozzle tip. This spray swath compose the base for the spray fan triangle, this method used by (Zhou, Miller, Walklate, & Thomas, 1996). The measurement of droplet size after transferring the nozzle in different positions alongside the spray pattern could be used also to estimate the spray swath and then the spray angle, this method was used by (Miller, Butler Ellis., Lane., O Sullivan., & Tuck., 2011; Miller, Tuck, Murphy, & Ferreira, 2008). Beside those two methods, there were few attempts to calculate the spray angle theoretically depending mainly on factors relating to the nozzle design, spray pressure, and liquid properties (Roşu, Matache , Vlăduţ , Căsăndroiu , & Bungescu , 2015; Zhou, Miller, Walklate, & Thomas, 1996). Roşu, Căsăndroiu, Matache, Vlăduţ, & Pruteanu (2018) found that the theoretical model proposed by them previously to estimate the spray angle did not differ significantly from the measured values and recommending using this mathematical model in practice. Zhou, Miller, Walklate, & Thomas (1996) reported in their study of relating the spray angle of flat fan nozzle to its internal geometry that the measured spray angle ($\theta$) which was measured using a standard spray patternator had smaller values comparing with the predicted spray angle ($\theta_0$) with difference range between 5 to 10%. However, the study concluded a close agreement between the predicted and measured spray angle. Miller, Butler Ellis., Lane., O Sullivan., & Tuck (2011) reported that the measured spray angles were different from the nominal values supplied by the manufacturer. Moreover, Bai (2014) found that the spray angle values were within the range of 69-104˚ which is different than what was given by the nozzle manufacturer (100˚). The objective of this research was to compare different methods of measuring the nozzle spray fan angle and finding which method gives results that are close to the nominal value of spray angle.

## MATERIALS AND METHODS

In this research, three methods were used to measure the spray angle (Figure 1),including: using photographs of the spray fan, using the data from the spray patternator, and using data of the drop size measurement by laser diffraction device. The standard flat fan nozzles (TeeJet XR 110/03 VP Spraying Systems Co.) were used in the tests. The nozzles had a 110˚ nominal fan angle at 3.0 bar pressure.

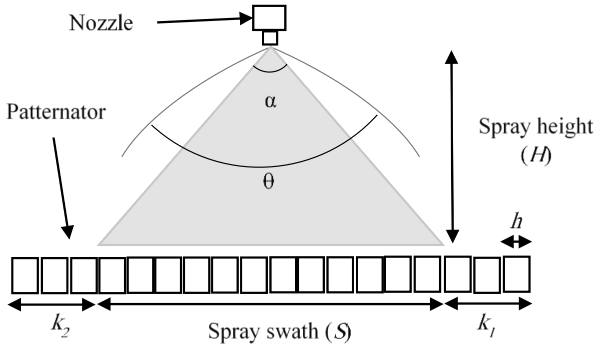


Fig. 1. Measurement setting of the actual (α) and extended (θ) spray angle.

**Measuring the spray angle using photographs of the spray fan**

In this method we can distinguish two possibilities to measure the spray angle (Figure 2), the first represents the actual spray angle (α) while the second represents the extended spray angle (θ). The difference between these two angles could be due to the surface tension, air entrainment and gravity effects. These factors contract the liquid sheet inwards and the direction of drops will be changed in turn (Zhou, Miller, Walklate, & Thomas, 1996). High resolution camera was used to capture photos of the spray fan, those photos then were used directly to measure the extended spray angle (θ), or they were analysed by image processing software (ImageJ-NIH) to measure the actual spray angle (α). The type of the photos was converted to 8-bit and adjusted to proper brightness and contrast scales, and then using the "angle tool" within the software the angle was measured.

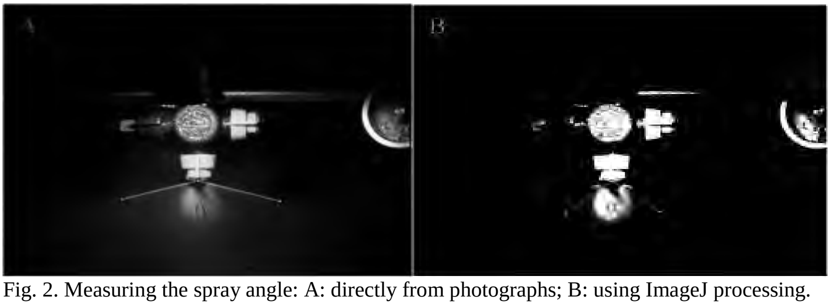


Fig. 2. Measuring the spray angle: A: directly from photographs; B: using ImageJ processing.

**Measuring the spray angle using the data of spray volumetric distribution**

The data of the volumetric spray distribution which were collected by the individual nozzle patternator (details of this device in (Sawa , Huyghebaert , & Parafiniuk , 2012)) were used to estimate the spray angle. The patternator had 250cm width table consisting of 50 "V" shaped grooves (dimensions: 5.0cm width; 10cm depth; 100cm length). The water collected on those groves was directed to the graduated cylinders. The distance between the nozzle orifice and the upper edge of the table was set to 50 cm. The nozzle sample consisted of 12 nozzles with three replications for every nozzle. After collecting the data of the spray distribution, the spray angle was measured using the following equation:

$$\alpha = arctg\left(\frac{(n-k_1-k_2)\frac{h}{H}}{1-\left(\frac{n}{2}-k_1\right)\left(\frac{n}{2}-k_2\right)\frac{h^2}{H^2}}\right) \quad (1)$$

Where: α: The spray angle, degrees.

*n:* number of grooves on the table.

*h*: width of the single groove, cm.

*H:* height of the nozzle from the grooves table, cm.

$k_1$, $k_2$: numbers of the extreme grooves (right and left side), in which no liquid collected.

**Measuring the spray angle during the measurement of drop size**

This method involved estimating the spray angle by using the data collected during the drop size measurement by the laser diffraction device (Sympatec GmbH-HELOS-VARIO/KR). The detailed measurement procedure can be found in (Subr, Sawa, & Parafiniuk, 2016). The long axis of the single spray pattern was transversely sampled, the measurements were taken in nineteen positions (nine positions to the left and the same for the right side of the spray centreline) with 10cm intervals. The total length of the sampled pattern was 180cm with measurements height of 50cm from the nozzle orifice to the sampling zone. To estimate the spray angle, it has been assumed that some critical or abrupt change in the values of volume median diameter or in one of the drops size distribution ranges (≤ 100; 100-200; 200-300; 300-400; 400-500; ≥ 500μm) could happen at the end points (left and right edges) of the spray fan swath. After determining the spray swath (the triangle base), the spray angle can be calculated as follow:

$$\alpha = 2(\tan^{-1}\frac{S}{2H}) \quad (2)$$

## RESULTS AND DISCUSSION

The spray angle resulted from the photography are presented in Figure 3. The actual spray angle values (α) were closer to the nominal values provided by the manufacturer than the extended spray angle (θ). There was non-significant relationship between the two angle values ($R^2$=0.32, p=0.11 for 1 bar pressure, $R^2$=0.15, p=0.30 for 2 bar pressure, and $R^2$=0.20, p=0.22). This is probably because of the effect of different factors such as the liquid turbulence on the region where the extension of the spray fan happen at the edges. For both of the methods, there were highly significant positive relationships between the spray angle and the spray pressure ($R^2$ was 0.55, p<0.01and 0.94, p<0.01 for α and θ, respectively).

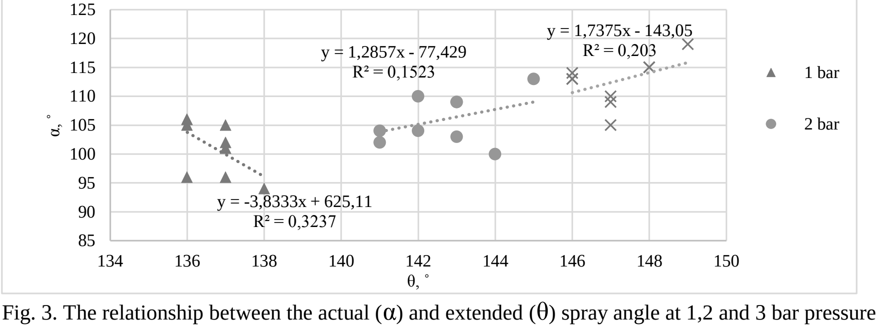


Fig. 3. The relationship between the actual (α) and extended (θ) spray angle at 1,2 and 3 bar pressure.

The spray angle measurement depending on the data from the spray distribution patternator resulted in a value of 123˚ (minimum was 121˚; maximum was 124˚) at 3

bar pressure. The averaged value for $k_1$ was eight, and the averaged value for $k_2$ was five. This mean that the spray swath was ≈ 185 cm and there was a 40 cm neglected to the right of the spray swath, and 25 cm neglected to the left of the spray patternator width (250 cm).
The results of the measurement of spray angle depending on the drop size were interesting, from Figure 4 we can notice that there was a clear and sudden changing in the percentage of drop size ranges 200-300; 400-500; and ≥500μm at the positions 70cm to the right and left of the centreline. This may reveal that spray swath is 140cm and then the spray angle is 110˚. The VMD results and the drop size ranges of ≤ 100; 100-200; 300-400μm did not show clearly a change in their values at the edges of the spray swath.

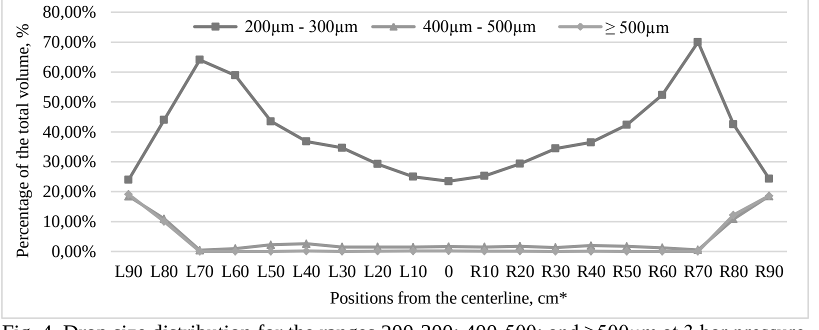


Fig. 4. Drop size distribution for the ranges 200-300; 400-500; and ≥500μm at 3 bar pressure
*R: right side; L: left side, of the spray swath centreline.

The derivative of the drop size percentage (range 200-300μm) against the distance away from the centreline was calculated to investigate the distance at which the drop size percentage changed its trend (Figure 5). The derivative was calculated considering the 0-centimeter distance as the reference (the target), therefore the derivative was calculated for the two opposite direction away from the target based on the following equation:

$$\frac{\Delta y}{\Delta x} \tag{3}$$

Where: $\Delta y$ is the difference between two subsequent drop size percentages.
$\Delta x$ is the difference between two subsequent distances and it is always a positive value.

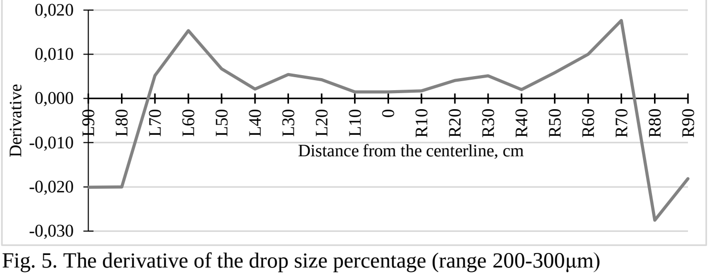


Fig. 5. The derivative of the drop size percentage (range 200-300μm)

## CONCLUSION

The measurement of the spray angle depending on the photograph of the spray fan after processing with image processing software resulted in the closer values to the nominal spray angle (110˚). Moreover, the measurement of the spray angle depending on the data of drop size distribution (especially the ranges 200-300; 400-500; and ≥500μm), to find the spray swath and then the spray angle, resulted in the same value as the nominal.

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## 2.19. ONLINE PEST WARNING SYSTEM AS A TOOL SUPPORTING AGRICULTURAL PRACTICE IN THE INTEGRATED CONTROL REQUIREMENTS

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**Keywords:** integrated control; sustainable agriculture, management; *Online Pest Warning System*

**ABSTRACT**
The principles of integrated plant protection within the framework of Community action for the sustainable use of pesticides, must be implemented by all professional users in Poland. The national action plan to reduce the risks and impacts of pesticide use recommends promotion of general principles of integrated plant control rules. To this aim the publicly available web based integrated pest control platform has been developed. The database summarizes current practices and scientific knowledge on plant protection, and contains the results of monitoring of most important pests in crop plants. The pest signalling platform has become a multilateral tool which supports decision making in integrated pest management.

## INTRODUCTION

Since January 1, 2014, pursuant to the October 21, 2009 Directive of the European Parliament and of the Council establishing the framework for community action with regard to the use of pesticides (2009/28/CE), all professional users have had to observe the rules of integrated plant protection.

The rules and guidelines for integrated plant protection specified in Annex III “General rules for integrated plant protection” emphasize the application of all possible and available methods aimed at reducing the development of population of harmful organisms to a level of harmlessness. Countrywide rules and methods of integrated protection constitute inter-disciplinary actions requiring cooperation between different specialists and including many areas such as entomology, phytopathology, land and plant cultivation. Popularizing integrated programs of protection of different types of cultivations throughout the country requires taking actions such as preparing advisory services for propagating and supervising integrated protection, changing academic curriculums at all levels of education and most of all changing the attitude towards protection of plants and agricultural environment what was described by Pruszyński (2011) and Tratwal & Baran (2018).

Annex III in sections 2 and 3 states:

Section 2: Harmful organisms must be monitored using appropriate methods and tools, if available. Such tools shall include monitoring of fields as well as warning systems and systems of forecasting and early forecasting based on solid scientific evidence, when application thereof is possible, as well as advice from people with relevant and adequate professional qualifications.

Section 3. Based on the results of monitoring actions a professional user must decide whether to apply plant protection methods and when to apply them. The main factor contributing to the decision making are thresholds of harmfulness of harmful organisms which shall be certain and determined based on solid scientific research. If it is possible, before the treatment the user should take into account the harmfulness thresholds for a given region, area, cultivation and particular weather conditions.

Systematic monitoring of pests is an extremely important element of integrated protection. It is a fundamental action aimed at recognizing the dangers for cultivated plants from harmful organisms, i.e. the phytosanitary condition of cultivated plants. Monitoring the occurrence of pests allows the researchers to determine the phytosanitary condition of cultivated plants for the purposes of determining the optimum time for applying a protection treatment, in other words for signalling the treatment what was described by Walczak (1999, 2010). Capable use of the results of the research on appearance and intensification of occurrence of pests contributes to minimizing the risk of possible damages and eliminating excessive and often unnecessary use of plant protection chemicals, which is emphasized by the Directive on integrated plant protection. Monitoring allows for the treatment to be applied at an optimum time, taking into consideration the threshold of harmfulness.

The National Action Plan for limiting the risks associated with the use of plant protection products for years 2013-2017 and 2018 - 2020, primarily aimed at the promotion of the general principles of integrated pest management and the prevention of hazards related to the use of plant protection products, has been implemented through many projects. Importantly, all these projects have been realized with the active participation of advisory services, research institutions, public administration, and sectoral organizations.

Essential elements supporting the implementation of objectives and measures adopted in the National Action Plan include, for example, multiannual programmes carried out by research institutes supervised by the Ministry of Agriculture and also ensuring the transfer of knowledge from theory to practice. One of the key new tasks carried out under the framework of multiannual programmes in the field of plant protection is the development and launch of the Online Pest Warning System (Platforma Sygnalizacji Agrofagów, www.agrofagi.com.pl, Fig. 1) and the monitoring of plant pests which are economically important in agriculture. The system is operated by the Institute of Plant Protection - NRI in close cooperation with the Institute of Horticulture, Institute of Soil Science and Plant Cultivation - NRI, Plant Breeding and Acclimatization Institute – NRI, Research Centre for Cultivar Testing, environmental and life sciences universities and others.

Online Pest Warning System enables broad and coherent cooperation in the area of plant protection between all stakeholders and organizations by providing information on:

- notifications under the pest warning system,
- methods for monitoring and alerting the occurrence of plant pests,
- functionality of decision support systems in plant protection,
- methods for the integrated protection of the most important crops, vegetables, orchard plants and industrial crops,
- methods of integrated plant production,
- online programmes and recommendations on plant protection, including those regarding organic agriculture,
- options for the combined use of chemicals in agriculture,
- search engines of plant protection products and their labels,
- technical aspects of plant protection,
- safe use of plant protection products.

Considering the experience of research institutions, public administration and sectoral organizations, as well as their previous cooperation in the promotion and implementation of the general principles of integrated pest management, we encourage the active use of the *Online Pest Warning System*, including the monitoring of pests in crops and sharing observations with farmers.

Online Pest Warning System consist of six main parts (Fig. 2 -3):

- Pest Warning System,
- Control of plant pests,
- Methods and guides,
- Organic agriculture,
- Agricultural consulting services,
- Project partners.

In first part, for example – Pest Warning System on can find such information like: alerts on plant pests (about 300 localization in Poland – Fig. 4), monitoring of maize, methods for alerting and monitoring of plant pests, tools supporting the monitoring of plant pests, decision support systems in plant protection, pest Risk Assessment.

Platforma
**Sygnalizacji Agrofagów**

Fig. 1. Online Pest Warning System logo

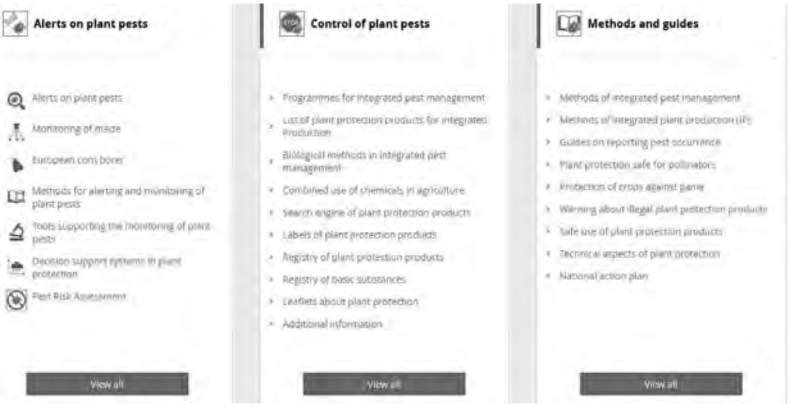


Fig. 2. The first three modules of the Online Pest Warning System main page


Fig. 3. Next modules of the Online Pest Warning System main page


Fig. 4. Map of the country with monitoring points of harmful organisms in crops of agricultural plants.

## CONCLUSION

Data base of *Online Pest Warning System* contains about 600 files in pdf format and about 40 links to other websites. In the years 2017 - 2018, there were over 417,000 visits to the website http://www.agrofagi.com.pl. This shows that the website is very popular and the need to maintain a dynamically developing portal, which offers accessible and modern knowledge in the field of widely understood integrated production, management and sustainability in agriculture.

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# 2.20. STUDY ON THE HONEY PRODUCTIVE POTENTIAL OF THE BEE FORAGE SPECIES IN NORTHEAST PART OF BULGARIA IN SILISTRA REGION

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**Keywords:** investigation, honeybee, apiary, productive potential

## ABSTRACT
The study aimed to investigate honey productive potential of the bee forage species in selected area in Northeast part of Bulgaria in Silistra region, Glavinica town in 2019 year. The study was conducted based on the assessment existing bee forage resources and the number of bee colonies kept in the investigated area. This article proposes a technological solution for an apiary of 45 bee colonies located in the study area. The decision takes into account the peculiarities of the flat hilly areas of bee pastures and the presence of competing of 1617 bee colonies in the flight range of 3 km of the apiary under study. From the calculations, it was found that the total amount of honey that is expected to be extracted from the hive for the entire period of investigation is 18.65 kg. The predominant pasture is sunflower which is expected to yield about 13 kg per hive. It was found that higher yields could not be obtained from available bee pasture resources with a total area of 537.83 ha. The information generated is useful in apiary site selection and to estimate the honeybee colony carrying capacity of an area.

## INTRODUCTION

Beekeeping is an important sector of agriculture, bearing in mind its importance in crop pollination. The great biodiversity of plant species, favourable climatic conditions, improvement of the productive qualities of the local breed of bee *Apis mellifera macedonica*, as well as the financial resources received under National and European programs, have led to the rapid increase of apiaries and bee colonies in Bulgaria.

From the statistical survey of the "Agro-statistic" department to the Ministry of Agriculture, Food and Forestry in Bulgaria it was established that for 2018 the bee colonies are 783.3 thousand pieces, which was by 2.3 % more than in the previous year. The average number of bee colonies per farm increased from 57.0 pieces in 2017 to 63.9 pieces in 2018. Despite of the positive trends in the sector, honey produced is reduced to 10 338 tonnes in 2018, with an annual decrease is estimated at 12.4%. The average yield per bee colony for 2018 is 16.8 kg, or by 15.6% below compared to the previous year. One of the reasons for this is the lack of control over the design of new apiaries and the correct selection of the location of bee colonies, which leads to the accumulation of a large number of bee farms in areas with abundant pollen, without taking into account the productive potential of flowering vegetation. Another disadvantage is mono-crop farming, using plant varieties and hybrids with lower nectar and pollen yields and shorter flowering periods, which reduces both biodiversity and the area used for bee grazing. The specific climatic conditions, the relief, the type of flowering vegetation, the size of the arable land determine Northeastern Bulgaria, as an area with very high potential for beekeeping development. Despite the favourable natural resources, there is a lack of scientifically sound technological solutions for bee breeding, which leads to incomplete exploitation of the productive potential of the area. Some authors, (Atanasov, A. *et al.*, 2017) found that the concentration of a large number of bee colonies in some regions of North-eastern Bulgaria led to a decrease in honey production by three times. Many publications (Al-Ghamdi *et al.*, 2016; Hinson, E. *et al.*, 2015; Vaudo, A., 2012) have proposed solutions for determining the optimum number of bee families for different forage species in individual beekeeping areas. Automatically transferring approaches and technologies from one area to another without considering the specific conditions would be a wrong practice.

The aim of our work is to investigate the influence of the productive potential of flowering vegetation and the density of bee families on honey production in flat hilly regions.

**MATERIALS AND METHODS**

The study area is located in the Northeast part of Bulgaria in Silistra region, Glavinica town. Geographical location of experimental apiary in Glavinica is 43°54'52.74" N, 25°50'11.61" E and at an altitudinal range of 114 m above sea level. In the region major honey source plants are Lime (*Tilia cordata*) and Acacia (*Robinia pseudoacacia*), Gleditsia (*Gleditsia triacantha L.*) of forest tree species. Of great importance for honeybee in the study regions are Sunflower (*Helianthus annuus L*), Oilseed rape (*Brassica napus*) and, lavender (*Lavandula officinalis*). The total land area of the study sites was about 28.12 $km^2$.

The research included third main stage: 1) determine existing bee forage resources; 2) calculation the expected honey yield for current year; 3) an assessment of the optimal number of bee colonies for the experimental area.

The data for forests and cultivated crops in the experimental area were obtained through the detour of the areas and determining their coordinates with the (GPS). The data for geographical locations of apiaries around of the experimental apiaries within a radius of 3 km were received by the conducted survey of beekeepers.

All collected data about the location of apiaries and areas with the forests and cultivated crops were incorporated into Google Earth professional in order to be created a map of the experimental areas.

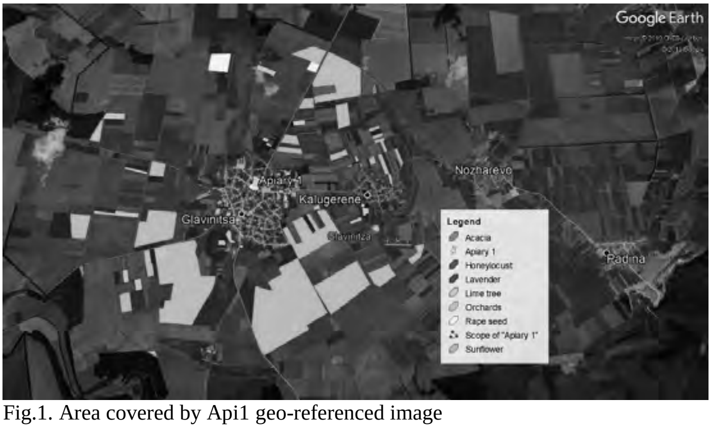

Fig.1. Area covered by Api1 geo-referenced image

Fig.2. The circles of the five apiaries and the quadrants of their overlaps from A to I

The calculation was made for flowering bee forage species within a radius of 3 km around the experimental apiary (Api1), which is equal to 537.83 ha. For easier operation and data processing, the apiaries around Api1 are combined into 5 main apiaries Api1, Api2, Api3, Api4, Api5 with a total of 1617 bee colonies. The area covered by Api1 is reflected in the red circle map Fig.1. The circumference of Api1 is divided into separate areas that are conventionally designated as overlapping zones (A-I) in which we have overlapping of different apiaries Fig.2.

To determine the optimum storage of nectar of the investigated area of overlap and the expected amount of honey per hive, we use these formulas as follows.

$$O_{NP} = \frac{N_{SP} \times A}{2} \text{ , } kg/ha \tag{1}$$

$O_{NP}$ -The optimal quantity of stocks of nectar, kg/ha
$N_{SP}$ - Nectar secretion potential, kg/ha
A- Area, ha

$$H_Y = \frac{O_{NP}}{n} \text{ , } kg \tag{2}$$

$H_Y$ - The expected quantity of honey per hive, kg
n - Number of bee colonies

**RESULTS AND DISCUSSIONS**

Based on the nectar secretion amount and dynamics study, the average honey production potential for the individual overlapping zones A-C is shown in some Table 1, Table 2, and Table 3. The values for the other zones of D-I are similarly calculated.

From the calculations made it was found that the total quantity of honey expected to be obtained per hive for the entire honey-collection period for 2019 is 18.65 kg. The prevailing honey is of sunflower which is expected to give about 13 kg yield per hive.

The total quantity of honey expected from the experimental apiary of 45 hives is about 840 kg per year.

Table 1. Results of the calculations made for Overlap Zone A

| Overlap Zone A | | | | | |
|---|---|---|---|---|---|
| Forage species | Area, ha | Number bee colonies | Nectar secretion potential, kg/ha | Optimum honey yield expected potential, kg | Expected honey yield for experimental apiary, kg/hive |
| Sunflower | 6.0 | 839 | 60 | 180 | 0.215 |
| Oilseed rape | 12.2 | 839 | 59 | 359.9 | 0.429 |
| Gleditsia | 19.9 | 839 | 160 | 1592 | 1.897 |
| Orchards | 5.15 | 839 | - | 0 | 0.000 |
| Lime | 5.0 | 839 | 291 | 727.5 | 0.867 |
| **Total** | 48.25 | 839 | | | 3.408 |

Table 2. Results of the calculations made for Overlap Zone B

| Overlap Zone B | | | | | |
|---|---|---|---|---|---|
| Forage species | Area. ha | Number bee colonies | Nectar secretion potential. kg/ha | Optimum honey yield expected potential. kg | Expected honey yield for experimental apiary. kg/hive |
| Sunflower | 75.6 | 1142 | 60 | 2268 | 1.986 |
| Gleditsia | 6.23 | 1142 | 160 | 498.4 | 0.436 |
| Orchards | 11.8 | 1142 | 0 | 0 | 0.000 |
| Lavender | 1.8 | 1142 | 125 | 112.5 | 0.099 |
| Acacia | 0.8 | 1142 | 300 | 120 | 0.105 |
| **Total** | 96.23 | 1142 | | | 2.626 |

Table 3. Results of the calculations for Overlap Zone C

| Overlap Zone C | | | | | |
|---|---|---|---|---|---|
| Forage species | Area, ha | Number bee colonies | Nectar secretion potential, kg/ha | Optimum honey yield expected potential, kg | Expected honey yield for experimental apiary, kg/hive |
| Sunflower | 55.44 | 892 | 60 | 1663.2 | 1.865 |
| Lime | 1.1 | 892 | 291 | 160.05 | 0.179 |
| **Total** | 565.4 | 892 | | | 2.044 |

The final results of the calculations for the experimental apiary of 45 hives is illustrated on Fig.3.

It was found that with the available bee forage species with a total area of 537,83 hectares and with a total number of bee colonies 1617, higher yields cannot be obtained.

In order to increase honey production with the available resources, it is necessary to reduce the number of bee families in the Glavinica town. In order to determine the optimum number of honeybee colonies, the following assumption was made. In Europe one colony consumes between 60-202 kg of honey per year (Seeley, T.D. *et al.*, 1991), this honey is used to maintain the life cycle in the bee colony. In turn, well managed hive can produce 60 kg and more honey per year.

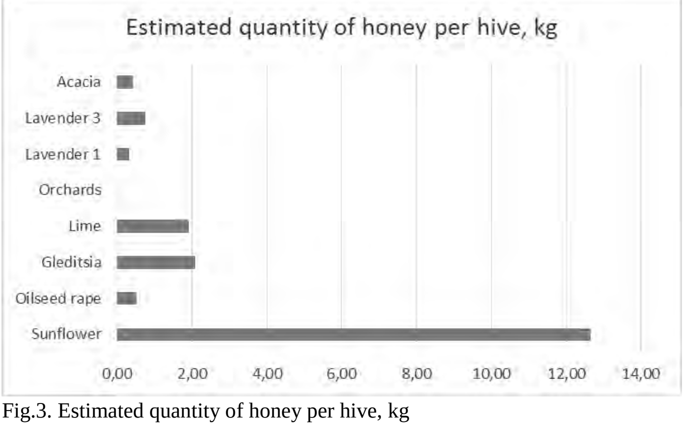


Fig.3. Estimated quantity of honey per hive, kg

In this case, assuming that for the conditions of Northeastern Bulgaria the beehive consumes 80 kg of honey per year and the desired commodity honey is between 30-60 kg of the hive, then the calculated optimal number of bee colonies for Glavinitsa town is shown in Fig. 4. In this calculation we assume that all factors such as air temperature, humidity, atmospheric pressure, rainfall and etc. have been ignored.

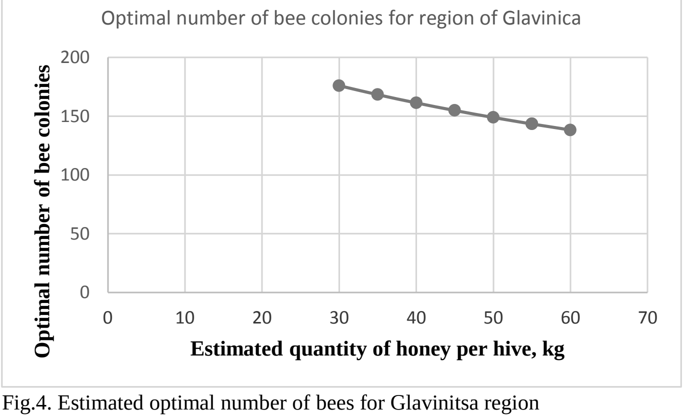


Fig.4. Estimated optimal number of bees for Glavinitsa region

## CONCLUSIONS

The productive potential of the bee forage species of Lime (Tilia cordata) and Acacia (Robinia pseudoacacia), Gleditsia (Gleditsia triacantha L.) Sunflower (Helianthus annuus L), Oilseed rape (Brassica napus) and, lavender (Lavandula officinalis) for Glavinica town, Sulistra region has been determined. For the experimental apiary, it was found that the total quantity of honey expected to be obtained per hive for the entire honey-collection period for 2019 is 18.65 kg. The prevailing honey is of the kind called sunflower which is expected to give about 13 kg yield per hive.

It was found that with the available bee forage species with a total area of 537.83 hectares and with a total number of bee colonies 1617, higher yields cannot be obtained.

The optimal number of hives for the experimental area is between 175 and 138 and depends on the hive yield forecast.

The information generated can be useful for the beekeepers in apiary site selection and to estimate the honeybee colony carrying capacity of an area.

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# 3. ENERGY

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# 3.1. ENERGETIC AND ECONOMIC COMPARISON BETWEEN BIOGAS PLANT SUPPLIED BY VEGETABLE AND SLAUGHTER BASED SUBSTRATES

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**Keywords:** biogas production, substrate, slaughter waste

## ABSTRACT
The biogas plant feeding can play main role in economic balance during installation exploitation. It seems that waste-based substrates can increase the profitability of biogas plant contrary to typical agricultural substrates. The aim of this research was to compare the energetic and economic performance of biogas plant (class 500 kW of electric power) using two different feeding variants: Variant I with classical agricultural substrates (maize silage and pig slurry) and Variant II with different waste-based substrates from the slaughterhouse. The results show that calculated economic balance was clearly better in case of Variant II (over 210 kEUR comparing to Variant I). The profit from energies sold is almost similar, the most important role in economic balance for both analysed Variants is played by kind of substrates. That is why the guaranty of biogas plant stable economic position can be reached mainly in case of efficient and cheap biowaste usage.

## INTRODUCTION
The biogas plant feeding can play main role in economic balance during installation exploitation (Czekała 2019). Typically, the most commonly used substrate in European agricultural biogas sector is maize silage (Kozłowski *et al.*, 2019). Only in Germany, the amount of maize silage used for biogas plant feeding reaches 60 mln Mg per year. For production so large amount of silage, over 10% of agricultural surface in Germany is taken. Maize silage buying creates important costs for biogas plant owners. The average price of this material in Poland varies from 22 to 35 euro/Mg (most often it is approximatively 30 euro/Mg), however in Germany it reaches 50 euro or more in the years with bad weather conditions influencing on lower maize yield.

Typical biogas plant working in NaWaRo technology (or its clones) with 1 MW of electric power needs for feeding 20-22 thousands Mg/a of maize silage. The installations working in new, efficient technologies (like ProBioGas or Dynamic Biogas) can reduce the needs up to 16 thousands Mg/a. This means that even in new technologies the cost for buying maize silage reaches 480 thousand euro/a and up to 660 thousand euro in installations typical. This last value is over half of total yearly profit from electric energy sold (1,215 thousand euro) and strongly decrease the biogas plant rentability.

The inverse scenario can be observe in case of biogas plant feeding with biowaste usage (Christiansen *et al.*, 2018, Martí-Herrero *et al.*, 2019). Most of biowaste (especially from agro-food industry) can be receive by biogas plant with low price or even only for transport cost (Kim et Dale 2015). This fact let economize a lot of money which should be spend for silages buying in typical feeding scenario (Wandera *et al.*, 2018). The exceptional situation can be found in case of slaughter waste. This kind of waste is problematic to manage (storage, transport, utilization, strong odors emission) and needs special precautions like i.e., hygienisation or pasteurization. However, while receiving this kind of waste, biogas plant can be payed by biowaste owners which additionally increase the profitability of that substrate usage.

The research aimed to compare the energetic and economic performance of biogas plant (class 500 kW of electric power) using two different feeding variants: classical agricultural substrates like maize silage and pig slurry (Variant I) and different waste-based substrates from the slaughterhouse (Variant II). This analysis was made in the framework of preparation for Przybroda biogas plant technological run which will be held by the Institute of Biosystem Engineering team in autumn 2019.

## MATERIALS AND METHODS

Agricultural biogas plant in Przybroda experimental farm (belonging to Poznan University of Life Sciences, PULS) was initially planned as installation working with maize silage and animal excrement (Dach *et al.,* 2014). This feeding scenario is the most dominant in the whole European biogas sector. Within the decreasing of biogas plant profitability, it became important to avoid costly substrates (i.e., maize silage) and look for cheaper but also energetically efficient substrates. That is why the alternative feeding variant, based on slaughter waste, was analysed.

All analysed substrates were processed in Ecotechnologies Laboratory (EL) at Institute of Biosystems Engineering (PULS) for their biogas performance. Ecotechnologies Laboratory is the biggest Polish biogas laboratory (with over 250 different fermenters) and was the first Polish laboratory which has received the Proficiency Test Biogas certificate in the international test organized by German KTBL. The EL works using the known German methodologies DIN 38 414 / S8 and VDI 4630 (Dach *et al.,* 2016). Because of huge numbers of fermenters and close cooperation with private sector (especially agro-food industry), the EL team has collected one of the biggest European database with biogas productivities of over 2500 substrates, mainly from agronomy and food industry.

In this study, two different feeding variants were analysed:

Variant I (classic): maize silage, slurry;

Variant II (based on slaughter waste): cow slurry, category II waste, category III waste (Regulation 1069/2009), sewage sludge, fat.

The data about methane productivity of substrates used in the present analysis are from the EL own research. The costs of substrates (expressed in EUR/Mg) were received from personal investigation between the specialists from an agricultural and slaughterhouse sectors. The energetic and economic calculations are based on the procedures described in Cieślik *et al.,* (2016). It has to be underlined that in typical feeding scenarios for agricultural biogas plant, the substrates generate usually cost of buying (i.e., maize silage – 30 EUR/Mg, distillery stillage 8 EUR/Mg, sugar beet pulp 10 EUR/Mg). Only the slurry can be received for free but only in the case when the biogas plant is placed near to farm and transport can occur by an underground pipe. In all other cases, the transport by slurry tanks has to be taken into account. In contrary – the biowaste from slaughterhouse are very problematic to manage and thus it can give a profit for biogas plant (even 20 EUR/Mg). This can be an additional economic advantage for biogas installation owner. The additional profit can be also obtained because of digestate sold (Czekała *et al.,* 2020). In Poland, the average market price for digestates is approximatively 6 EUR/$m^3$.

## RESULTS

The volume of methane which guarantee the stable energy production (8500 h/year) with the electrical efficiency of CHP unit on level 42% is about 1.013-1.015 mln $m^3$. Thus, we calculate the amount of substrates, taking into account their efficiency in order to reach this value. The calculations for both Variants are presented in tables 1 and 2.

Table 1. Variant I: Classic agricultural substrates scenario for biogas plant feeding

| Substrates | Mass Mg/a | $CH_4$ yield $m^3$/Mg | $CH_4$ volume $m^3$ |
|---|---|---|---|
| Maize silage | 7700 | 125 | 962500 |
| Pig slurry | 4500 | 11.3 | 50850 |
| | | **Total $CH_4$:** | **1013350** |

Table 2. Variant II: slaughter waste substrates scenario for biogas plant feeding

| Substrates | Mass Mg/a | $CH_4$ yield $m^3$/Mg | $CH_4$ volume $m^3$ |
|---|---|---|---|
| Cow slurry | 391 | 14 | 5592 |
| Category II waste | 2086 | 400 | 834286 |
| Category III waste | 495 | 290 | 143654 |
| Sewage sludge | 339 | 26 | 8812 |
| Fat | 52 | 441 | 22995 |
| | | **Total $CH_4$:** | **1015339** |

Comparing both tables, it has to be underlined the huge difference in the methane productivity between the substrates from I$^{st}$ and II$^{nd}$ Variant. Slaughter waste, except sewage sludge, have several time higher methane productivity then maize silage, the most popular substrate for the European biogas plant. This has a consequence in much smaller mass (3363 Mg) of slaughterhouse waste needed for feeding biogas plant during whole year contrary to typical scenario (maize silage + slurry) where even 12200 Mg of materials are needed.

It has to be also added that sewage sludge from the slaughterhouse is not the urban waste and thus can be used in agricultural biogas plants. However, the slurry is also produced in a slaughterhouse by waiting animals and contrary to typical farm connected to the biogas plant – this slurry is problematic to manage and can create some additional transport costs. The energetic analysis of biogas plant working in both described Variants is presented in table 3.

Table 3. Energetic analysis of both biogas plant feeding variants

| Parameter | Variant I | Variant II | Unit |
|---|---|---|---|
| Working time of CHP | 8500 | 8500 | hours/a |
| Electric efficiency of CHP | 42 | 42 | % |
| Thermal efficiency of CHP | 48 | 48 | % |
| Electric energy production | 4242 | 4251 | MWh |
| Heat production | 17455 | 17489 | GJ |
| Electric power | 0.499 | 0.500 | MW |
| Thermal power | 0.570 | 0.572 | MW |

Because of the fact, that in both Variants the CHP units are the same (500 kW of electric power), the energies production is similar. The main differences between

Variants I and II are related with used substrates. The comparison of costs and profits for used substrates in each Variant is shown in table 4.

Table 4. Profits from substrates used for both variants of biogas plant feeding

| Substrates | Price for processed substrate EUR/Mg | Variant I kEUR | Variant II kEUR |
|---|---|---|---|
| Maize silage | -30 | -231 | 0 |
| Pig slurry | 0 | 0 | 0 |
| Cow slurry | 2 | 0 | 1 |
| Cat. II waste | 6 | 0 | 13 |
| Cat. III waste | 15 | 0 | 7 |
| Sewage sludge | 22 | 0 | 7 |
| Fat | 16 | 0 | 1 |
| | **Profit from substrates:** | **-231** | **29** |

The analysis clearly shows that typical, conventional scenario for feeding biogas plant (Variant I) generates the yearly cost of over 230 thousand euro. However, in the case of slaughter waste, the biogas plant can be paid up to 29 thousand euro per year. This parameter, together with the value of digestates sold, has the biggest influence on the total economic balance of both Variants (table 5).

Table 5. Profits from energies and digestates sold

| Energy production | Variant I | Variant II | |
|---|---|---|---|
| Electric energy price | 143 | 143 | EUR/MWh |
| Heat price | 5 | 5 | EUR/GJ |
| Electric energy profit | 607 | 609 | kEUR/a |
| Profit from heat sold | 70 | 70 | kEUR/a |
| **Total profit** | **677** | **679** | kEUR/a |
| ***Profit from digestates*** | | | |
| Mass of digestates | 11224 | 2960 | Mg/a |
| Digestate price | 6 | 6 | EUR/Mg |
| **Profit from digestate sold:** | 67 | 18 | kEUR/a |
| **Total economic balance*:** | **514** | **725** | kEUR/a |

**including substrates cost/profit*

The economic balance has clearly shown a better profit in case of Variant II (over 210 kEUR). In this analysis, 3 main groups of profits/costs were taken into account: substrates, energies and digestates. Graphical presentation of those parameters is shown in figure 1.

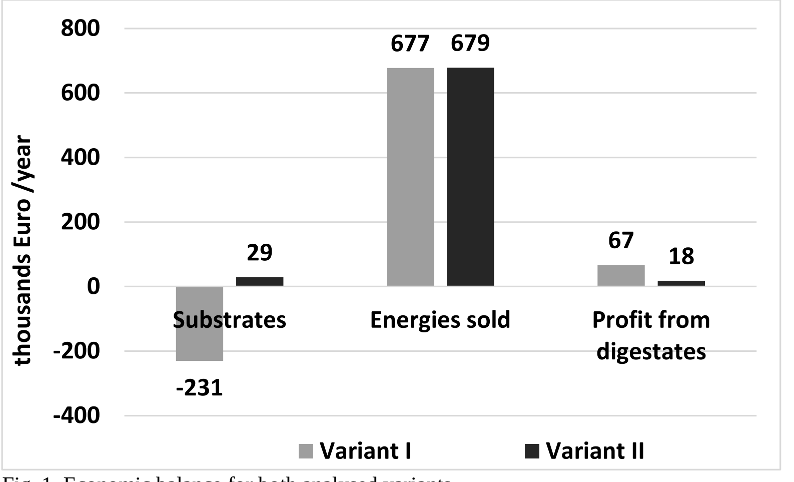

Fig. 1. Economic balance for both analysed variants

It has to be underlined that the profit from energies sold is almost similar, the most important role in economic balance for both analyzed Variants is played by kind of substrates. That is why the guaranty of biogas plant stable economic position can be reached mainly in case of efficient and cheap biowaste usage. It seems that slaughter waste is one of the best choices for the biogas plant feeding scenario because of it can offer additional money because payment from external enterprises for their biowaste processing.

## CONCLUSIONS

Based on research made in this paper, the following conclusions were formulated:

- Slaughter-based substrates have in general significantly higher methane productivity during fermentation than vegetable substrates. That is why amount of slaughter waste (in Variant II) is approximatively 3 times smaller comparing to traditional feeding using maize silage and slurry (Variant I).
- Variant I generates the yearly cost of over 230 thousand euro, mainly because of maize silage buying high cost. In contrary, the slaughter waste can create the additional profit reaching 29 thousand euro for biogas plant owner.
- The cost of maize silage buying is the main factor influencing economic balance of Variant I, which is over 210 thousand euro yearly smaller comparing to Variant II of biogas plant feeding.
- The biowaste from slaughterhouse is very good choice for the biogas plant feeding because it can offer additional profit related with biowaste processing in biogas plant.

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# 3.2. POSSIBILITIES OF USING HERBACEOUS BIOMASS FOR ENERGY PURPOSES IN THE SUSTAINABLE DEVELOPMENT CONCEPT

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**Keywords:** herbaceous biomass, sustainable development, combustion, impact on the environment

## ABSTRACT

Taking into account issues related to the ecological and economic conditions for the production of energy from biomass, research was undertaken to assess the possibility of using herbaceous biomass for energy purposes in the concept of sustainable development. During the study, pellets made of wheat straw and hay were analysed as representative raw materials for herbaceous biomass. Analysing the results, attention was drawn to increase NO emissions, which may be associated with relatively higher nitrogen content in herbaceous biomass. Therefore, the use of this biomass in power boilers brings the possibility of exceeding applicable emission standards. However, this is not a significant emission. At the same time, it was stated that it would be advisable to carry out research on the possibility of reducing NO emissions when burning herbaceous biomass in low-power heating devices. The use of this fuel should not be associated with "the consolidation of significant health threats or social injustice", which is consistent with the principles of sustainable development.

## INTRODUCTION

The concept of sustainable development is a way to ensure harmony between maximizing the efficiency and improving the condition of environment. It assumes comprehensive action based on factors conditioning the process of change, in which the exploitation of resources, investment directions and technical progress, as well as institutional changes remain in harmony, while maintaining the ability to meet current and future human needs and aspirations (Baum, 2003). Rules of this concept are widely known. However, its implementation causes many doubts. One of the manifestations is the emergence of sustainable energy concept. At the same time, it is difficult to find a broad explanation of what this concept is. It is usually equated with the use of renewable energy sources, but this approach should be considered too simplistic (Pawłowski, 2011). One of many definitions indicates that sustainable energy is not only a problem of sustainability, but also an issue of allowing the use of energy sources that cause minor damage to the environment and human health (Project definition ..., 2012). This provision is important, because in practice there is no energy source that does not cause damage to the environment, thus any theory assuming the possibility of harmless energy acquisition is utopian (Prandecki, 2014).

In the context of energy sources, the problem of building sustainable development boils down to the use of such energy sources:

- that are not significantly depleted by continued use;
- the use of which does not cause significant emissions of pollutants or other substances dangerous to the environment;
- the use of which does not involve the consolidation of significant health risks or social injustice (Boyle *et al.,* 2004).

In Poland systematically increasing demand for energy (GUS, 2018) and changing requirements for emissions from low-power power boilers (Regulation ..., 2015) also affect the change in interest in individual renewable energy sources. In Poland in 2017, the share of energy from renewable sources in gross final energy consumption decreased by 0.32% - to 10.97% compared to the previous year. Over the last decade, the share of biomass in the structure of the use of individual renewable energy sources has also decreased from over 90% to 67.9%. However, the energy of the sun and wind increased. (GUS, 2018). The raw material resources regulate the use of biomass for energy purposes. At the same time, it is desirable to increase the share of biomass utilization from agricultural rather than forest origin, thus excluding the extraction of biomass for energy purposes from areas with high biodiversity and from soils abundant in carbon (Stuczyński *et al.*, 2008).

In scientific literature, as energy crops that can be cultivated in Poland for the purpose of solid and liquid biofuels, the most commonly mentioned are: Willow, Poplar, Black locust, Thornless rose, Virginia mallow, Miscanthus, Jerusalem artichoke and Rapeseed (Igliński *et al.,* 2009). However, there are also possibilities of using waste biomass from agricultural crops, defined as herbaceous biomass for energy purposes, which includes straw, grass, residues of oilseed crops, legumes and flowers as well as fruit biomass that includes production residues from the orchard (PN-EN ISO 17225-1:2014).

Applicable requirements for emissions CO, OGC and dust from low power heating appliances, tightened in 2012 (PN-ISO 303-5:2012). The Regulation (Regulation ..., 2015) on the implementation of the Directive of the European Parliament and Council 2009/125/EC regarding eco-design requirements for solid fuel boilers, also make NOx emission standards. In addition to technical criteria (the use of appropriate heating devices), the possibilities of meeting these requirements are also associated with the type of biofuels used. In this case nitrogen content of herbaceous and fruit biomass, which is increased compared to wood, translates into higher NOx emissions and associated CO emissions. Moreover, creation of sinters and deposits that, by worsening the conditions in the combustion chamber, also affect the increased CO and NOx emissions (Nussbaumer, 2002, Obernberger, 2006), causes difficulties in using such a fuel.

Given the above issues related to the ecological and economic conditions for the production of energy from biomass, research was undertaken to assess the possibility of using herbaceous biomass for energy purposes in the aspect of sustainable development concept. During the study, pellets made of wheat straw and hay were analysed as representative raw materials for herbaceous biomass, at the same time, noting the possible differentiation of CO, NO and $SO_2$ emissions during combustion in a low-power grate boiler resulting from the different chemical composition of the fuel.

## MATERIALS AND METHODS

Wheat straw and meadow hay that were agglomerated into pellets, were selected for the tests. The biomass for their production came from agricultural holdings located in Lublin province. Representative samples of the selected 25 kg biomass were taken from the field, then ground with a H-111 hammer mill with 10 mm sieves. Pelleting was carried out in a granulator using an 8 mm matrix.

Following methods were used to determine the physical and chemical properties of these biofuels (measurements were carried out in triplicate):

- geometrical features (diameter and length) - according to PN-EN ISO 16127:2012, randomly selecting a $100^{+1}$ g fuel portion;
- moisture - weight method according to PN-EN ISO 18134-3:2016;

– density - calculated on the basis of geometrical features in the random samples and the mass of biofuel portions, using the following formula:

$$\rho_w = \frac{4 \cdot 10^6 \cdot m}{\pi \cdot d^2 \cdot l} \text{ (kg·m}^{-3}\text{)}$$

where:

$\rho_w$ – density of pellets (kg·m$^{-3}$),
$m$ – mass of fuel, pellets portions (g),
$d$ – average diameter of pellets (mm),
$l$ – sum of lengths of pellets in the fuel portion (mm).

– carbon, hydrogen, nitrogen - determination according to PN-EN ISO 16948:2015;
– sulphur - determination according to PN-EN ISO 16994:2015;
– net calorific value - after calculating the calorific value according to PN-EN ISO 18125:2017;
– ash - according to PN-EN ISO 18122:2016.

The fuel collected for testing in portions of 1 kg was burned in a grate heating device, fuelled periodically. Composition measurements, process timing and flue gas temperature were carried out continuously, i.e. from the moment of ignition initiation to the time the reaction expired, for which the flue gas temperature drop to 200 °C was assumed. This corresponded to obtaining a stabilized layer of embers constituting a suitable base for initiating the flame during the subsequent refuelling. Flue gas was taken from the chimney. The measuring probe was connected to an exhaust gas dryer, from which the exhaust gas went to the exhaust gas analyser. During tests, a portable exhaust gas analyser based on infrared sensors (NDIR) was used for the following gases: CO, $CO_2$, NO, $SO_2$ and electrochemical - $O_2$. The temperature was measured using a K-type thermocouple that was located in the exhaust gas sampling probe.
Excess air coefficient was calculated using the formula:

$$\lambda = 20{,}95/(20{,}95-O_2)$$

where:

$O_2$ – oxygen content by volume in dry gas (%).

## RESULTS

Physical and chemical properties of the pellets considered are shown in Table 1.

Table 1. Physical and chemical properties solid biofuel used.

| Parameter (mean value) | Unit | Pellets made from wheat straw | Pellets made from hay |
|---|---|---|---|
| Length | mm | 32.3 | 31.7 |
| Diameter | mm | 8.2 | 8.3 |
| Total moisture | % | 10.00 | 10.78 |
| Density | kg·m$^{-3}$ | 1130 | 1122 |
| C | % | 47.70 | 46.04 |
| H | % | 5.50 | 5.64 |
| N | % | 0.77 | 1.37 |
| S | % | 0.06 | 0.61 |
| Net calorific value in working condition | MJ·kg$^{-1}$ | 16.32 | 16.14 |
| Ash content in working condition | % | 2.31 | 6.21 |

*Source: own study*

Pellets obtained during the tests have even humidity and geometrical features, which is caused by equal conditions during their agglomeration (fragmentation, input humidity, granulator parameters). Chemical features of the obtained pellets resulting from the diversity of raw materials in this case constitute a factor that may affect the course of their combustion process. The recorded parameters of pellet combustion process are shown in Table 2. The combustion tests of fuels selected for testing were conducted under comparable conditions when fed with an air stream from below under the grate, with an average speed of 1 $m \cdot s^{-1}$. During tests, the combustion speed for pellets from wheat straw was 4.43 $kg \cdot h^{-1}$, while for hay pellets, the value of this parameter was slightly lower, amounting to 3.96 $kg \cdot h^{-1}$. These trends are also visible in the value of the excess air coefficient (lambda). For wheat straw pellets, the excess air average was 8, while for hay test biofuel 7. The lower process dynamics observed for hay pellets is also reflected in the flue gas temperature indications, which for wheat straw biofuel was on average 309 °C, while for hay 247 °C (Table 2).

Table 2. Parameters of the combustion process.

| Shape of fuels | Statistical function | Air speed ($m \cdot s^{-1}$) | Combustion speed ($kg \cdot h^{-1}$) | Excess air coefficient (-) | Flue gas temperature (°C) |
|---|---|---|---|---|---|
| Pellets made from wheat straw | Minimum | 0.9 | 4.23 | 0 | 54 |
| | Maximum | 1.1 | 4.63 | 44 | 597 |
| | Mean | 1 | 4.43 | 8 | 309 |
| Pellets made from hay | Minimum | 0.9 | 3.81 | 0 | 52 |
| | Maximum | 1.1 | 4.11 | 70 | 396 |
| | Mean | 1 | 3.96 | 7 | 247 |

*Source: own study*

The CO, NO, $SO_2$ emission factors from the combustion of selected pellets are presented in Table 3.

Table 3. Emission of CO, NO, $SO_2$ during combustion of pellets.

| Parameter | Unit | Pellets made from wheat straw | | | Pellets made from hay | | |
|---|---|---|---|---|---|---|---|
| | | Minimum | Maximum | Mean | Minimum | Maximum | Mean |
| CO | ppm | 0 | 5620 | 1631 | 0 | 4870 | 2661 |
| | $g \cdot m^{-3}$ at 10% $O_2$ | 0 | 57.27 | 11.08 | 0 | 68.87 | 14.20 |
| | $g \cdot GJ^{-1}$ | 0 | 24962 | 5874 | 0 | 23123 | 5813 |
| NO | ppm | 0 | 344 | 132 | 0 | 307 | 161 |
| | $g \cdot m^{-3}$ at 10% $O_2$ | 0 | 2.42 | 0.34 | 0 | 2.49 | 0.51 |
| | $g \cdot GJ^{-1}$ | 0 | 1702 | 203 | 0 | 1330 | 244 |
| $SO_2$ | ppm | 0 | 142 | 30 | 0 | 83 | 26 |
| | $g \cdot m^{-3}$ at 10% $O_2$ | 0 | 2.33 | 0.23 | 0 | 1.62 | 0.34 |
| | $g \cdot GJ^{-1}$ | 0 | 1024 | 121 | 0 | 583 | 135 |

*Source: own study*

The study revealed that during combustion of pellets in question, the highest CO emissions were achieved during the initial combustion phase, during which the emission factors exceeded combustion standards. During the actual combustion period, there was a significant reduction in CO emissions, with the average value for pellets from wheat straw being smaller, 11.08 $g \cdot m^{-3}$ at 10% $O_2$, than for hay pellets - 14.20 $g \cdot m^{-3}$ at 10% $O_2$. During the tests, an increase in NO emission to the atmosphere was also observed, with a value of about 0.51 $g \cdot m^{-3}$ at 10% $O_2$ for pellets made of hay, while for wheat straw pellets, this emission was 0.34 $g \cdot m^{-3}$ at 10% $O_2$. Similar trend of increased emissions for hay pellets was also observed when analysing $SO_2$ emission factors. In this case, however, the values were less varied, because for wheat straw pellets, the emission was 0.23 $g \cdot m^{-3}$ at 10% $O_2$, while for hay pellets it was 0.34 $g \cdot m^{-3}$ at 10% $O_2$ (Table 3).

## DISCUSSION

A review of the literature as well as research results indicate that used biomass is an interesting and valuable energy resource. Points to it net calorific value with an average value of 16.32 and 16.14 $MJ \cdot kg^{-1}$, which is slightly smaller than wood pellets (Demirbas, 2004, Szyszlak-Bargłowicz *et al.*, 2006, Szyszlak-Bargłowicz *et al.*, 2017). During the study, increased emissions were observed when burning biofuels from meadow hay, which is a representative raw material for the herbaceous biomass group. Other researchers also point to emission problems associated with higher nitrogen content in some biofuel species (Demirbas, 2004, Obernberger, 2006). Nussbaumer (2002) even reports that problems with excessive NOx emissions appear with a nitrogen weight ratio of 0.6% and this applies in particular to cereal straw, grass and fruit residues. Often, increased NO emissions are also accompanied by CO emissions, however, during our own research, increased CO in exhaust gas resulted from the nature of the heating device. The obtained values and relations between the emission and chemical properties of fuels were comparable with data presented by other researchers (Juszczak, 2014, Szyszlak-Bargłowicz *et al.*, 2006, Szyszlak-Bargłowicz *et al.*, 2017).

In terms of meeting the assumptions of sustainable development concept developed by Boyle *et al.*, (2004), herbaceous biomass, due to the widespread occurrence and in the majority of having the status of waste biomass during its use, falls under the criterion of “not depleting the natural environment”. However, the use of this biomass in power boilers in the scope of NO emissions brings the possibility of exceeding the implemented emission standards. However, this is not a significant emission. The legislator in the Regulation ... (2015) also draws attention to this by excluding from the power of this regulation boilers fed with non-wood biomass, however, reserving the possibility of changing this provision after reconsidering their impact on the environment.

## CONCLUSIONS

A characteristic feature of biomass is not only the variability of its physical and chemical characteristics due to the type of species, but also difference in these characteristics that can also occur within one species. Fuel standardization is able to normalize, above all, moisture content and geometric features. However, to a small extent, and usually not at all, it affects the chemical composition of the fuel. In the aspect of assessing the possibility of using herbaceous biomass for energy purposes in the aspect of sustainable development concept during research, attention was drawn to increase NO emissions, which may be associated with relatively higher content of nitrogen in herbaceous biomass. Hence, it would be advisable to conduct research on the possibility of reducing the NO emissions when burning herbaceous biomass in low-power heating devices so that the use of this biofuel does not involve the consolidation of significant health threats or social injustice, which is consistent with the principles of sustainable development.

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# 3.3. SELECTED PHYSICAL AND MECHANICAL PROPERTIES OF PELLETS MADE FROM THE MIXTURE OF PEAT AND BARK BEECH

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**Keywords:** biomass, mechanical durability, pellet, quality assessment

## ABSTRACT
The work presents the assessment of the number of pellets with fissures, length, diameter, fine material amount and mechanical durability of pellets depending on the composition, moisture content of the raw material (11 and 19%) and sieve diameter in the beater mill (3 mm and 5 mm) for fragmentation material for the pelleting process. Pellet samples used in the tests were produced on a pelleting line with a capacity of 250 kg·h$^{-1}$, a granulator equipped with a flat matrix of 8 mm-diameter openings. The raw material used to produce pellets was a mixture of peat and beech bark in a 1:1 (m:m) ratio. The bulk density of the pellets was calculated in accordance with EN 15103:2009 standard. The moisture content of the tested samples was carried out in accordance with EN 14774-3:2009 standard. Holmen Ligno-Tester was used to measure the mechanical durability of pellets. Calculations of mechanical durability of pellets were made in accordance with the assumptions of EN 15210:2009 standard. The mechanical durability of pellets made from a mixture of peat and bark beech, stored at 20°C and a sieve with a diameter of 3 mm used in the beater mill was 90.3% at the moisture content of material 11%, while for material moisture 19% was 88.5%. When used in a beater mill a sieve with a diameter of 3 mm the mechanical durability was 90.9% for moisture content of material of 11% and 92.0% for material with moisture content of 19%. The average bulk density of the pelletized mixtures ranged from 610.5 to 711.8 kg·m$^{-3}$.

## INTRODUCTION

Renewable fuels obtained from biomass during combustion emit less amounts of greenhouse gases into the atmosphere than fuels such as natural gas and crude oil. Thus, they contributing to inhibiting the greenhouse effect (Lewandowski and Klugman-Radziemska, 2017; Maj *et al*., 2019). Nevertheless, the raw plant biomass is characterized by low density, which hinders its transport, storage and alloying in practice (Niedziółka and Szpryngiel, 2014; Azargohar *et al*., 2019). Therefore, there is a need to agglomerate plant biomass. The highest bulk density is characterized by pellets. Pellet production is based on three processes (Maj and Kuranc, 2014): drying, milling and pressing. The pellet is in the form of a cylinder with a diameter of 4 to 10 mm and its length is 20 to 50 mm. The most common are pellets with a diameter of 8 and 6 mm (Niedziółka and Szpryngiel 2012). Biomass intended for agglomeration should be characterized by optimal fragmentation, as the material should fill as much as possible of empty inter-grain spaces (Niedziółka and Szpryngiel 2012). The optimum moisture content for agglomeration should be 12-14%, which usually requires drying the raw material before the process. The compacting material should be free of mechanical, mineral and chemical impurities, which are undesirable in the pelleting process, as they reduce the quality of the obtained product and negatively affect the production line (Castellano 2015; Mostafa *et al.* 2019).

Important from the perspective of the final recipient is the quality of the produced pellets, which determines the energy properties, including the pollutants or ash content (Williams *et al*. 2018; Djatkov 2018). Standards are used to classify pellets according to the qualitative assessment of physical and mechanical parameters. The standards contain ranges of parameters for which the obtained granulate can be qualitatively assessed, i.e. whether it meets certain parameters. Standards divide pellets into quality classes based on the parameters characterizing a given product (Stasiak *et al.* 2017).

There are many national standards on the European Union market, i.e. German DIN *Plus, Austrian ÖNORM M 7135 or Swedish SS 187120. Since 2011, the EU pellet* quality standard EN-14961 has been in force, classifying pellets in terms of three different groups of manufacturing materials.

The aim of the study was to assess the pellets quality made of beech bark and peat in the form of: length and diameter of the obtained pellet, number of transverse, longitudinal and mixed cracks, fine material amount and mechanical durability.

## MATERIAL AND METHODS

The tests were carried out for pellets, which were made of peat and beech bark in a ratio of 1:1/m:m. Samples of pellets used in the tests were produced on a pelletizing line with a capacity of 250 kg/h with a granulator equipped with a flat matrix with thickening channels with a diameter of 6 mm. The pellet production line consisted of the following elements: beater shredder, cyclone, screw conveyor, conditioner and pelletiser.

Each batch of pellets was divided into two samples, which independent tests of the impact of moisture content (11 and 19%) and chaff length (3 mm and 5 mm) on mechanical durability were carried out for. The following pellet parameters were measured: number of pellets with cracks, length, diameter, fine material amount and mechanical durability. Samples of pellets were determined taking into account their chaff length and material moisture as follows:

1. PC3M11 - pellets - chaff length 3 mm, material moisture 11%,
2. PC3M19 - pellets - chaff length 3 mm, material moisture 19%,
3. PC5M11 - pellets - chaff length 5 mm, material moisture 11%,
4. PC5M19 - pellets - chaff length 5 mm, material moisture 19%.

The moisture content of the tested samples (M) was made in accordance with EN 14774-3: 2009 and calculated according to the formula (1):

$$M = (m_2 - m_3)/(m_2 - m_1) \tag{1}$$

where: M - moisture content (%), $m_1$ - empty pot weight (g), $m_2$ - pot weight with sample before drying (g), $m_3$ - pot weight with sample after drying (g).

The bulk density of pellets ($BD_{ar}$) was calculated according to the formula (2) specified by the EN 15103: 2009 standard. The tests were carried out using a vessel with a volume of 0.001 $m^3$.

$$BD_{ar} = (m_2 - m_1)/V \tag{2}$$

where: BDar – bulk density ($kg \cdot m^{-3}$), $m_2$ - sample vessel weight (kg), $m_1$ - empty vessel weight (kg), V - vessel volume ($m^3$).

Holmen ligno-tester was used to measure the amount fine material (F). First, a pellet sample of approx. 1.2 kg (+/- 50 g) was taken, and then four samples, 300 g each were prepared. Samples were placed in the tester's chamber (covered with a filter) which they were fluctuated into the stream air for 30 s in. After stopping the tester, the filter with the dusty part was removed, and the remaining sample (clean) after the test from the tester chamber was weighed. Calculations of pellet fine parts were made according to the formulas (3-4):

$$F_a = mE - mA \tag{3}$$

where: Fa- weight of fines (g), mE – weight of pellets before the test (g), mA – weight of pellets after the test (g).

$$F = (F_a/mE) \times 100 \quad (4)$$

where: F – fine material amount.

The mechanical durability of the pellets (DU) was made using a ligno-tester by the Holman method. The test material was prepared based on the EN 15210-1 standard. A 100 g sample of pellets was placed in the tester's chamber, which was introduced into the air stream and, circulating in it, hit the perforated walls of the tester's chamber. After 60 seconds, the sieve residue was weighed and the kinetic durability of the granulate was calculated (Obidziński, 2014). The mechanical durability according to Holman is defined as the ratio of the mass of the sample after the test to the mass of the sample before the test according to equation 5:

$$DU = (mA/mE) \times 100 \quad (5)$$

where: DU – mechanical durability (%), mA - weight of pellets after the test (g), mE - weight of pellets before the test (g)

The diameter and length of the pellets were measured in accordance with EN 16127: 2012 using a calliper with a measurement accuracy of up to 0.01 mm. 10 randomly selected pellets from a 100 g sample were measured. The number of pellets with longitudinal, transverse and mixed cracks (longitudinal and transverse) was also determined. The study consisted of randomly selecting 100 pellets from a 500 g sample. Then, from the selected sample, pellets with visible cracks were selected and divided into three groups, depending on the type of crack. Based on the number of damaged pellets, their percentage share in a given sample was determined.

Statistical analysis was performed using the Statistica 13.1 program. For the parameters tested their compliance with the normal distribution was checked. Decomposition tests were carried out with the Shapiro-Wilk test. The critical level of significance was assumed for p-value = 0.05. The effect of the material on individual features was determined by performing a one-way ANOVA variance analysis. The influence of individual parameters, i.e. the moisture content and chaff length separately and the interaction of this parameters on the examined features were analysed. The significance of differences in individual groups was determined by the Tukey test.

## RESULTS

Table 1 shows the percentage of pellets with cracks depending on the type of pellet.

Table 1. The results of the number and type of cracks depending on the moisture content and length of the chaff of pellets

| Parameter | The number of pellets with cracks depending on the moisture content and chaff length (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| Crack type | transverse | | longitudinal | | mixed | | total |
| | (pcs.) | F-test | (pcs.) | F-test | (pcs.) | F-test | (pcs.) |
| PC3M11±$S_x$ | 16±0.57b | 52.38* | 3±0.95a | 41.70* | 4±1.53a | 152.95* | 31 |
| PC3M19±$S_x$ | 8±1.00a | | 2±0.58a | | 11±0.58b | | 21 |
| PC5M11±$S_x$ | 6±1.53a | | 8±1.00b | | 7±0.58a | | 21 |
| PC5M19±$S_x$ | 8±1.00a | | 9±0.78b | | 25±1.96c | | 42 |

Sx - standard deviation; * - Significant value of the F test at significance level α = 0.05; different letters horizontal indicate significance differences at p<0.05 according to Tukey’s; F - F test

Based on the observations of the samples, it should be stated that the smallest percentage of pellets with cracks was obtained for pellets PC3M19 and PC5M11. While the highest for PCD5M19. In contrast, PD5W19 pellets were characterized by twice the number of pellets with 42% cracks. Statistical analysis showed the impact of the type of material on the number of cracks obtained for all tested objects. In addition, the effect of moisture content on the obtained pellet length at 3 mm chaff length (p-value = 0.032) was demonstrated.

The obtained results of pellet diameter measurements are presented in table 2.

Table 2. The results of the diameter measurements of the tested pellets (mm)

| Material | Diameter of pellets | | | F | p-value |
|---|---|---|---|---|---|
| | min. | Mean ± $S_x$ | max. | 5.592 | 0.003 |
| PC3M11 | 6.10 | 6.16±0.051a | 6.24 | | |
| PC3M19 | 5.99 | 6.10±0.08ab | 6.26 | | |
| PC5M11 | 6.12 | 6.23±0.09b | 6.37 | | |
| PC5M19 | 6.10 | 6.26±0.13b | 6.49 | | |

Sx - standard deviation; * - Significant value of the F test at significance level α = 0.05; different letters horizontal indicate significance differences at p<0.05 according to Tukey's; F - F test

The smallest average diameter was found for PC3M19 pellets, while the largest mean diameter of pellets was observed for PC5M19. The statistical analysis carried out confirmed statistically significant differences in the values of average pellet diameters depending on the type of material. In addition, statistical analysis showed that the chaff length affects the pellet diameter at 19% humidity (p-value = 0.005).

Table 3 summarizes the results of length measurements of the tested pellets.

Table 3. The results of measuring the length of the tested pellets (mm)

| Material | The length of the pellets | | | F | p-value |
|---|---|---|---|---|---|
| | min. | Mean ± $S_x$ | max. | 3.787 | 0.019 |
| PC3M11 | 14.95 | 23.22±5.02a | 30.79 | | |
| PC3M19 | 25.22 | 27.03±1.29ab | 29.62 | | |
| PC5M11 | 14.76 | 21.75±4.15ab | 27.93 | | |
| PC5M19 | 19.06 | 25.226±3.47b | 29.70 | | |

Sx - standard deviation; * - Significant value of the F test at significance level α = 0.05; different letters horizontal indicate significance differences at p<0.05 according to Tukey's; F - F test

The smallest average value of length was found for PC5M11 pellets at a moisture content of 11% and a diameter of 5 mm, while the highest average value of pellet length was observed for pellets PC3M19 and they were 20% longer than the shortest. The statistical analysis carried out confirmed statistically significant differences in average pellet length values depending on the pellet diameter and material moisture. In addition, statistical analysis showed the effect of moisture content on the length of pellets obtained at 11% moisture (p-value = 0.032).

The results of the fine material amount from the tested pellets are presented in table 4.

Table 4. The fine material amount (%)

| Material | Fine material amount | | | F | p-value |
|---|---|---|---|---|---|
| | min. | Mean ± $S_x$ | max. | 11.60* | 0.002 |
| PC3M11 | 0.3 | 0.6±0.36a | 1 | | |
| PC3M19 | 0.8 | 1.3±0.39ac | 1.7 | | |
| PC5M11 | 1.8 | 1.85±0.07bc | 1.9 | | |
| PC5M19 | 0.7 | 0.77±0.12b | 0.9 | | |

Sx - standard deviation; * - Significant value of the F test at significance level α = 0.05; different letters horizontal indicate significance differences at p<0.05 according to Tukey's; F - F test

The smallest average value of the fine material amount was found for PC3M11 pellets with a material moisture content of 11% and a diameter of 3 mm pellets, while the highest average value of fine material amount in pellets was observed for PC5M11 pellets and generated 67% more fine material amount than PC3M11. The statistical analysis carried out confirmed statistically significant differences in the average fine material amount for all tested pellets depending on the pellet diameter and material moisture. Statistical analysis also showed the impact of 19% moisture (p-value = 0.001) and 3 mm chaff length (p-value = 0.004) on the fine material amount obtained.

Table 5 shows the results of mechanical strength for the tested objects.

Table 5. Mechanical durability of pellets depending on the moisture content and length of the chaff of pellets (%)

| Material | Mechanical durability (DU) of the pellets | | | F | p-value |
|---|---|---|---|---|---|
| | min. | Mean ± $S_x$ | max. | 1.95 | 0.14 |
| PC3M11 | 86.87 | 90.30±1.36 | 92.02 | | |
| PC3M19 | 89.72 | 91.26±0.84 | 92.54 | | |
| PC5M11 | 86.37 | 89.90±1.93 | 91.96 | | |
| PC5M19 | 89.22 | 90.92±1.04 | 92.12 | | |

Sx - standard deviation

The lowest average value of mechanical durability was found for PC5M11 pellets at 11% moisture and diameter 5 mm, while the highest average value for mechanical durability was observed for PC3M19 pellets and they showed only 0.5% higher durability. The statistical analysis did not confirm statistically significant differences in average values for the mechanical durability of the pellets depending on the diameter of the pellets and material moisture.

## CONCLUSIONS

Based on the research carried out in the work, the following conclusions were made:

1. It was found that the material from which the pellets are made has an impact on the sum of all types of cracks. The highest total number of cracks was recorded for the material with chaff length 5 mm and moisture content 19%, while the lowest for PC3M19 and PC5M11.

2. The highest average value of pellet length (27.03 mm) was found for pellets made of a mixture of beech bark and peat with a chaff length of 3 mm and moisture of 19%. Statistical analysis showed a significant impact between the material of manufacture and length.

3. The highest content of the fine material amount (1.85%) was characteristic for pellets made of a mixture of beech bark and peat with a chaff length of 5 mm and 11% moisture content.

4. The highest mechanical durability was characterized by PC3M19 pellets (91.26%). Statistical analysis did not show any significant relationship between the material used for pellet production and its mechanical durability.

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# 3.4. WASTE CO-SUBSTRATES AND SEWAGE SLUDGE AS BIOMASS FOR BIOGAS PLANTS

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**Keywords:** sewage sludge, biogas plants, co-substrate, agri-food waste, biomass

## ABSTRACT

The circular economy is one of the most important environmental and economic aspects in the world. That is why synergistic solutions are sought, thanks to which agri-food waste and sewage sludge could be processed effectively. Based on the analyses carried out, the sewage sludge generated in treatment plants does not fully secure its own energy needs. Therefore, it is often necessary to supplement the load with co-substrates in the form of biodegradable waste that can be obtained from a given region. This combination of waste streams gives, apart from utilization, also a significant increase in biogas efficiency, which directly affects the energy balance of the biogas plant.

As part of the work, an analysis was made of the use of sewage sludge and various biodegradable substrates for energy purposes.

## INTRODUCTION

At present, the environmental situation is significantly worse due to the increased anthropogenic load exceeding the biosphere's ability to support the self-regeneration process. The crisis is a consequence of the practice of consumer behaviour in relation to the natural environment. As stated by Kiselev *et al*. (2019) during their evolution and diversification, industrial economies almost did not go beyond one basic feature established in the early days of industrialization: a linear model of resource consumption in line with the "take, use, throw away" pattern. The direct and easily overlooked consequence of the growing amount of waste around the world is the particularly increasing amount of municipal sewage sludge, according to Oladejo *at al*.(2019), caused by the rapidly growing population growth and urbanization, this is also confirmed by analyses carried out by e.g. Smoliński *et al*. (2019). Unfortunately, the diversity of wastewater types, their origin and the production / treatment process leads to differences in sludge properties. In addition, the additional resources, energy consumption and costs associated with the processing and proper disposal of this waste have led to an increase in dumping, particularly on developing continents such as Africa and Asia as pointed out by Smoliński *et al*. (2019) and Oladejo at al. (2019) - for example, around 85% of sludge produced in China is currently improperly discharged into water bodies.

According to Millar et al. (2019) and Czekała *et al*. (2020) in the past few decades, the circular economy has been increasingly advertised as an economic model that can replace the current “linear” economy while addressing environmental deterioration, social justice and long-term economic growth, with a clear suggestion that it can serve as a tool for sustainable development.

One of the effective methods aimed at stabilizing organic matter (destroying pathogens, eliminating odours and reducing volatile components) contained in sewage sludge is methane fermentation, which is confirmed by many authors, research teams such as: Rabi *et al*. (2019), Smurzyńska et. al. (2018) and Pilarska *et. al*. (2014) wrote about it. Biogas produced from sewage treatment plants is an ecological concept and is a universal material that transforms the safe use of sewage sludge into another valuable product that can be used instead of fossil fuels. After anaerobic digestion process, sludge can be used as a fertilizer and additionally included in energy recovery by the possibility of using the produced biogas from the fermentation chamber. As described by Caruso *et al*. (2019) methane fermentation is a biological process conversion of organic compounds into biogas through the use of microorganisms. The use of naturally occurring microorganisms for biodegradation involves several biochemical stages, including hydrolysis, acidogenesis (fermentation), acetogenesis and methanogenesis. Subsequent processes lead to a reduction in the volume and mass of sludge, and as the final product biogas is produced. The first stage is hydrolysis, which involves the transformation of organic substances into simple sugars, fatty acids and amino acids. In turn, during acidogenesis and acetogenesis they produce from the hydrolysis products: acetates, carbon dioxide and hydrogen. From them, as a result of methanogenesis, methane is formed.

The potential for using energy from sewage sludge fermentation, however, accounts for about 50% of the energy (mainly electric) consumed in sewage treatment facilities, as confirmed by the research Oladejo *et al*. (2019), Mills *et al*. (2014), Xu *et al*. (2014) and Appels (2008). The rest of the energy needed can be supplied from other sources or an additional source of readily available organic matter should be used. Therefore, why synergistic solutions are sought, thanks to which agri-food waste and sewage sludge could be processed effectively.

Agri sources that are most often used in fermentation processes include mainly: livestock manure or fruits and vegetables waste. Animal manure is a mixture of faeces (faeces and urine) and other materials that end up in farming, including sand, cleaning water, straw and other bedding material. As a substrate used in fermentation processes, it should meet various requirements in terms of suitability, digestibility and lack of inhibitors and other contamination as described by Czekała (2018). The energy value of animal manure in biogas production depends on many factors, including: the levels of total solids (TS) and volatile solids (VS), pH and the ratio of carbon to nitrogen (C/N). The dry matter content is one of the most important parameters when choosing the size and capacity of biogas chambers. As the authors Caruso *et al*. (2019) argued, too diluted animal manure reduces the profitability of investments, while too high dry matter content, especially above 15% often causes operational problems. Also the concentration of the substrate is an important operational factor affecting stability and methane efficiency of manure. The final efficiency of methane from manure, in addition to process parameters, can also be influenced by: animal diet, animal species, their intestinal microorganisms and the amount and type of bedding material as well as storage conditions before adding to the fermentation chamber.

Food waste comes from both the processing (agri-food industry) and distribution as well as from final consumption according to Czekała (2017). As demonstrated Caruso et al. (2019) less than 20% of FVW is consumed by fermentation and the remainder is discarded or used as animal feed or burned with negative effects such as odours, air, water and soil pollution. As the scientists argue the C/N ratio in the aforementioned substrates is often about 20; therefore, an additional nitrogen source should be used to obtain an elevated substrate pH, higher biogas yield at 50% methane content, and 80% VS removal. This is why the combination of sewage sludge, with a low C: N ratio often below 10, creates favourable conditions for efficient fermentation processes.

Agri-food waste, as well as the organic fraction of sewage sludge, have been investigated as potential co-substrates for anaerobic digestion at small wastewater plant in the Wielkopolska region.

## MATERIALS AND METHODS

The regional biogas installation at the wastewater treatment plant near Poznań was analysed for the use of co-substrates to increase electricity production. The amount of energy generated at the biogas installation was to meet the requirements for the plant to be energy independent. To this end, it was possible to import agro waste only from a given region for economic and legal reasons.

An important assumption was to avoid expensive substrates and that they had a high C:N ratio. The mono-substrate and agri-food variant was considered.

The analysed substrates were either tested in the Ecotechnology Laboratory at the Institute of Biosystems Engineering of Poznań University of Life Sciences (PULS) in terms of their biogas efficiency and physicochemical parameters. Analyzes at PULS were performed in accordance with German methodology DIN 38 414/S8 and VDI 4630.

The biogas plant is to be equipped with a cogeneration unit (it will produce electricity and heat), its planned size is to have an electric power of 250 kW (ca. 0.55 million $m^3$ of methane per year, 0,85 million $m^3$ of biogas). On this basis, the amounts of additional substrates added to the sludge were selected to achieve the assumed production volume.

Substrate prices (expressed in EUR/Mg) come from local suppliers. Economic and energy calculations are in accordance with the procedure described by Cieślik *et al.* (2016).

## RESULTS

It was assumed that energy production will be using modern technological solutions, i.e.: energy production - 8450 h/year, efficiency of cogeneration: electric at 42% and thermal 45%.

With these assumptions, the amount of additional agri-food substrates was calculated. The list of calculations is presented in tables 1 and 2.

When comparing methane production from both of the above tables, it can be seen that an increase of almost five times of the efficiency required about 250 Mg/a vegetable waste, 650 Mg/a potato pulp and 900 Mg/a of sweet waste from jam and co-production. These are significant quantities and can only be achieved with an additional charge related to transport, which will be presented later.

These are significant quantities and can only be achieved with an additional charge related to transport, which will be presented later. Sweet waste from jam and co-production turned out to be the most efficient in terms of biogas production, but their sources came from several sources several dozen kilometres away from the treatment plant.

Table 1. Substrate - only sewage sludge, with no added substrate

| | Fresh mass (FM) | $CH_4$ yield (of FM) | $CH_4$ volume, (of FM) |
|---|---|---|---|
| Substrates | Mg/a | $m^3$/Mg | $m^3$ |
| Sewage sludge | 4300 | 23 | 98900 |
| | | **Total $CH_4$:** | 98900 |

Table 2. Substrate - sewage sludge + added regional substrate

| | Fresh mass (FM) | $CH_4$ yield of FM) | $CH_4$ volume, (of FM) |
|---|---|---|---|
| Substrates | Mg/a | $m^3$/Mg | $m^3$ |
| Sewage sludge | 4300 | 23 | 98900 |
| Vegetable waste | 250 | 40.5 | 10125 |
| Potato pulp | 650 | 228 | 148200 |
| Sweet waste from jam and co-production | 900 | 320 | 288000 |
| | | **Total $CH_4$:** | **545225** |

Calculation indicators and energy analysis for examined cases are presented in table 3.

Table 3. Indicators and energy analysis for examined cases

| Parameter | only sewage sludge | sewage sludge + added regional substrate | Unit |
|---|---|---|---|
| Working time of CHP | 8450 | 8450 | hours/a |
| Electric efficiency of CHP | 42 | 42 | % |
| Thermal efficiency of CHP | 45 | 45 | % |
| Electric energy production | 381 | 2100 | MWh |
| Heat production | 1322 | 7290 | GJ |
| Electric power | 0,045 | 0,25 | MW |
| Thermal power | 0,048 | 0,27 | MW |

Obviously, the production of electricity and heat is over 5 times higher when using co-substrates. However, significant differences can be seen by analysing the profits of both tested cases - table 4 and 5.

Table 4. Profit of substrates

| | Price for analysed substrate | sewage sludge + added regional substrate |
|---|---|---|
| Substrates | EUR/Mg | kEUR |
| Vegetable waste | 48 | 12 |
| Potato pulp | 0 | 0 |
| Sweet waste from jam and co-production | 40 | 36 |
| | **Profit from substrates:** | **48** |

The transport costs of sweet waste from jam and co-production amount to about 20% of the price for collecting waste. A wastewater treatment plant can earn on receiving waste. During the year, it may reach approx. 48,000 euro.

The final analyses carried out indicate that the benefit of energy production if using co-substrates is about 4.4 times greater than when using only the sludge. However, during the year it is about 279 thousand euro.

Table 5. Profits from energies and digestates sold

| Energy production | only sewage sludge | sewage sludge + added regional substrate | Unit |
|---|---|---|---|
| Electric energy price | 143 | 143 | EUR/MWh |
| Heat price | 5 | 5 | EUR/GJ |
| Electric energy profit | 54.5 | 300.3 | kEUR/a |
| Profit from heat sold | 6,6 | 36.4 | kEUR/a |
| **Total profit** | 61.1 | 336.7 | kEUR/a |
| Mass of digestates | 3960 | 4580 | Mg/a |
| Digestate price | 5 | 5 | EUR/Mg |
| **Profit from digestate sold:** | 19.8 | 22.9 | kEUR/a |
| **Profit from substrates collection:** | 0 | 48 | kEUR/a |
| **Total economic balance:** | 80.9 | 359,6 | kEUR/a |

The cost of a biogas installation with a cogeneration unit is about 1.5 million euros. It should also be remembered that fermentation tanks must be kept at a constant temperature of approx. 40-42$^{o}$C throughout the year, hence it is necessary to ensure heat supply for heating the tanks, especially in winter. The thermal power needed to heat the fermenters is about 80 kWt.

When analysing Simple rate of return in a perspective of 15 years, it is 3.6; this means that the investment could pay back in less than 4 years. Of course, this is a very simplification - a simple rate of return, like the payback period, does not include the time value of money, i.e. the discount of future cash flows, in its calculations.

## CONCLUSIONS

The circular economy is one of the most important environmental and economic aspects in the world. That is why synergistic solutions are sought, thanks to which agri-food waste and sewage sludge could be processed effectively. High amounts of sewage sludge and fruit and vegetables wastes are produced daily worldwide, and the effective disposal of such highly biodegradable waste is a challenge.

The production of electricity from sewage sludge together with agro waste is effective and environmentally friendly. Unfortunately, the process of biogas combustion in cogeneration is often accompanied by the production of significant amounts of heat, for which there is no demand at the sewage treatment plant. The heat generated can be used for technological purposes, central heating and hot water, but often there is still excess water that needs to be discharged (using electricity) directly into the atmosphere. Fruit and vegetable waste (FVW) is characterized by a high moisture content and biodegradable organic compounds with good potential as a fermentation substrate, and finally digestate is obtained, which can be further used as an organic fertilizer or soil improver. Unfortunately, this is not always possible due to the content of heavy metals in sewage sludge and other contamination.

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# 3.5. ENERGETIC VALUE OF CORN COBS

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**Kaywords:** corn cobs, energetic value, combustion, harvesting corn cobs

## ABSTRACT

During the past decade, biomass thermochemical conversion has attracted global attention as an environmentally - and economically - attractive alternative energy generation route to replace fossil fuels as much is possible. To thermal conversion the good energetic material is corn stover. Crops residues after corn grain harvest make 47-50% the yield dray matter of whole corn plants. For this reason Institute of Biosystems Engineering in Poznan University of Life Sciences realize the project "Research and development work on prototype technology for harvesting and processing corn cob cores for energy purposes".

The aim of this paper presents the physical properties, chemical composition, high heat value and calorific value of corn cobs. The analyses show that the corn cobs had high content of coal, hydrogen and cellulose. High heat value of corn cobs was 18.9 MJ/kg.

## INTRODUCTION

During the past decade, biomass thermochemical conversion has attracted global attention as an environmentally - and economically - attractive alternative energy generation route to replace fossil fuels as much as possible (Hosseinpour *et al*. 2017, Kraszkiewicz *et al*. 2015). However, it should be noted that being overzealous about largescale biomass production as a source of heat and power can lead to food shortages and cause massive deforestation (Aghbashlo *et al.* 2016). To address this predicament, many countries have heavily promoted the use of alternative fuel sources such as agricultural wastes as biomass fuel to generate heat and electricity (Chun-Yang 2011). Biomass, is the fourth largest energy resource in the world (Mekhilef *et al*. 2011).

The good energetic material to thermal conversion is corn stover. The world production of corn grain growth up in the last decade by 40%. Nowadays, the global corn grain production is greater than 1100 million tons. In 2017 in Poland produced more than 3.2 million tons of corn grain (CSO 2018) and the level of production increasing year to year. Crops residues after corn grain harvest make 47-50% the yield dray matter of whole corn plants (Sokhansanj *et al*. 2010). Corn stover consists of all the above-ground, non-grain fractions of the plant including the stalk, leaf, cob and husk (Shinners *et al*. 2009). There are 0.15 kg of cobs, 0.22 kg of leaves, 0.14 kg husks and 0.5 kg stalks per 1 kg of dry matter corn grains produced (Sokhansanj *et al*. 2010).

For this reason Institute of Biosystems Engineering in Poznan University of Life Sciences realize the research project "Research and development work on prototype technology for harvesting and processing corn cob cores for energy purposes" No. POIR.04.01.04-00-0018/18 financed by The National Centre for Research and Development within the Action 4.1 “Scientific research and development”, Sub-measure 4.1.4 “Application projects” Smart Growth Operational Programme 2014-2020, co-financed from the European Regional Development Fund. The aim of the project is to develop an innovative technology of harvesting and drying corn cob cores designed as an alternative fuel for the needs of the professional power industry and as so-called grill settlement, i.e. alternative grill fuel.

The aim of this paper presents the physical properties, chemical composition, high heat value and calorific value of corn cobs.

## MATERIAL AND METHODS

### Description of the materials

The experimental material was corn cobs of the Podium corn cultivar from the KWS company (FAO 200) (Figure 1), obtained from farm Agrokam company, which corn was cultivated for grain production. The farm was located in the north part of the Wielkopolska region in Kołybki village (Poland).

Fig. 1. Corn cobs

### Chemical analyses

The percentage of carbon and nitrogen in the samples was determined with a Flash 2000 elemental analyser (Thermo Fisher Scientific, USA) in CHNS/O configuration according to the EN 15104 standard. The instrument was calibrated with standard BBOT (2,5-bis-(5-tert-butyl-benzoxazol-2-yl)thiophene) (Thermo Fisher Scientific, USA) and the Birch leaf certified reference material (Elemental Microanalysis Ltd., UK) to measure the C/N ratio. The correctness of the method was verified by elemental analysis of the Alfalfa certified reference material (Elemental Microanalysis Ltd., UK) for the C/N ratio.

The cellulose content was measured according to Seifert's method (Browning 1969), using a mixture of acetylacetone, 1,4-dioxane and hydrochloric acid to isolate cellulose. The acid-insoluble (72% $H_2SO_4$) lignin content was measured using the TAPPI T 222 om-06 standard method (TAPPI 2006).

### Calorific value

Total solid (TS) in the raw materials was determined in accordance with PN-EN-ISO 18134-3:2015-11 standard (PN-EN-ISO 2015) by using laboratory dryer with forced air circulation. The samples were dried at 105°C until a constant mass was achieved.

The calorific value (CV) of the corn cobs was calculated based on the high heat value (HHV) of combustion determined with the calorimetric method using Isoperibol calorimeter of Parr 6400 type, in accordance with PN-EN-ISO 18125:2017-07 standard (PN-EN-ISO 2017).

The ash content was determined after ashing the corn cobs sample at a final temperature of 550°C, in accordance with PN-EN-ISO 18122:2016-01 standard (PN-EN-ISO 2016).

## RESULTS

### Chemical composition

Before calorimetry test the corn cobs were analysed chemical composition. The coal (C) content was 44.8% of TS, nitrogen (N) content was 0.5% of TS, hydrogen (H) content was 5.9% of TS and oxygen (O) content was 45.0% of TS. The analyses show that the corn cobs had high content of cellulose – 37.8% and high content 13.5% of lignin. The C:N ratio corn cobs was 84 (Table 1). For comparison Channiwala and Parikh (2002) presented that the wheat straw content 42.9% of C, 5.3% of H and 46.9% of O.

Table 1. Chemical composition of corn cobs

| Material | C [TS %] | N [TS %] | H [TS %] | O [TS %] | Cellulose [%] | Lignin [%] | C/N |
|---|---|---|---|---|---|---|---|
| Corn cobs | 44.8±0.04 | 0.5±0.04 | 5.9±0.04 | 45.0±1.00 | 37.8±0.25 | 13.5±0.38 | 84±7 |

±standard deviation

For the contrast Li et al. (2012) presented that the corn stalk ring content 0.95% of N, 20.1% of total lignin and 39.4% of cellulose. The same Authors presented that the corn leaves content 1.21% of N, 17.4% of lignin and 31.3% of lignin.

## Energetic value

Before calorimetry test the corn cobs were analysed relative moisture content and ash content. The relative moisture content was 5.05% and ash content was 2.19%. For the contrast Li et al. (2012) presented that the corn stalk ring content 9.9% of ash and the corn leaves content 11.3%.

Table 2. Physical property and energetic value of corn cobs

| Material | Relative moisture content [%] | Ash [%] | HHV [MJ/kg] | CV [MJ/kg] |
|---|---|---|---|---|
| Corn cobs | 5.05±0.06 | 2.19±0.01 | 18.9±0.03 | 17.70±0.03 |

±standard deviation

Higher heat value (HHV) is an important fuel property which defines the energy content of the fuel (Channiwala and Parikh 2002). The high heating value of a biomass fuel can be determined experimentally by employing an adiabatic bomb calorimeter which measures the enthalpy change between reactants and products (Yin 2011). The corn cobs Heat higher value was 18.9 MJ/kg. For contrast Channiwala and Parikh (2002) presented that the wheat straw HHV was 17.9 MJ/kg, rice straw HHV was 14.8 MJ/kg. Yin (2011) presented that the corn stover HHV was 17.9 MJ/kg and willow wood HHV was 19.6 MJ/kg.

## CONCLUSION

Results of the realized research indicate that the corn cobs have great potential as fuel to professional power and heat industry. The corn cobs characterized the high content of coal and hydrogen. That are the important chemical elements from the point of combustion process. It is also important for combustion process is the ash content in biomass. Corn cobs have low content of ash. Moreover corn cobs are not contaminated with soil past harvest, because have not contact with field surface. Main requirement of professional power and heat industry is a high energy concentration in fuel. Corn cobs have high calorific value in comparison to other biomass.
The project "Research and development work on prototype technology for harvesting and processing corn cob cores for energy purposes" realizing Institute of Biosystems Engineering in Poznań have a great potential to commercialize the research results. The Polish market renewable energy need constant sources of renewable energy raw materials. The corn cobs is easy available biomass, with is due to the popularity of corn growing.


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# 3.6. ASSESSMENT OF THE ENERGY POTENTIAL OF THE VIRGINIA MALLOW (*SIDA HERMAPHRODITA* R.)

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**Keywords:** Virginia mallow, biochemical methane potential, biomass combustion, energy yield

## ABSTRACT
The study compares the efficiency of biochemical and thermochemical biomass energy conversion processes of Virginia mallow. The research was carried out taking into account the usability of tested biomass in the methane fermentation process, by determining the potential of biomethane production BMP (biochemical methane potential) and the suitability of the biomass for direct combustion basing on determining its technical and elementary characteristics. Comparing the energy yield in the studied biochemical and thermochemical conversion processes a significantly higher energy efficiency was found for the thermochemical biomass conversion process.

## INTRODUCTION

Biomass is currently one of the most important sources of renewable energy. There can be pointed three basic methods of biomass conversion: biochemical, physicochemical and thermochemical. (Hawrot-Paw *et al*., 2019). Complement to the supply balance of biomass in the energy market may be its acquisition from targeted perennial plantations of native energy crops or species introduced to Poland (Stolarski *et al*., 2014; Niedziółka *et al*., 2015).

One of the plants of a high energetic potential is the Virginia mallow (*Sida hermaphrodita R.*), a plant cultivated and studied mainly in Poland. It was described in detail in terms of its cultivation and use in the environment protection and phytoremediation (Szyszlak-Bargłowicz *et al.*, 2013; Słowik *et al.*, 2015) as well as in terms of emission of toxic exhaust components during the combustion of pellets made of Virginia mallow biomass (Szyszlak-Bargłowicz and Zając, 2015; Szyszlak-Bargłowicz *et al*., 2015; Zajac *et al*., 2017). Virginia mallow is a plant capable to create relatively high weight of its aerial stems. The average yield is at the level of 12 tonnes of dry matter (TS – Total Solid) per hectare, and the potential yield comes up to 30 tons and indicates its usefulness in use for energy purposes (Budzynski and Bielski, 2004). For direct combustion purpose the stems should be harvested in winter, because then the dry matter content is higher and fluctuates around 63-77%. Therefore there is a possibility of direct combustion of the raw material without a need of additional drying (Borkowska and Styk, 1997; Kościk, 2003). Moreover, it is a plant which in favourable conditions can reach a height of over 4 m. It is strongly leafy and the leaves can be used for biogas production.

Bearing in mind the fact that modern diverse energy conversion technologies require a detailed analysis of biomass properties, the purpose of the work was defined, which was the assessment of energy yield in the processes of biochemical and thermochemical conversion of Virginia mallow biomass.

The research was carried out in two areas. The first was to determine the usability of tested biomass in the methane fermentation process, by determining the potential of biomethane production BMP. The second study area concerned the suitability of the biomass for direct combustion by determining its technical and elementary characteristics.

## RESEARCH METHODOLOGY

The object of the research was the biomass of Virginia mallow obtained from own field experience. To determine the biomethane production potential stems of the Virginia mallow were collected before flowering at the end of spring (June). They were chopped to chaff (1-2 cm) and ensiled by adding commercially available silage additive (5 g per 0.5 l of water).

The pickling lasted 6 weeks. However, to characterize the parameters of the Virginia mallow biomass in terms of its suitability for combustion as a solid fuel, plant stems were collected after the end of the vegetation period and natural drying (December).

The study of BMP (biochemical methane potential) was carried out using AMPTS II tester made by Bioprocess Company. It is an analytical device developed for on-line measurements of ultra-low biomethane flows, produced during anaerobic digestion of biodegradable substrates.

The fermentation process of the biomass silage mixed with inoculum was carried out in six reactors of 400 ml capacity each, assuming the ratio of dry organic matter content in the substrate to dry organic matter content in inoculum as 1:2. Moreover, the inoculum was separately fermented in 3 reactors. It was a mesophilic fermentation process carried out at a temperature of 38 °C for 30 days.

The determination of moisture content (M), ash (A) and volatile compounds (V) was carried out by thermogravimetric method using LECO TGA 701 (LECO Corporation, USA) in accordance with the requirements of M- EN ISO 18134, A - EN ISO 18122, and V - EN ISO 18123. The combustion heat (HHV) was determined with LECO AC 600 isoperibolic calorimeter according to EN ISO 18125 (LECO Corporation, USA). The calorific value (LHV) was calculated on the basis of combustion heat. The content of carbon, hydrogen, nitrogen in dry biomass was determined by instrumental methods (C and H by high-temperature combustion with IR detection, N by means of the catarometer method) according to EN 15104, EN ISO 16948, using elemental analyser LECO CHNS 628 (LECO, USA). The tests were carried out upon dry samples.

## RESEARCH RESULTS

Table 1 presents the results of the research on the biomethane production potential (BMP) based on Virginia mallow silage.

Table 1. Yield of biogas from the Virginia mallow silage

| Parameter | Unit | Value |
|---|---|---|
| Virginia mallow TS (Total Solid) content in the tested silage | % | 30.71 |
| Virginia mallow VS (Volatile Solid) content in the tested silage | % | 90.64 |
| Biochemical Methane Potential (BMP) | $dm^3 \cdot kg^{-1}$ VS | 437 |
| | $dm^3 \cdot kg^{-1}$ TS | 396 |
| Energy yield | $MJ \cdot kg^{-1}$ VS | 11,38 |
| | $MJ \cdot kg^{-1}$ TS | 10,32 |

Based on the obtained test results the biomethane production potential (BMP) was calculated and its value was 437 $dm^3 \cdot kg^{-1}$ VS (Volatile Solid) and 396 $dm^3 \cdot kg^{-1}$ TS. It was a higher value than determined for other substrates (Sadecka and Suchowska-Kisielewicz, 2016) that can be used in biogas plants (grass 237 $dm^3 \cdot kg^{-1}$ TS; haulm tomatoes and chicken manure 185 $dm^3 \cdot kg^{-1}$ TS; mushroom substrate 122 $dm^3 \cdot kg^{-1}$ TS), and at the same time lower than the biomethane production potential determined by Szlachta (Szlachta *et al.*, 2014) for maize silage (590-600 $dm^3 \cdot kg^{-1}$ TS).

Assuming 35.7 $MJ \cdot m^{-3}$ as the calorific value of methane, calculations were conducted and the energy yield reached 11.38 $MJ \cdot kg^{-1}$ VS and 10.32 $MJ \cdot kg^{-1}$ TS. That was twice as the value obtained by Kowalczyk-Juśko (2016) in tests of biogas yield from Miscanthus silage (5.84 $MJ \cdot kg^{-1}$ VS) and lower than values which can be obtained in the methane fermentation process from the most commonly used energetic plants (corn 20.3 $MJ \cdot kg^{-1}$ VS, sorghum 21 $MJ \cdot kg^{-1}$ VS) (Klimiuk *et al.*, 2010; Kowalczyk-Juśko *et al.*, 2015; Oniszczuk *et al.*, 2017). Table 2 presents the technical and elementary characteristics of the Virginia mallow biomass.

Table 2. Technical and elementary characteristics of the Virginia mallow biomass

| Parameter | Unit | Value |
|---|---|---|
| Total moisture | % | 9.5 |
| Ash | % | 3.5 |
| Volatile matter content | % | 82.68 |
| Carbon | % | 45.4 |
| Hydrogen | % | 5.61 |
| Sulphur | % | 0.06 |
| Nitrogen | % | 0.46 |
| Heat of combustion<br>HHV (High Heat Value) | $MJ \cdot kg^{-1}$ | 17. 8 |
| Calorific value<br>LHV (Low Heat Value) | $MJ \cdot kg^{-1}$ | 15. 4 |

The obtained research results show that the Virginia mallow is a plant characterized by a high calorific value which is the most important parameter determining the suitability of a given type of biomass for its combustion. The calorific value (LHV - Low Heat Value) of the Virginia mallow biomass was 15.4 $MJ \cdot kg^{-1}$ and was comparable to the calorific value of other energy crops (Miscanthus 15.3 $MJ \cdot kg^{-1}$ (Kowalczyk-Juśko, 2016), Jerusalem artichoke 15.2-16.1 $MJ \cdot kg^{-1}$ (Frączek *et al.*, 2011; Kowalczyk-Jusko *et al.*, 2017).

The calorific value (LHV) of fuel is primarily determined by the carbon and hydrogen content, which in tested biomass amounted to 45.4% and 5.61%, respectively, as well as the low humidity, which amounted to 9.5%.

It is worth emphasizing that the tested biomass was characterized by a low sulphur content of 0.06%. It is important in the context of its combustion because the higher sulphur content in fuel the higher amount of $SO_2$ (sulphur dioxide) emitted into the atmosphere. The nitrogen content was 0.46% and the volatile matter content 82.68%. These contents are comparable with other types of plants usually used for energetic purposes (Kowalczyk-Jusko, 2010).

## COMPLETION AND CONCLUSIONS

An important aspect in improving the efficiency of biomass conversion processes and in their optimization is the appropriate selection of the methods and technical solutions focused on energy recovery. Unfortunately, currently used technologies using various types of biofuels are not free of negative impact on the environment. There is still a need to improve their ecological-energetic efficiency.

Conducting an energy assessment of biomass use, based on the example of a selected energy plant recommended for specifically targeted crops is important to ensure the effective operation of modern biomass utilization systems.

The results of performed tests allowed to conclude that the Virginia mallow silage is characterized by a high biomethane production potential, amounted to 396 $dm^3 \cdot kg^{-1}$ TS, and a high value of the potential energy yield of 10.32 $MJ \cdot kg^{-1}$ TS. Based on the obtained technical and elementary characteristics of the Viginia mallow biomass, it was found that its energy efficiency is high. The calorific value was 15.4 $MJ \cdot kg^{-1}$, where the humidity was 9.5%, and the heat of combustion 17.8 $MJ \cdot kg^{-1}$. The energy parameters of the Viginia mallow biomass were similar to other energy crops. Moreover, this biofuel contains low sulphur content, as well as low humidity during harvest in autumn and winter.

Nevertheless, when comparing the energy yield in the biochemical process and thermochemical conversion it should be noticed that the efficiency of biomass combustion equipment is much lower than that of combustion engines fuelled with biogas, especially those working in cogeneration.

In addition, biomethane combustion does not entail high emission of toxic exhaust and including particle matter PM components, which may occur in higher concentration when solid biofuels are combusted, especially in inefficient older installations.

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# 3.7. INFLUENCE QUALITY OF CORN STOVER SILAGE FOR METHANE YIELD

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**Keywords:** corn stover silage, methane fermentation, silage quality

## ABSTRACT

Anaerobic digestion technology has been widely used as a sustainable alternative to recycle, reuse and reduce agricultural residues to produce biomethane. Particular attention has recently been paid to lignocellulose wastes as they are particularly suitable for energy applications because of their availability on a large scale and at low cost. Corn stover is one of the most abundant components in agricultural cellulose waste. The aim of this research was setting influence quality of corn stover silage for methane yield in anaerobic digestate process.
Corn stover silage on this research have methane yield potential between 220.6 to 353.9 $m^3$/Mg of TS. Pearson's correlation shows that the pH and content of volatile fatty acids have very strong influence for cumulative methane yield. On this base, it can be concluded that the quality of corn stover silage influence for methane yield.

## INTRODUCTION

Climate change has been directly related to fossil fuel combustion, which generate $CO_2$ and it is the energy production predominating worldwide since the last century (DeMarco 2017). Anaerobic digestion technology has been widely used as a sustainable alternative to recycle, reuse and reduce agricultural residues to produce biomethane (Martínez-Gutiérrez 2018). The use of biomass from edible plants to biofuels production has been a topic of debate, because it could increase the competition for availability of agricultural lands and water bodies and displace food crops (Martínez-Gutiérrez 2018). Producing second-generation biofuel from renewable cellulosic biomass offers the possibility to offset the energy demand and environmental problems caused by fossil fuels consumption (Ding *et al*. 2012, Sarkar *et al*. 2012, Xin *et al*. 2020). For this reason particular attention has recently been paid to lignocellulose wastes as they are particularly suitable for energy applications because of their availability on a large scale and at low cost (Ferreira *et al*. 2014).
Corn stover is one of the most abundant components in agricultural waste (WenBo *et al*. 2019). Crops residues after corn grain harvest make 47-50% the yield dray matter of whole corn plants (Sokhansanj *et al*. 2010). Combined corn production is recommended. It means that one field is used for simultaneous production of feed and biogas substrates, i.e. corn grains and stover. This solution does not arouse ethical doubts, because there is no conflict between the production of food and energy (Wojcieszak *et al*. 2018).
In Poland corn is harvested for grain in late autumn (October-November), when the air temperature drops and the humidity go down. Under these conditions the moisture of corn grains usually ranges from 30% to 35%. The moisture of maize residue ranges from 47% to 66%. It is impossible to dry maize straw in the field. Ensilage is the only reasonable solution in the storage of maize straw (Przybył *et al*. 2018).
The aim of this research was setting influence quality of corn stover silage for methane yield in anaerobic digestate process.

## MATERIALS AND METHODS

### Description of the materials

The corn stover ensilage experiment was conducted during production at the Stary Gołębin farm which belongs to the Top Farms Wielkopolska company. It was one variant experiment. The factor was the corn stover ensilage method, i.e.

- natural ensilage (CSS1),
- ensilage with bacterial preparation (*Pediococcus acidilactici, Lactobacillus plantarum, Enterococcus faecium*) (CSS2),
- ensilage aided with organic preparation (sodium benzoate, propionic acid and sodium propionate) (CSS 3).

Silage was made in film-wrapper cylindrical bells with the stover after corn cultivar PR39A79 (Pioneer company, FAO 300) had been harvested for grain. The total solid (TS) in corn stover was 68% and the organic matter content was 87%. The corn stover was harvested with a round baller New Holland 644 (Fig. 1) and wrapped with bell wrapped Sipma Tekla OZ 5000.

Fig. 1. The harvest of corn stover with the round baler New Holland 644.

### Laboratory analyses of silage

Corn stover silage samples weight about 2 kg were from film-wrapper cylindrical bells in order to conduct physical and chemical parameters. The analyses of raw corn stover silage samples where conducted in laboratory of the Department of Animal Nutrition and Feed Management, Poznan University of Life Sciences. The laboratory analyses of the silage samples include:

- pH measurement,
- the analysis of dry matter content (TS),
- the analysis of the content of volatile fatty acids.

The pH value of silages was determined by measuring the concentration of hydrogen ions with an electrode coupled with a WTW pH 730 InoLab pH-meter. Liquid chromatography was applied to measure the content of volatile fatty acids: lactic acid, acetic acid and butyric acid. The content was measured by means of a Waters 2690 chromatograph with a Waters 2487 absorbance detector. The dry matter content was determined by means of the drying and weighing method, according to the Polish Standard PN-ISO 6496:2002 (Przybył *et al.* 2018, Wojcieszak *et al.* 2018).

## Laboratory experiment the anaerobic digestion

The methane yield was investigations of corn stover silages were performed in the Ecotechnology Laboratory in the Institute of Biosystems Engineering at the University of Life Sciences in Poznan, under DIN standard 38 414-S8. The research was done at a 21-reactor workstation which the laboratory was equipped (Dach *et al*. 2014). The biogas volume production was measurement ever 24 h with an accuracy of 0.01 $dm^3$. Qualitative and quantitative composition of the fermentation gases was determined by a absorption sensors working in an infrared and electrochemical sensor line. The type Mg-72 and Mg-73 heads for gas concentration measurement were used (ALTER S.A.). The analyser range of measurements was as follows: 0-100% $CH_4$, 0-100% CO2, 0-25% $O_2$, 0-2000 ppm $H_2S$. The detectability of the photoacoustic spectrometer used for measurements of gas concentrations was as follows: 0.02 ppm $NH_3$ and 0.03 ppm $N_2O$.

## Statistical analyses

A statistical analysis of the laboratory research results was performed in STATISTICA 13 software. Calculations included performing an analysis of the ANOVA variance for a factor system followed by the HSD Tukey test for each variable method of silage $\alpha=0.05$.

Pearson (r) correlations between the variables were also calculated with the STATISTICA 13 software. The strength of the correlation was described using the guide that Evans (Evans 1996) suggested for the absolute value of r: 0.00-0.19 - very weak, 0.20-0.39 – weak, 0.40-0.59 – moderate, 0.60-0.79 – strong, 0.80-1.0 – very strong.

# RESULTS

## Properties of silages

Before testing the biogas and methane efficiency the substrates were analysed physically and chemically (Table 1). The pH of corn stover silage CSS1 was 6.06 and pH CSS3 was 6.88. The pH of silage CSS1 was less than the pH of silage CSS1 was less and was 4.88. The total solid content in silage CSS1 was 36.1%, in silage CSS2 was 45.1% and total solid content in silage CSS3 was 39.5%. The difference was significant ($\alpha=0.05$).

Table 1. Physical and chemical parameters of corn stover silages

| Corn stover silage | pH | TS [%] | Lactic acid [%] | Acetic acid [%] | Butyric acid [%] |
|---|---|---|---|---|---|
| CSS1 | 6.06±0.00 | 36.1±0.09$^c$ | 0.17±0.00 | 0.20±0.00 | 0.24±0.00 |
| CSS2 | 6.88±0.00 | 45.1±0.00$^a$ | 0.80±0.00 | 0.31±0.00 | 0.13±0.00 |
| CSS3 | 4.91±0.00 | 39.5±0.71$^b$ | 0.29±0.00 | 0.51±0.00 | 0.42±0.00 |
| n | 3 | 3 | 3 | 3 | 3 |

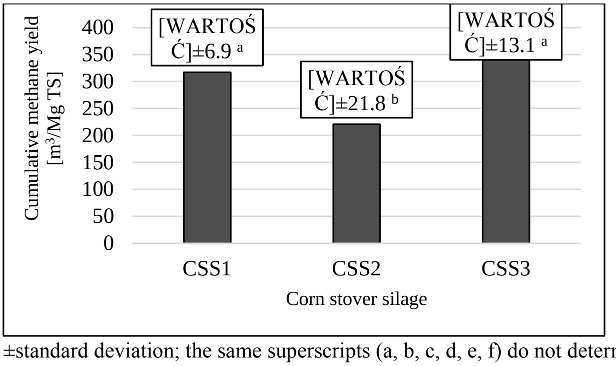
The average values (n) ±standard deviation; the same superscripts (a, b, c, d, e, f) do not determine a considerate difference between average values in columns according to the HSD Tukey test (ANOVA) for the investigated factors.

By contrast, Cieślik *et al*. (2016) presented that the content of dry matter in the naturally ensilaged corn stover was 46,1% and the pH was 4,86.The corn stover silage CSS1 content 0.17% lactic acid, 0,20% acetic acid and 0,24% butyric acid. The heights content of butyric acid was silage CSS3.

**Methane yield**

Cumulative methane production of investigated corn stover silage presented in Figure 2. The performed analyses of the variance indicated that the methane yield of the corn stover silage ensilage aided with an organic preparation (CCS3) was significantly higher comparing to methane yield of the corn stover natural ensilage (CCS1) and silage with bacterial perpetrate (CSS2).

The methane yield potential and methane production rate of substrates are two important indices for anaerobic methane production (Dong *et al.* 2016). After 25 days of digestion the accumulated production of methane from corn stover silage CSS1 amounted to 317.2 $m^3$/Mg of TS. The accumulated production of methane from corn stover silage CSS3 was higher i.e. 353.9 $m^3$/Mg of TS. The accumulated production of methane from silage CSS2 was lower i.e. 220.6 $m^3$/Mg of TS. The ANOVA analysis demonstrated also that the method of ensilage corn stover affected the methane yield considerably. By contrast, Czekała *et al.* (2016) gained 344 $m^3$/Mg of TS methane from peaches fruit.




±standard deviation; the same superscripts (a, b, c, d, e, f) do not determine a considerate difference between average values in columns according to the HSD Tukey test (ANOVA) for the investigated factors.

Fig. 2. Cumulative methane yield of corn stover silages

The Pearson correlation coefficient was calculated for all the results (Table 2) with indication on (r = -0.92) very strong negative correlation between cumulative methane yield and pH. The above explain us to the lowest methane yield and the highest pH value.

Table 2. Pearson's correlation coefficients between methane yield, Physical and chemical parameters of corn stover silages

| | Silage method | pH | TS | Lactic acid | Acetic acid | Butyric acid | Methane yield |
|---|---|---|---|---|---|---|---|
| pH | -0.91 | - | - | - | - | - | - |
| TS | -0.78 | 0.53 | - | - | - | - | - |
| Lactic acid | -0.88 | 0.70 | 0.97 | - | - | - | - |
| Acetic acid | 0.41 | -0.71 | 0.21 | 0.01 | - | - | - |
| Butyric acid | 0.90 | -0.99 | -0.50 | -0.66 | 0.74 | - | - |
| Methane yield | 0.26 | -0.92 | -0.78 | -0.88 | 0.41 | 0.90 | - |

Correlations are significant at $P<0.05$

On the other hand there was a strong negative correlations between methane cumulative methane yield and TS content (r = -0.78), and lactic acid content (r = -0.88).

## CONCLUSION

Results of the realized research indicate that the ensiling is good method for corn stover conservation. Corn stover silage have good physical and chemical parameters for be a substrate to the methane fermentation in biogas plants. To the contrast, results the laboratory research on physical parameters showed decrease in the total solid between fresh corn stover and corn stover silage.

Methane yield samples shows that the preparation for ensiling based on the lactic acid bacterial reduced the cumulative methane yield in comparison to natural ensiling method. Laboratory analyses indicate that the methods of ensiling have influence for quality of corn stover silage. Pearson's correlation shows that the pH and content of volatile fatty acids have very strong influence for cumulative methane yield.

On this base, it can be concluded that the quality of corn stover silage influence for methane yield.

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# 4. PROCESSES

# 4.1. VERMICOMPOSTING OF PAPER WASTE AND CASSAVA PEELS RESIDUES: EFFECT OF DURATION AND FEEDSTOCK LOADING RATE

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**Keywords:** Vermicomposting, Cassava peels, Paper waste, Duration/Loading rate, Physico-chemical properties

## ABSTRACT
The problems associated with agricultural and municipal solid waste management in many countries especially, developing countries of the world, cannot be over emphasized. The objective of this research was to determine the effect of composting duration and feedstock loading rate on vermicomposting of cassava and paper waste in Nigeria, with respect to the pattern of physico-chemical changes of some essential nutrients needed for plant growth, such as nitrogen, potassium, phosphorous, and calcium. Effect of duration (0, 20, 40 & 60 days), rate of feedstock loading (300, 400 and 500 g) and feedstock type (cassava peels and paper residues) on physico-chemical properties (pH, Ph, Ca, K, N and Organic Carbon) of compost yields during vermicomposting was studied using central composite experimental design in a batch experiment. Results showed that duration and feedstock loading significantly ($p > 0.05$) affected the pH, P, Ca, N, and OC. The C:N ratio in all combination were similar and the values ranged from 2.06 to 4.27. The C:N ratio of less than 20 obtained during the process of decomposition, indicated an advance degree of organic matter mineralization and stabilization which reflected a satisfactory degree of organic wastes conversion maturity. Paper waste gave the optimum yield of physico-chemical properties of good compost at 41.7 days with a loading rate of 500 g.

## INTRODUCTION
The problems associated with agricultural and municipal solid waste management in Nigeria and other developing countries cannot be over emphasized. Chief among these is the paper waste and cassava peels. Paper appears to be the most common material used in many areas such as stationeries, cartons for packaging, disseminating news to people and many more, after which were discarded as paper waste. On the other hand, Cassava peels according to Calvosa and Amoriggi (2009) constitute a substantial by-product of the cassava processing, being about 10-13% of total tuber weight. Peels normally consist of the thin pericarp and the thicker rind as most processes remove both along with some pulp adhered to the peels. Cassava peels are used for animal feeds but one of the main drawbacks is its low protein content and could only be used for selected few animals such as pigs and fish (Calvosa and Amoriggi, 2009). Therefore, considerable quantity of the peels is abandoned in nearby processing places, used as land fill or burnt. These constitute a serious threat to the environment, and vermicomposting could be a better way of disposing them.

Compost is defined as the product resulting from the controlled biological decomposition of organic material from both municipal (domestic and commercial) and industrial streams (Sinha *et. al*., 2010). Compost is valued for its organic matter content, and it is typically used as a soil amendment to enhance the chemical, physical and biological properties of soil. There are various types of compost depending on the process, and method undergone, and one of them is the vermicomposting. Vermicomposting is an aerobic process of organic waste, decomposition involving earthworms feeding on carbon-based materials. Waste eater earthworms, such as red wigglers, white worms, and other earthworms can physically handle a wide variety of organic wastes creating a complex mixture of decomposing organic matter in the course of vermicomposting within 2-4 weeks compared with conventional composting (20 week) as it depends on microbes alone (Nagavallemma *et. al*. 2004). The end product of vermicomposting known as: Vermicast, worm castings, vermicompost, worm humus or worm manure, have been shown to contain reduced levels of contaminants and a higher saturation of nutrients than organic materials before vermicomposting (Nagavallemma *et al*., 2004). They provide many benefits to agricultural soil, including increased ability to retain moisture, better nutrient-holding capacity, better soil structure and higher levels of microbial activity (Arancon *et al*., 2006).

The basic requirements during the process of vermicomposting are as follows: suitable bedding, food source, adequate moisture (60 -70%), adequate aeration, suitable temperature (10-35$^{o}$C, and suitable pH (7.5 – 8.0) (Sinha *et. al*., 2010). The objective of this research is to determine the effect of composting duration and feedstock loading rate on vermicomposting of cassava and paper waste, with respect to the pattern of physico-chemical changes of some essential nutrients needed for plant growth such as nitrogen, potassium, phosphorous, and calcium.

## METHODS

### Waste Collections and Pre-treatment

The samples of paper wastes were collected from wastepaper basket in offices at the Federal University of Agriculture, Abeokuta, Nigeria (FUNAAB) campus. While the fresh cassava peels sample were collected from a local cassava, gari processing mill, located at Kofesu village, along Alabata road, near FUNAAB. The peels were sundried for about two weeks, in order to reduce its moisture content, before used for the experiment. From all wastes, the non-biodegradable foreign fractions such as plastic, rubber, polythene bags, glass and stones were separated and discarded manually by hand sorting. The pre-treated sample wastes were stored in large sized sacs for the experiment. The cow dung, used for bedding, was obtained from animal section of the FUNAAB farm. *Eisenia* foetida earthworms were obtained by hand picking during rainy season from FUNAAB environment and cultured in a plastic bin for about 6 months.

### Experimental Design

Duration at four levels (0, 20, 40 & 60 days), rate of feedstock loading at three levels (300, 400 and 500 g) and feedstock type at two levels (cassava peels and paper residues) to determine physico-chemical properties (pH, Ph, Ca, K, N and Organic Carbon) of compost yields during vermicomposting was studied using Central Composite Design (CCD) of the Response Surface Methodology (RSM). The CCD builds a second order model for responses without the need to use a complete three-level factorial experiment. It allows viewing interactions among experimental variables within the range studied, leading to better knowledge of the process and therefore reducing research time and costs (Dairo *et. al.* 2016). The design involved three factors and six responses. Feedstock type: a qualitative variable, while feeding rate and duration were the quantitative variables. Physico-chemical properties (pH, available total Phosphorus (P), total Calcium (Ca), total Potassium (K), total Kjeldahl nitrogen (N) and total Organic Carbon (OC) were the responses or the independent variables. Experimental design matrix involved 26 runs.

### Experimental Set up

The experiments were conducted in rectangular plastic containers with 53 cm x 15 cm x25cm which were perforated on the top and sides for aeration and at the bottom for drainage purpose. The containers were filled to a 10cm height with shredded paper and soil as bedding material. All wastes were mixed with cow dung and treated with *E. foetida*

earthworm in waste and worm mass proportions of 100 g cow dung and 100 g of earthworm, while paper and cassava peel were varied between 300 and 500 g at the step of 100 g. Healthy *Eisenia foetida* (earthworms) were selected from the culture bin and introduced into the prepared samples. The homogenized samples from each sample containers were collected at 20 days interval and air dried to monitor the changes in physico-chemical characters. The samples were analysed for pH in a 1:1 sample to water suspension using a pH meter (Maclean, 1982). Organic carbon was determined by the dichromate wet oxidation method of (Walkley and Black, 1934). Total Nitrogen (N) was determined by macro kjedahl method (Brookes *et al*., 1985) and available phosphorus (P) was determined by method Anderson and Ingram (1993) method, while total potassium and calcium were both determined following the procedure described by Simard (1993). The quantity of Ca was determined using AAS while K was obtained using flame photometry. The temperature and moisture were recorded during vermicomposting. The temperature was recorded using mercury in tube thermometer while the moisture content was measured by drying sample in an oven at 105$^o$C for 24hrs.
The experimental data were subjected to analysis of variance (ANOVA) procedure and regression analysis by fitting to a second order polynomial given by equation

$$Y = \beta_0 + \sum_{i=1}^{3}\beta_i x_i^1 + \sum_{i=1}^{3}\beta_{ii} x_i^2 + \sum\sum_{i<j=1}^{3}\beta_{ij} x_i\, x_j \qquad (1)$$

Where: Y is the predicted response, 3 is number of factor variables, $\beta_0$, $\beta_i$, $\beta_{ii}$ and $\beta_{ij}$ are the model constant, linear, quadratic and interaction coefficients respectively, while $x_i$ and $x_j$ are the uncoded independent variables.

The quality of fit of model was expressed by the coefficient of determination $R^2$, and its statistical significance was determined by *F*-test.

## RESULTS AND DISCUSSION

Table 1 shows the results and the experimental design of the experiment. Generally, effect of duration and feedstock loading rate on the vermicomposting was observed to produce a significant ( $p < 0.05$) increase in the values of N, P, Ca, and K and reducing the values of pH and OC as the duration and loading rate increased until a peak was reached at 41.37 and 40.94 days for paper and cassava peels respectively. After these days, a decrease was observed in the values of N, P, Ca as the duration and the loading rate increases. This observation can be evidently seen in the response surface diagram show in Fig. 1a and 1b. Successive rise in the value of P from first day on till a peak was reached at about 40$^{th}$ day was observed as the duration of the experiment and the rate of loading of the feedstock increases and decreased with a further increase in the duration of the experiment.
Similar trend was observed for Total Kjeldhal Nitrogen (N) and Total Calcium (Ca). Venkatesh and Eevera (2008) also observed similar trend in their research work on vermicomposting of fly ash, however, there was a gradual decline of P after 45$^{th}$ day. The rise of total P might be due to the action of earthworms' phosphatases and phosphorous solubilizing microorganisms in the worm cast. Degefe (2012) reported that as the organic residue passes along the earthworms gut the unavailable form of phosphorous in the biomass is converted to available forms that plants could use. This observation was however different from observations of Degefe (2012), Ananthakrishnasamy *et al*. (2009) and, Chauhan and Joshi (2010) observed increase in available P throughout the duration of their studies. The observed values of Ca followed trend Similar to P as made by some researcher who had previously worked on vermicomposting of various organic wastes such as: vegetable waste (Jadia and Fulekar, 2008), various mixtures of urban solid wastes

(Anasri, 2009), urban green wastes (Pattnaik and Reddy, 2010) vegetable waste amended with Cow Dung (Degefe *et al* 2012). This decline the values of Ca with further increment in the duration of the experiment which might be as a result of leaching by excess water that drained through as observed by Elvera *et al* (1998) in vermicomposting of sludge from paper mill and diary industries, and Chaudhuri *et al* (2000) in vermicomposting kitchen wastes. The Ca content increased as the feedstock feeding rate increases which are an indication that earthworm in samples could still handle more waste feedstock.

Table 1. Experimental design and data for vermicomposting of paper waste (PW) and cassava peels (CA)

| Runs | A[1] | B[2] | C[3] | pH | N(%) | P(mg/kg) | Ca (mg/kg) | OC (%) | K(mg/kg) | C/N |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 300 | 20 | PW | 8.10 | 0.99 | 38.96 | 21.69 | 4.11 | 210 | 4.15 |
| 2 | 400 | 40 | PW | 6.50 | 1.61 | 45.72 | 28.14 | 3.32 | 290 | 2.06 |
| 3 | 500 | 20 | CA | 6.80 | 1.11 | 42.11 | 26.55 | 4.39 | 280 | 3.95 |
| 4 | 300 | 40 | CA | 7.80 | 1.31 | 46.01 | 28.61 | 3.21 | 380 | 2.45 |
| 5 | 500 | 60 | PW | 7.40 | 1.15 | 41.88 | 25.62 | 3.41 | 340 | 2.97 |
| 6 | 400 | 40 | CA | 6.50 | 1.39 | 47.38 | 31.48 | 3.32 | 290 | 2.39 |
| 7 | 400 | 20 | CA | 6.90 | 1.08 | 41.92 | 24.12 | 4.07 | 260 | 3.77 |
| 8 | 400 | 40 | PW | 6.50 | 1.61 | 45.72 | 28.14 | 3.32 | 290 | 2.06 |
| 9 | 400 | 40 | PW | 6.50 | 1.61 | 45.72 | 28.14 | 3.32 | 290 | 2.06 |
| 10 | 300 | 60 | PW | 7.30 | 1.11 | 38.61 | 24.36 | 2.90 | 310 | 2.61 |
| 11 | 300 | 40 | PW | 7.30 | 1.36 | 44.89 | 27.36 | 3.04 | 270 | 2.24 |
| 12 | 500 | 40 | CA | 6.50 | 1.49 | 48.92 | 32.14 | 3.44 | 310 | 2.31 |
| 13 | 300 | 60 | CA | 7.10 | 1.12 | 38.92 | 21.87 | 2.97 | 315 | 2.65 |
| 14 | 500 | 20 | PW | 5.60 | 1.26 | 45.81 | 28.67 | 5.01 | 285 | 3.98 |
| 15 | 400 | 40 | CA | 6.50 | 1.39 | 47.38 | 31.48 | 3.32 | 290 | 2.39 |
| 16 | 400 | 40 | CA | 6.50 | 1.39 | 47.38 | 31.48 | 3.32 | 290 | 2.39 |
| 17 | 400 | 40 | PW | 6.50 | 1.61 | 45.72 | 28.14 | 3.32 | 290 | 2.06 |
| 18 | 500 | 60 | CA | 7.20 | 1.15 | 40.89 | 25.33 | 3.24 | 345 | 2.82 |
| 19 | 400 | 60 | PW | 7.20 | 1.12 | 41.23 | 25.48 | 3.17 | 325 | 2.83 |
| 20 | 400 | 20 | PW | 5.80 | 1.13 | 41.36 | 24.51 | 4.82 | 270 | 4.27 |
| 21 | 400 | 40 | PW | 6.50 | 1.61 | 45.72 | 28.14 | 3.32 | 290 | 2.06 |
| 22 | 500 | 40 | PW | 6.30 | 1.68 | 49.33 | 32.38 | 3.80 | 300 | 2.26 |
| 23 | 400 | 40 | CA | 6.50 | 1.39 | 47.38 | 31.48 | 3.32 | 290 | 2.39 |
| 24 | 300 | 20 | CA | 7.40 | 0.99 | 40.36 | 20.78 | 3.96 | 340 | 4.00 |
| 25 | 400 | 60 | CA | 7.10 | 1.14 | 40.11 | 23.73 | 3.22 | 325 | 2.82 |
| 26 | 400 | 40 | CA | 6.50 | 1.39 | 47.38 | 31.48 | 3.32 | 290 | 2.39 |

[1]Rates, [2]Days, [3]Feedstock

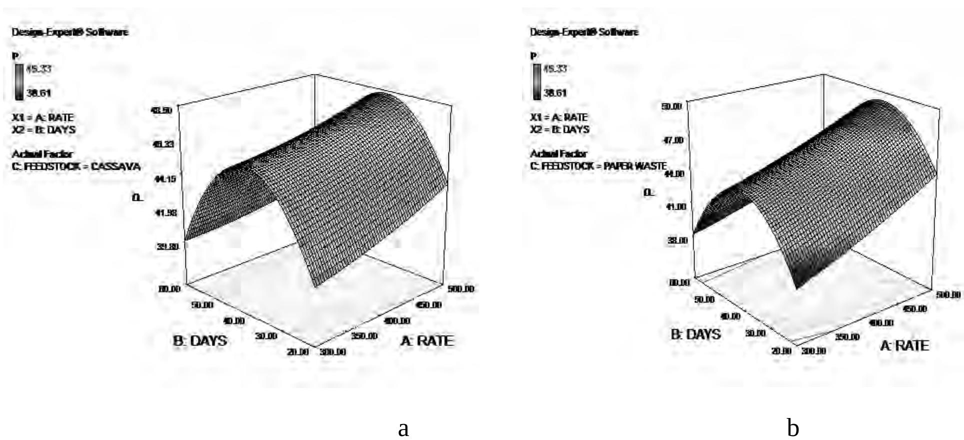
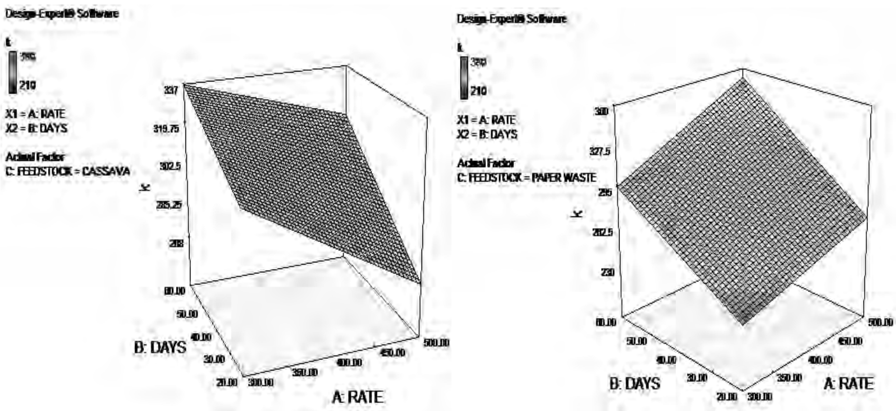



Fig. 1. Effect of experimental duration and feeding rate on the yield of Phosphorous for (a) cassava and (b) paper of during vermicomposting.

The quantity of N also followed the same pattern observed for both P and Ca where there was a gradual decline of nitrogen after 45th day. Similar observation was reported by Venkatesh and Eevera, (2008) in their work on vermicomposting fly ash. Degefe et al (2012) reported that, in addition to the initial nitrogen content in the organic feedstock, earthworms also contribute immensely in enhancing and improving the nitrogen profile of the waste by addition of mucus as well as decaying tissue of the dead worms, nitrogenous casts and by facilitating microbial mediated nitrogen mineralization.

The concentration of K increased in vermicompost of both the paper waste and cassava peels as the duration of the experiment and the rate of loading increased throughout the period of the experiment as shown Figures 2 a and b. This might be due to enhanced microbial activity during the vermicomposting process as cast material contains high concentration of exchangeable K and consequently enhanced the rate of mineralization (Suthar 2007). Delgado *et al*. (1995) have also reported a higher content of K in the new sewage sludge vermicompost.

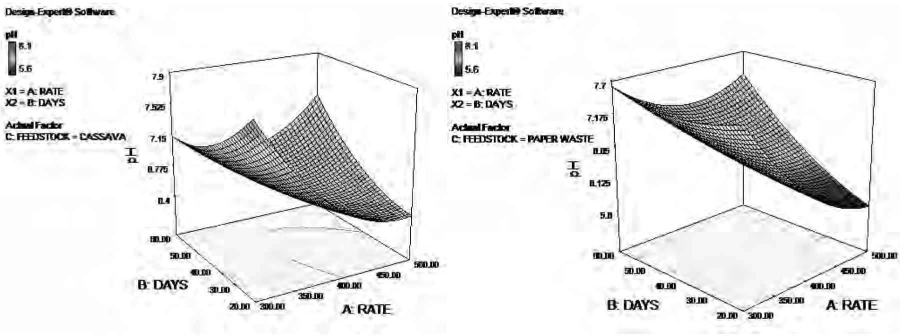



a b

Fig. 2. Effect of duration of the experiment and feedstock loading rates on the K of vermicomposting of a) paper waste and b) cassava peels

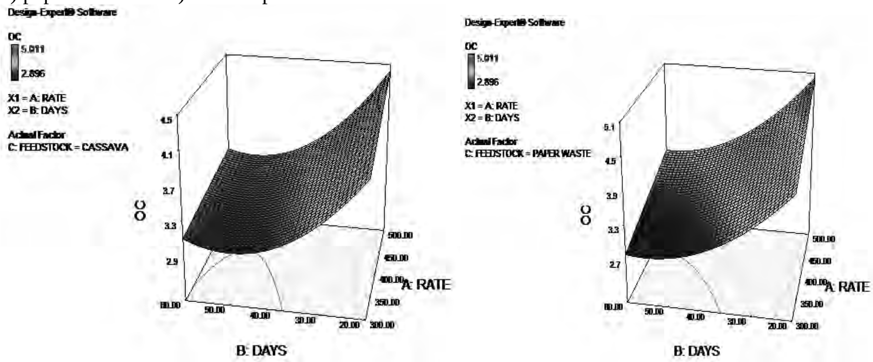
The amount of OC in the decreased initially at a more rapid rate as the duration of the experiment increases from day 0 up to around 40$^{th}$ day and at a gentler rate towards the 60$^{th}$ day of the experiment (Figures 3a and b). This might indicate maturation takes place at around 40$^{th}$ day and that the experiment should not be extended beyond this day. The reduction of carbon in vermicompost might be due to respiration and mineralization of the organic matter mainly by microorganisms and earthworms as vermicomposting is a combined action of earthworm and microorganisms (Degefe *et al*., 2012)

The overall decrease of pH from the initial near alkaline towards slightly acidic conditions (Figure 4a and b) might be due to the decomposition of organic substrates by microbial activity resulting in the production of $CO_2$ and other intermediate species of organic acids in vermicomposting (Degefe et al,2012). This shifted from alkaline to slightly acidic pH which is the characteristic of good quality compost and such reduction is advantageous in retaining nitrogen as this element is lost as volatile ammonia at high pH values (Hartenstein and Hartenstein, 1981).




a b

Fig. 3. Effect of duration of the experiment and feedstock loading rates on the pH of vermicomposting of a) paper waste and b) cassava peels




a b

Fig. 4. Effect of duration of the experiment and feedstock loading rates on the OC of vermicomposting of a) paper waste and b) cassava peels

The C:N ratio obtained for all experimental combination ranged from 2.06 and 4.27. The decline in C:N ratio to less than 20 during the process of decomposition, indicated an advanced degree of organic matter mineralization and stabilization and reflects a satisfactory degree of organic wastes maturity as reported by Suthar (2008). A similar reduction in C:N ratio was reported by Bansal and Kapoor (2000). Degefe et al (2012) reported that a C:N ratio below 20 is an acceptable maturity level, while a ratio of 15 or lower is highly preferable for agronomic purpose. This result for both samples treated by both species of earthworms showed that C:N ratio are within the acceptable limit for agricultural usage.

## CONCLUSIONS

Vermicomposting of cassava peels and paper waste was successfully carried out using red wiggler earthworm. Good compost evidenced from the C:N was achieved at about 42 days and a loading rate of 500 g. This was faster than conventional composting which took about 90 days.

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# 4.2. RESEARCH FOR IMPROVING STABILITY OF RYE WHEAT STEM RUST

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**Keywords:** stem rust, sustainability, production, winter rye, developing

## ABSTRACT

Winter rye (*Secale cereal* L.) play an important role in German breeding programs and Polish companies and breeding companies. One of the most dangerous diseases affecting rye is stem rust (*Puccinia graminis* f. sp. *secalis*). Stem rust is caused by basidiomycete fungus *P. graminis*, belonging to the uredinales. The fungus exists in several races. Like most rust fungi it requires two taxonomically diverse hosts to complete its life cycle. It causes loses in the range of 10 to 50% depending on the year and region. The protection of rye against stem rust is based on the use of resistant rye varieties and divided fungicidal treatments. Pathogen for development needs high temperature (25-30°C during the day and 15-20°C at night), and the symptoms of paralysis are visible in the later stages of rye development. Therefore, it is not possible to perform a fungicide treatment for brown and stem rust at the same time. Additional treatments increase production costs. The aim of the task is to study and apply breeding treatments, monitoring and breeding resistant varieties to increase rye resistance. The experiment was carried out in two locations (ZDOO Kościelna Wieś and Danko Plant Breeding Plant in Laski). Subject of research were sets of objects composed of varieties, self-incompatible populations, inbred lines and segregating populations.

## INTRODUCTION

Stem rust infections are present annually in all rye-growing regions. In the most years they are negligible, but for certain years they have been epidemic. The most serious epidemics in rye were in northern Europe (Roelf 1985). With global climate change, higher temperatures will arise in northern and Central Europe that support epidemics of stem rust. With resistant rye cultivars, the full agricultural sector involved could be prevented from tremendous losses. When calculating an overall yield loss by stem rust of only 5%. The main rye growing areas within the EU are located in Poland (760,000 ha), Germany (570,000 ha) and with a large gap, Spain (157.000 ha, FAOSTAT 2016). In total, 13 million tons of rye were produced worldwide in 2016, 60% thereof within the EU, mainly in Germany (3.2 million tons) and Poland (2.2 million tons, FAOSTAT 2016).Winter rye (*Secale cereale* L.) plays an important role in Germany and Poland within plant breeding associations and SMEs. Both countries are the largest rye producers within the EU with a total acreage of 1.93 million hectares in 2016 (FAOSTAT 2016), thus contributing about 70% of the total world rye production. In Germany, about 20 percent of the harvest are used for bread making, 60 percent for feeding and 20 percent for the production of biogas and bioethanol. Stem rust has detrimental effects on grain production reducing grain yield and 1000-grain weight considerably. There is a good choice of varieties with different properties on the market. In 2017, 8 population and 25 hybrid varieties have been listed in Germany for the different purposes. With a smaller percentage of hybrid cultivars, in Poland even 55 cultivars are registered, 21 of them are Polish breeds (COBORU 2017). However, all these registered cultivars are moderately to highly susceptible to stem rust.

## MATERIALS AND METHODS

Developing a new rye variety is cost- and time-intensive and particularly challenging because of the large number of traits that have to be combined, most of them with complex inheritance. Given similar climatic conditions, German rye cultivars can be

marketed in Poland and *vice versa*. There are prominent examples for transferring cultivars in both directions. Stem rust resistance is urgently needed in hot-summer climates. Resistance would therefore open new markets for the participating SMEs.
For sustainable production, new varieties will be important, which are better adapted to changing socioeconomic and climatic environments and combine good yield and quality traits with decreased stem rust susceptibility. For artificial inoculation and successful selection of resistances to rust, it is necessary to evaluate the population structure of the pathogen in Germany and Poland and to select highly virulent isolates for inoculum production. This ensures that always those resistances in rye are detected that are still effective. For a virulence survey, samples of rust-infected rye stems are collected by the partners and about 120 single-pustule isolates are tested per country and year. Virulence of the collected isolates is subsequently analysed by leaf-segment tests with an actual differential set in Germany and Poland. Specific isolates are selected for inoculum production enabling identification of different race specific resistance genes in lab tests and selection of rye material with high adult plant resistance in field tests.
Adult-plant testing in the field by artificially inoculating genotypes in Poland and Germany. Six biparental populations with 92 lines each and 60 inbred lines will be planted on one-row plots in 2 replications at 3-4 locations per set and 8 locations in total. Technical challenges may be wet weather conditions in the sowing period. For the inoculation of all field-testing sites, large quantities of rust inoculum (about 15 g per year) are needed. Five to eight highly virulent single pustule isolates will be increased on a susceptible rye cultivar. Seven-days-old plants are sprayed with a 0.1% agar urediniospore suspension. After two weeks, the urediniospores can be harvested and stored at 4°C in Petri dishes over glycerol. All plots will be artificially inoculated. Inoculation was performed in the evening or early morning, when the humidity was higher. Evaluation of individual susceptibility genotypes was once blades 15 (A set) and three times at weekly intervals (sets B and C). Estimated percent area affected by the blades and uredinio- teleutospory in the period of maturity to soft wax. Each plot will be rated for the percentage of stem area covered by uredinio- or teleutospores three times starting at the beginning of yellow ripening. Ratings will be calculated for first-degree statistics. Technological challenges might arise when weather conditions are unfavourable for stem rust. Observations from the field test are based on single plot data for each experiment in each location. All statistical computations will be performed with the ASReml package in R.

## RESULTS AND SUMMARY

Wheat stem rust can attack all above-ground parts of the plant, including the stem, leaves and inflorescence. Resistance genes are only worth to be considered for breeding when they are durable and effective, show resistance against a broad spectrum of pathogen races. Effectiveness will be tested within the project by inoculating resistance sources with highly virulent isolates from Poland and Germany. Resistance mechanisms of plants either follow a gene-for-gene principle (qualitative resistance), most of which can be detected already in seedling stage or act quantitatively. Stem rust is a highly diverse pathogen and qualitative resistances are often overcome rapidly. For successful breeding, either quantitative resistances are used, or several R-genes are combined in one cultivar to minimize the number of virulent pathogen races (gene pyramiding).
Potential risk linked to the proposed methodology will be minimized as far as possible. However, there is always the risk that artificial inoculation at some field sites will not

work due to adverse weather conditions (e.g. too cool, too dry) resulting in a stem rust severity that is too low for genotypic differentiation. Disease control against stem is not possible by fungicides because the epidemics occur much later in the season than those of leaf rust (*P. recondita*) and no fungicide is registered with the indication for rye stem rust. Thus, resistant cultivars are the only solution being environmentally friendly and not producing any extra costs for rye growers.

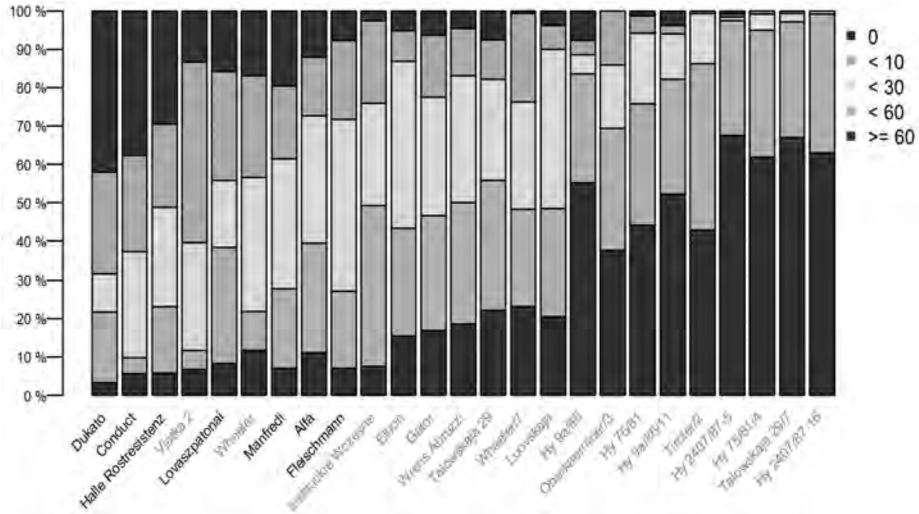


Fig. 1. Proportions electric individual objects in the first year of the study (with different levels of resistance) evaluated in the phase of a mature plant (15 blades / population 4 locations) - Set A.
The name of the color black - registered varieties.
Name in red (FSF) - a family of pełnosiostrzane selected cultivars.

Figure 1 shows the degree of infection of genotypes examined within the Set A. most infested proved Dukato and conduct the lowest paralysis was observed for variation of Fleischmann - 44 infected plants were at 10 - 30 area affected, and only about 4 infected plants was above 60 surface. of objects marked with the FSF (family selected from cultivars) proved to be the most infested Vjatka2, and most have proven to be resistant Hy 75/81/4, 29/7 Talowskaja and Hy 2407 / 87-16. Moreover, a group of objects from the FSF showed greater resistance to wheat stem rust than registered varieties.

Paralysis of the inbred lines is shown in Figure 2. For each of the sets of values are shown for the five (Set B1 and B2) or four (B3) of the village. Charts in each set were preceded by a characteristic of the total for all locations within the system. Inbred lines included B1 observed an average of 25 - 65 area affected plants. Approximately 50 all observations were located between 40 and 55 infected plant area and the average is about 50. The maximum infect recorded in Hoheneim (from 60 to 90 and 50 all observations were located between 70 and 85 infected area). Lowest infection (50 for all observations) was recorded in Petkus. B2 supplied to each object observed an average of from 5 - 55 area affected plants. Approximately 50 all observations housed between about 25 and 43 of the infested plant area and the average is about 35.

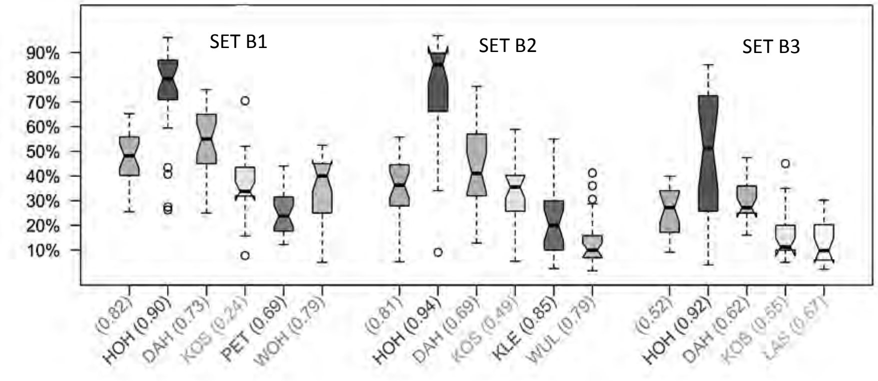


Fig. 2. Box plot graph of electric inbred lines. HOH - UHOH location (University of Hohenheim), DAH - location Danko (Laski), KOS - location Kościelna Wieś, KLE- location Kleptow, WUL - location Wulfsode

The maximum infect recorded in Hoheneim and the lowest infect recorded in Wulfsode. B3 supplied to each object observed an average of from about 10 to 40 area affected plants. Approximately 50 all observations housed between about 20 and 30 infected plant area and the average is about 28. The maximum infect recorded again in the lowest infected Hoheneim (50 for all observations) was recorded in Kościelna Wieś (Laski).

At the project, we will have proven whether for linkage mapping the LST is similarly suitable than the field test. We will have experiences with high-throughput testing and identify new stem rust resistance genes and their respective molecular markers that can directly be used by breeding companies to safeguard the income of rye growers and employees in the sector. The monitoring of pathogen races will show which resistances are still effective in practice and the most effective ones can be selected for each region.

The analyses, a high diversity and complexity of the population of wheat stem rust, both Polish and German wherein not detected pathotype of the dominant pathogen. as a result of the analyses made wheat stem rust isolates derived from single panels rust (SPI), a high virulence isolates tested, which coincided with the high average evaluation area affected blades in the analysis field. in the case of the study of parental lines of some of the tested isolates proved avirulent, and their assessment covered with poor ability to shackles lines tested in observations of field research carried out in the framework possible to obtain a highly virulent isolates of wheat stem rust necessary to test the resistance of varieties and strains of rye by breeders. This will have the added benefit of reducing or preventing future losses to this sporadic, but sometimes damaging disease. The inoculum concentration used in this study resulted in a moderate density of infection sites on plants. New pathotypes can be detected using this differential set and farmers and industry can be alerted to circumvent economic damage. In the long term, resistances from non-adapted populations should be introgressed into commercial rye cultivars.

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## 4.3. THE EFFECT OF THE FOAMING ADDITIVE ON THE POROUS STRUCTURE OF STARCH BASED FOAM MATERIALS

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**Keywords:** extrusion-cooking technique, starch based foam materials, porous structure, environmentally friendly materials

## ABSTRACT

The formation of a characteristic honeycomb structure is a very often observed phenomenon for many extrudates, also for starch based foam materials. The aim of the study was to evaluate the effect of the foaming additive on the porous structure of starch based foam materials. Structure analysis showed the effect of the amount and type of used additive on the size, density and quality of the pores. Starch based foam materials produced without the addition of functional additives were characterized by the open structure, large and irregular pores. The use of foaming agents in the production has allowed to improve the starch structure of the foam. The obtained materials were characterized by a spongy structure with numerous pores of relatively equal sizes and consistent position in the sample structure. The best effects and foamed structure were obtained for starch based materials with a 3% addition of PDE foaming agent.

## INTRODUCTION

The process of biodegradation of packaging materials is connected with organic recycling, which may take place under aerobic (composting) or anaerobic (biomethanisation) conditions (Ganjyal *et al.,* 2007, Narayan 1994, Rojek 2007, Żakowska 2005, Żakowska 2006). Biodegradation of natural materials produces valuable compost as the main product (together with water and carbon dioxide). The resulting $CO_2$ does not contribute to an increase in greenhouse gas emissions, because it is already part of the biological carbon cycle. Bio-waste not only ensures ecological waste management, but also enhances soil productivity and enables sustainable agriculture. Composting process of polymeric materials, together with other organic waste, simulates the natural recycling system, and thus the biological recycling of carbon (Narayan 1989). In the case of biodegradable packaging, the produced compost fulfils mandated quality requirements and does not have negative effect on plants and soil (Żakowska 2005). In the conditions of industrial composting, the speed of the biodegradation process is influenced primarily by the conditions of the process and the chemical features and structure of the packaging material (Jakucewicz 2006). Polymers with hydrolytically sensitive groups in the main chain are more susceptible to biodegradation. Polymeric materials with the addition of natural raw materials are used in agriculture in the production of various ornamental plants, in organic waste management systems and in the production of disposable dishes (Arif *et al.,* 2007, Izdebska and Podsiadło 2007, Lindner 2013).

## MATERIALS AND METHODS

Starch-based foam polymers obtained during the extrusion-cooking process of potato starch (raw material from PPZ Trzemeszno Sp. z o.o.) without or with the addition of foaming agents were used in these studies. Investigations of the extrusion-cooking process of starch based foam materials were carried out on a single-screw extruder-cooker type TS-45 with L/D = 12 equipped with a single die with φ = 3 mm hole. Before the extrusion-cooking process, the composed raw material mixtures were moistened to three humidity levels: 17, 18 and 19%. The extrusion-cooking process was carried out at temperatures from 80 to 160°C using 2 screw rotation speeds: 1.66 and 2.16 $s^{-1}$. The products were cut by means of a high-speed knife mounted at the head of the die. The knife rotation frequency was adapted to the assumed dimensions of the extrudates (length approx. 20 mm). In order to obtain a foamed structure, the following functional additives agents were incorporated into the mixtures in the amount of 1 to 3% by weight: Plastronfoam PDE - used for foaming thermoplastic elastomers and PVC (supplier - VGT Polska Sp. z o.o., Kraków); Polyvinyl alcohol AP - widely used in the production of biopolymers (supplier - POCH S.A., Lublin). Basic structure tests of starch-based foam materials were carried out by the optical microscope (Fig. 1) type MBL-3000T (manufacturer - microLAB, Lublin).

Fig. 1. Optical microscope type MBL-3000T.

The cross-sectional structure of the samples was studied using zoom from 40 to 200. The image was recorded by means of a digital camera Nikon Coolpix model 4500. A carbon steel scalpel was used to obtain the correct cross section of the foams (Fig. 2). Samples with a thickness of approx. 0.5 mm were prepared. The obtained structure pictures were analysed in the context of the used processing parameters of pressure and thermal treatment, i.e. moisture content of the processed mixtures, screw rotation speed of the extruder-cooker and the type and quantity of the applied functional foaming agents. The influence of the aforementioned parameters on the size and character of connections in the obtained foam pores was investigated.

Fig. 2. A sample prepared for tests.

## RESULTS

The resulting starch-based foam materials had a spongy structure and were porous as a result of the expansion process of the processed material under the influence of the extrusion-cooking process. The formation of a characteristic honeycomb structure is a phenomenon very often observed for many extrudates, particularly for starch-based foam materials (Mercier *et al.,* 1989, Mitrus 2004, Thomas and Atwell 1999). During the structural analysis, the size, density and quality of pores were taken into account. This showed the effect of the amount and type of used additive on the size, density and quality of the pores. Starch-based foam materials produced without the addition of functional additives were characterized by having open structure and large and irregular pores (Figure 3).

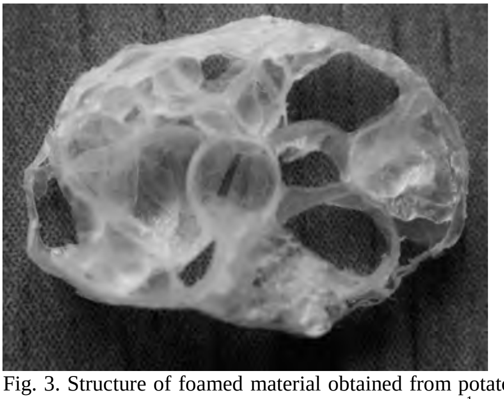

Fig. 3. Structure of foamed material obtained from potato starch without the addition of foaming agents (moisture content 17%, screw rotational speed 1.66 $s^{-1}$).

Similar results were observed when enlarged (Figures 4abc), regardless of moisture and screw rotational speed. The use of foaming agents in the production brought about improvement in the starch structure of the foam. The obtained materials were characterized by a spongy structure with numerous pores of relatively equal sizes and consistent position within the sample structure.

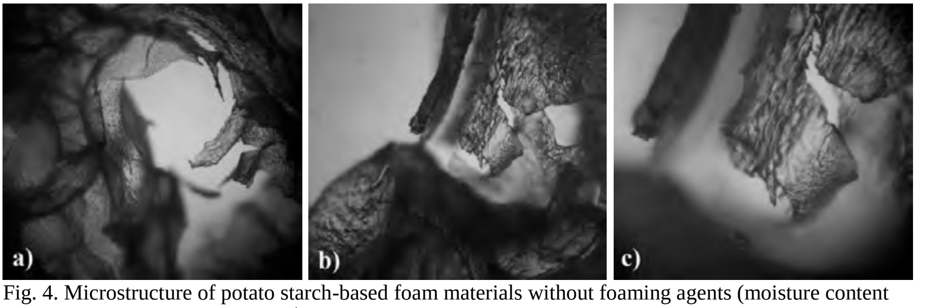


Fig. 4. Microstructure of potato starch-based foam materials without foaming agents (moisture content 17%, screw rotation speed 2.16 $s^{-1}$): a) zoom x40 b) zoom x100, c) zoom x200.

In case of PDE foaming agent addition, regular, small and mostly closed pores were obtained. Furthermore, with the increase addition of foaming agent, the volume of foam was increased. More closed pores were also formed in the structure of the foamed material, regardless of mixture moisture content and screw rotational speed (Figures

5abc). The observations of enlarged samples confirmed the perceptions of structurally better closed and more densely spaced pores (Figures 6abc).

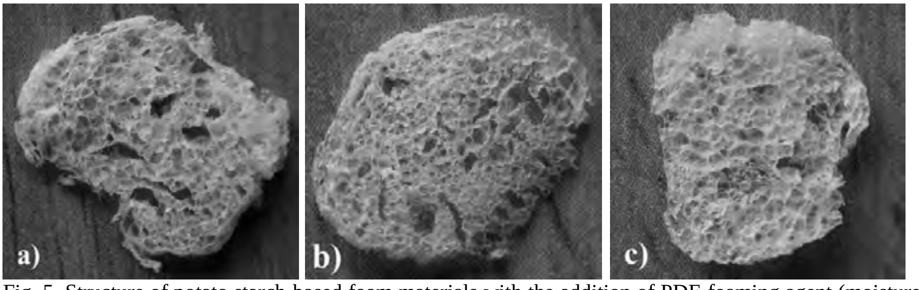


Fig. 5. Structure of potato starch-based foam materials with the addition of PDE foaming agent (moisture content 17%, screw rotation speed 2.16 $s^{-1}$): a) addition of 1%, b) addition of 2%, c) addition of 3%.

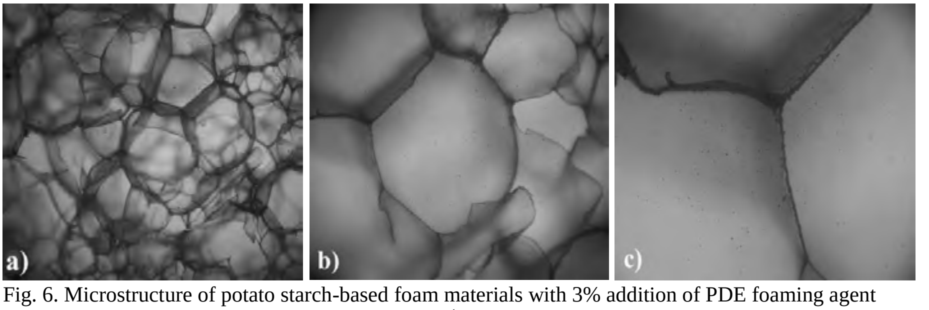


Fig. 6. Microstructure of potato starch-based foam materials with 3% addition of PDE foaming agent (moisture content 17%, screw rotation speed 2.16 $s^{-1}$): a) zoom x40 b) zoom x100, c) zoom x200.

The addition of polyvinyl alcohol AP also had positively influence on the structure of the starch-based foams. Compared to control samples made solely from starch, the extrudates were characterized by higher volume and greater number of pores (mostly closed). The higher addition of polyvinyl alcohol also allowed the greater generation of smaller pores (Figures 7abc).

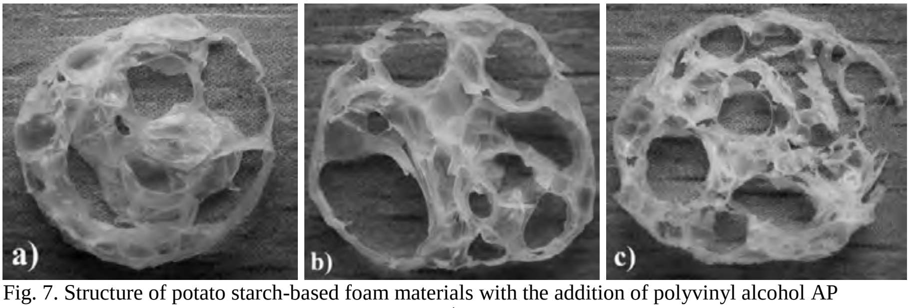


Fig. 7. Structure of potato starch-based foam materials with the addition of polyvinyl alcohol AP (moisture content 17%, screw rotation speed 2.16 $s^{-1}$): a) addition of 1%, b) addition of 2%, c) addition of 3%.

The observed results were confirmed through enlarged sample observation. Herein, starch-based foam materials produced with the addition of polyvinyl alcohol AP had a better structure in comparison to extrudates without functional additives (Figures 8abc).

Fig. 8. Microstructure of potato starch-based foam materials with the addition of polyvinyl alcohol AP (moisture content 17%, screw rotation speed 2.16 $s^{-1}$): a) zoom x40 b) zoom x100, c) zoom x200.

## CONCLUSIONS

Starch-based products can be found in everyday life. These include bags used for composting raw materials, garbage bags, household items (disposable bowls, cutlery, straws), disposable packaging film, golf equipment (ball pegs) and even personal care products (combs, disposable razors). The application of extrusion-cooking technique allows the production of foams with satisfactory spongy structure. Importantly, the obtained starch-based foam materials are environmentally friendly products. Materials produced with the addition of PDE and polyvinyl alcohol AP are characterized by the equal distribution of numerous, closed pores throughout the foam structure. No significant influence of raw material moisture content and screw rotational speed on the quality of foaming structure was observed during the studies. The best effects and foamed structure were obtained for starch-based materials with a 3% addition of PDE foaming agent. The observations of enlarged samples confirmed the perceptions of structurally better closed and more densely spaced pores.

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# 4.4. INFLUENCE OF NATURAL ZEOLITE AND NPK FERTILIZERS ON HEAVY METAL UPATKE BY REYGRASS IN A CONTAMINATED SOIL

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**Key words**: heavy metal, contaminated soil, zeolite, NPK fertilizers, metal uptake.

## ABSTRACT

Many studies have focused on the immobilization of heavy metals in contaminated soil of zeolites. Chemical fertilizers are used in agricultural soils to maintain soil fertility for sustainable crop production and quality. However, the effect of NPK fertilizers on heavy metal uptake by plants is little known. In this study, the influence of different rates of natural zeolite (0, 1.25, 2.5, 5, and 10% by weight) and a basal dose of NPK fertilizers (120-60-50 kg/ha) on the uptake of heavy metals from Italian ryegrass (Lolium multiflorium, L.) grown on a metal contaminated soil (Cambisol Rhodic, FAO, 2014) has been investigated in a pot experiment. The obtained results indicated that adding 10% zeolite reduced the contents of Cd, Cu, Ni and Zn in raygrass shoot at the end of the experiment by 37.1%, 45.3%, 92.9% and 56.1%, and the adding NPK fertilizers by 17%, 44%, 49%, 39%, respectively, as compared to control. Metal contents in roots decreased by 17% 21% 7.2% and 42.0% for Cd, Cu, Ni and Zn by the adding zeolite, and by 19%, 44.%, 3% and 26%, respectively by the addition of NPK in comparison to the control. It was found that the addition of 10% zeolite was more effective in reducing the heavy metal uptake by plants.

## INTRODUCTION

Soils around the former industrial sites in Albania are being widely used to grow food crops by local farm families. These soils have been found to be contaminated with various heavy metals (Sallaku, *et al*., 2009; Shtiza *et al*., 2005; Gjoka, *et al*., 2002). About 16500 ha of soil in the country are chemically polluted (Zdruli and Lushaj, 2001).

Our previous studies have indicated that the Cd, Pb and Cu contents in vegetable samples collected from industrial and agricultural areas exceeded the safe limit set by the Codex Alimentarius Commission for human consumption (Shkurta, *et al*., 2017; Kasa, *et al*., 2015). Use of soils contaminated with heavy metals for agricultural purposes poses a great threat to human health, as metals can be transferred and accumulate in the human body through the food chain (Jiang *at al*. 2004).

Soil contamination with heavy metals is almost irreversible, and where reversibility is attempted, the cost is high (Oldema, 1994). Thus, it is imperative that soil resources should be managed intelligently – to the best of our ability. Researchers have attempted to find suitable methods for the rehabilitation of metal contaminated soils, which consist of the use of various soil amendments. Information on the use of natural soil amendments to reduce metal uptake by plants in Albania is limited (Contin *et al*., 2019; Shkurta *et al*., 2016; Beqiraj (Goga) *et al*., 2008), and of NPK fertilizers is missing. This study was therefore undertaken to compare the effect of natural zeolite and NPK fertilizers on heavy metal uptake by ryegrass grown in a contaminated soil.

## MATERIALS AND METHODS

A pot experiment with six treatments (T1_0% zeolite, T2_1.25% zeolite, T3_2.5% zeolite, T4_5% zeolite, T5_10% zeolite, T6 N138P100K100) and four replications was carried out in 2008 in a greenhouse at the Agricultural University of Tirana, Albania, during April-June 2014.

The plastic pots were filled with 1.5 kg of dry soil-zeolite/NPK mixture. The experimental soil (Leptic Cambisols (Eutric) was collected from the surface layer (0-25 cm) of contaminated land near a former copper smelter in Rubik (northern Albania) and had a pH ($CaCl_2$) of 6.71, and contained 1.51 % total carbon, 42.6% clay, 7.44 mg/kg Cd, 299 mg/kg Cu, 140 mg/kg Ni and 228 mg/kg Zn.

We used a natural zeolite (Stilbite-Stellerite) collected from the Munella deposits (northern Albania) and chemically analyzed in the laboratories of the Soil Science and Soil Conservation Institute of Justus-Liebig University of Giessen, Germany that had a pH ($H_2O$) of 7.8, CECpot meq/100g, K 3.91 mg/kg, Na 75.90 mg/kg, Ca 1196 mg/kg, Mg 33.6 mg/kg, and Fe 33.60 mg/kg.

Seeds of ryegrass (Lolium multiflorium, L) were sown in pots. The NPK fertilizers (138, 100 and 100 kg/ha) were applied as basal dose to treatment 6 (NPK), and as top-dressing to all treatments, except T1). The pots were maintained at ambient temperature of 25°C and watered periodically with distilled water to maintain soil moisture at around 70% of WHC. The plants were cut at 52 and 82 days after sowing.

At the end of the experiment, the soil was analysed for plant availability and mobility of metals by the DTPA / TEA method (Lindsay and Norvell. 1978) and the TCLP procedure, respectively. The content of heavy metals in the plant tissue was determined by microwave-assisted acid digestion method. Metal concentrations in plant and soil extracts were determined by inductively coupled plasma-atomic emission spectrometry (ICP-AES). Data obtained were analysed by Microsoft Excel.

## RESULTS AND DISCUSSION

### Effect of zeolite and NPK on plant availability and mobility of heavy metals in soil

The results showed that adding 10% (w/w) natural zeolite decreased significantly DTPA-extractable heavy metals (Ni 29.3%, Cu 23.3%, Zn 18.8% and Cd 11.4%), while TCLP-extractable heavy metals decreased by adding 2.5% zeolite compared to control (Table 1).

Table 1. Content of metals extracted with DTPA and TCLP in the soil

| Treatment | DTPA-Soil (mg/kg) | | | | TCLP-Soil (mg/kg) | | | |
|---|---|---|---|---|---|---|---|---|
| | Cd | Ni | Zn | Cu | Cd | Ni | Zn | Cu |
| T1 | 0.70 | 2.76 | 27.1 | 133 | 0.24 | 1.09 | 10.25 | 19.01 |
| T2 | 0.74 | 2.53 | 28.7 | 128 | 0.26 | 1.10 | 11.84 | 17.25 |
| T3 | 0.69 | 2.45 | 26.8 | 105 | 0.23 | 1.08 | 10.24 | 13.08 |
| T4 | 0.75 | 2.68 | 29.2 | 115 | 0.30 | 1.40 | 12.94 | 15.41 |
| T5 | 0.62 | 1.95 | 22.0 | 102 | 0.27 | 1.13 | 10.65 | 14.73 |
| T6 | 0.65 | 2.68 | 27.2 | 90 | 0.25 | 1.23 | 10.93 | 8.44 |
| P-value | **0.002** | **0.000** | **0.000** | **0.012** | 0.098 | **0.002** | 0.133 | **0.022** |

The addition of NPK fertilizers decreased significantly DTPA-extractable Cu, Cd and Ni and TCLP-extractable Cu. The DTPA-extractable Zn and TCLP extractable Cd, Ni and Zn were increased.

The addition of zeolite at the rate of 5% w/w and NPK significantly increased heavy metals mobility from soil, except Cu. Czarnecki and Düring (2015) reported that mobile metal contents (in $NH_4NO_3$ extract$_)$ in the soils increased due to long-term mineral fertilization. Significant differences (p value <0.05) were observed on heavy metal contents between treatments, except for TCLP extractable Cd and Zn.

### Effect of zeolite and NPK on metal uptake by ryegrass

As shown in Figure 1, adding 5% (w/w) zeolite decreased significantly heavy metal uptake by ryegrass compared to control, where in the first cutting, Ni, Cd, Cu and Zn were decreased by 70.2%, 58.1%, 57.0% and 39.9%, respectively. At the end of the experiment (second cutting), heavy metal contents in shoots were decreased by 93%, 56.1%, 45.3% and 37.1% for Ni, Zn, Cu and Cd respectively, by adding 10% zeolite as compared to control. The decrease in mobility of heavy metals in treatments with zeolite can be explained by the mechanism of organic complexation Contin *et al*., 2019). Contents of Zn, Cu, Cd and Ni in plant roots decreased by 42%, 21.2%, 17% and 7%, respectively (Contin *et al*., 2019). Adding NPK fertilizers led to a decrease in the Cd, Cu, Ni and Zn contents in shoots respectively by 17%, 44%, 49% and 39%, while the respective contents of these metals in plant roots decreased by 19%, 44%, 3% and 26%. The Cd and Ni contents in ryegrass were within the normal range of heavy metal contents in plants (Cd 0.5-30, Ni 20-100 mg $kg^{-1}$), and Cu and Zn were over the normal range (Cu 2.5, Zn 0.02 -50 mg/kg) (FAO/WHO, 1976).

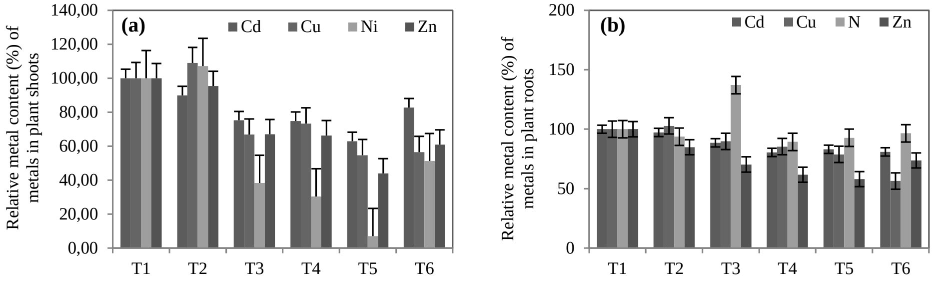


Fig. 1. Relative metal content (%) of metals in plant shoots (a) and roots (b)

### Metal transfer into plants

In order to evaluate the mobility of heavy metals by plants the transfer factor was calculated (Fig. 2). The TF values indicate that the mobility of heavy metals from soil into plants varied greatly with soil amendment (zeolite and NPK) and metal. This mobility decreased gradually with increasing the zeolite rate, except mobility of Ni, from soil into roots. Adding NPK fertilizers decreased the mobility of Cu, Cd and Zn from soil into roots as compared to control, and of Cu and Cd as compared to zeolite. Interestingly, the NPK fertilizers added had almost the same effect on Zn mobility from soil into roots, from roots into shoots, and from soil into shoots.

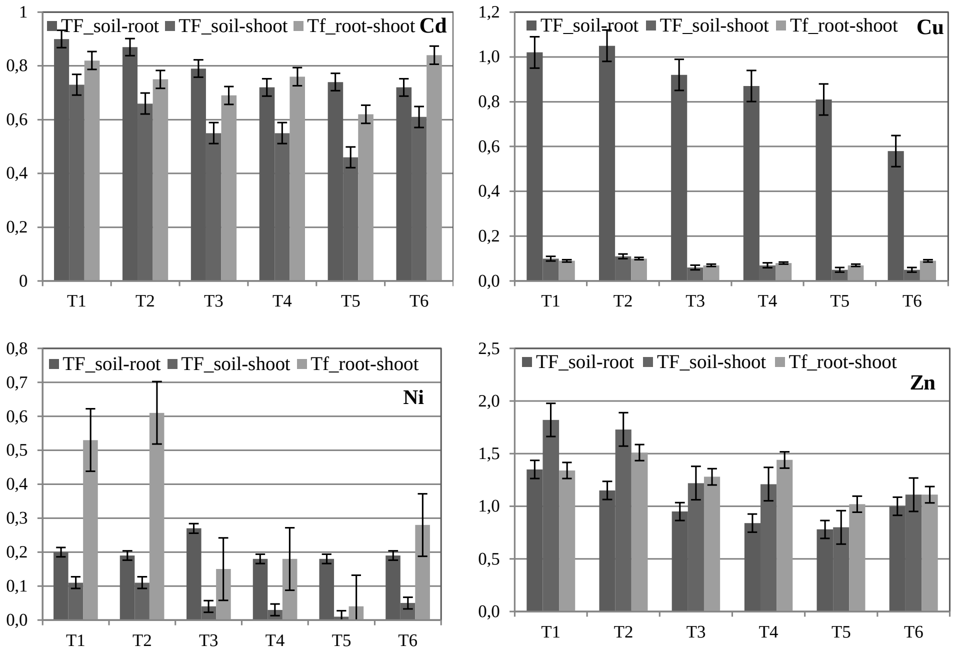


Fig. 2. Transfer factor (TF) of Cd, Cu, Ni and Zn for reygrass grown on experimental soil

## CONCLUSIONS

The adding inorganic amendments (natural zeolite and NPK fertilizers) in an industrially contaminated soil decreased the bioavailability and mobility of heavy metals and their uptake by ryegrass. From the treatments tested in this study, the adding 10% (w/w) natural zeolite worked better on decreasing DTPA-extractable heavy metals, while the adding 2.5% (w/w) zeolite has a better effect on decreasing TCLP-extractable metals as compared to control. While, the adding NPK fertilizers has a significant effect on decreasing DTPA-extractable Cu, Cd and Ni and TCLP-extractable Cu. On the other hand, the DTPA-extractable Zn and TCLP extractable Cd, Ni and Zn were increased. The adding 5% (w/w) zeolite and NPK significantly increased heavy metals mobility from soil, except Cu. The adding 5% (w/w) zeolite in first cutting and 10% at the end of experiment appeared to work better to decrease metal uptake by ryegrass. Also, adding NPK fertilizers led to a significant decrease in heavy metal uptake by plants. Results from this study indicated that the adding 10% (w/w) natural zeolite was the best treatment to decrease heavy metal availability and uptake by ryegrass. The natural zeolite can be used as a cost effective and environmentally friendly remediation material in heavy metal contaminated soils.

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# 4.5. THE STUDY OF HARD WHEAT GRINDING BY USING KNIFE MILL

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**Keywords:** knife mill, knife speeds, average particle size, specific grinding energy, grinding ability index, Sokołowski's grinding index

## ABSTRACT
The aim of this study was to determine the relations between physical properties of hard wheat and grinding characteristics by using a knife mill under different levels of speeds. Five samples of hard wheat cultivars about similar level of hardness (*HD*) were used for test. The kernel moisture content ranged from (7.4 to 7.7% w.b.). The particle size distribution of wholemeal flour was evaluated, and the grinding energy indices were calculated. It can be concluded that such properties as kernel mass, size and hardness are not always good indices of wheat milling value. The results showed that as the speed of knifes increased the specific grinding energy increased; ranging from 5.5 $kJkg^{-1}$ to 25.0 $kJkg^{-1}$. On the other hand, the grinding ability index and Sokołowski's grinding index were changing and varied when increasing of knifes speed from 0.95 $m^2/kg^{-1}$ to 2.09 $m^2/kg^{-1}$, and from 11.90 $kJkg^{-1}mm^{0.5}$ to 27.87 $kJkg^{-1}mm^{0.5}$, respectively. The statistical analysis showed in most cases there is a positive correlation between grinding indices and speeds changes, whereas the negative correlations was observed (r = -0.20) (r = -0.41) with grinding ability index for Ardente cultivar and Sokołowski's grinding index for Wintergold cultivar, respectively. Also, as the speed of knifes increased the average particle decreased, whereas mass fraction for all cultivars increased. The results revealed also that mass fraction of coarse particles (above 0.8 mm) decreased for all cultivars used at levels of increasing speed. The highest changes were observed in the fraction of fine particles (below 0.1 mm) for (Armet) cultivar at levels of speed 8000 rpm.

## INTRODUCTION

Recently, consumers' awareness of the need to eat functional foods - foods which contain ingredients that provide additional health benefits beyond the basic nutritional requirements is increasing (Ndife and Abbo, 2009). The increase in the number of whole grain products on the market together with the rise in the consumer demand for them has created an opportunity to revisit not only whole grain foods themselves (IFICF, 2013), but also milling processes and their resultant flours and meals (Jones *et al.*, 2015).. Whole wheat grain consists of bran, germ and endosperm. When refined, mainly carbohydrate rich endosperm is retained (Mellen *et al.*, 2008). It is also contained greater amounts of carotenoids and antioxidant activity than the endosperm fractions (Zhou 2004: Kumar 2011). Most of the nutritional values are concentrated in the bran layers and germ of wheat (Borneo *et al.*, 2011). However, regardless of the health benefits, there are difficulties in producing wholemeal flour that maintains the desired functionality and quality equivalent to refined grain products (Bressiani *et al.*, 2017). An increase of surface area to mass of wheat bran increased extraction of antioxidant and phenolic compounds with reduction in particle size (Brewer *et al.*, 2014). Size reduction or milling is one of the least energy-efficient operations in all of the unit operation. It increases the total surface area and particles size of the material (Asmeda *et al*, 2015). It is believed that decreasing bran particle size improves digestibility of products and improves the solubility of compounds (Hemery *et al*, 2011). The most important characteristic governing size is hardness because almost all size-reduction the techniques involve somehow creating new surface area and this requires adding energy (Sushant and Archana, 2013). And it is also one of the most important factors in assessing the quality of wheat, especially its milling value. Wheat hardness has a great influence on the milling process (Dziki and Laskowski 2005). (milling yield, flour particle size, shape and density of flour particles), baking and end-use properties (Mikulikova 2007). The hardness of the grain appears to be determined by the degree of adhesion between the starch granules and the protein matrix (Csóti *et al.,* 2005). Hard wheat varieties are typically higher in protein content (12–15%) and stronger gluten-forming proteins than soft wheat (5–10%) (Martin *et al.,* 2001). Hardness is commonly measured by using single-kernel characterization system (SKCS) and is often used to differentiate wheat classes for marketing purposes ( Anderssen and Haraszi 2009). Grain hardness is used as a grading factor to determine the type of wheat (Morris, 2002). In general, It was found a strong relationship between grain hardness and milling yield, hard wheat usually yields more flour with whiter color (Choy *et al.,* 2015). Hard grains generally gave coarser and better refined meals, and produced porridges that were firmer, compared to soft grains. (Kebakile *et al.,* 2008). Flour with coarser texture is produced by hard wheat, having broken granules of starch fracture planes and higher levels of starch damage with more power consumption in the flour mill. Hard wheat is more suitable for those breads which are leavened by yeast because broken starch granules (Peña, 2002).

Grinding is one of the most important and energy-consuming processes in cereal industry. This process consumes from 70% of total power during the feed production up to 90% during wheat flour milling. The grinding energy requirements depend on kinematical and geometrical parameters of the grinding machine and physical properties of the ground material (Glenn and Johnston 1992, Mabille *et al.,* 2001; Dziki and Laskowiki, 2006). very strong correlation between milling energy and kernel hardness (Szabó *et al.,* 2016). Especially, wholemeal flour production Such as bran ratio, and in some of the cases the higher germ content of the fractions (Tarjan *et al.,* 2009). And knowing grinding energy indices very important to describe grinding process (Hassoon and Dziki 2017). Where, it was found by (Dziki *et al.,* 2014) that wheat kernel hardness has significant and positive correlated with the grinding energy indices and the mass fraction of coarse particles, the grinding energy indices were also significantly correlated with wheat kernel, and kernel diameter (negative correlations). The physical factors affecting the grinding characteristics and flour yield are hardness, kernel size and shape (Gwirtz *et al.*, 2007). The aim of this study was to investigate the influence of speed of knifes on grinding process of hard what cultivars.

## MATIERIALS AND METHODS

Investigations were carried out on five wheat cultivars (Triticum aestivum, ssp. vulgare): Ardente, Armet, Floradur, Komnata and Wintergold. The grain came from the organic field experiment conducted in 2019 at Osiny Experimental Station belonging to the Institute of Soil Science and Plant Cultivation (State Research Institute) located in Puławy. These varieties are commercially important and commonly used in the production of the flour used for baking bread. Moreover, there are no investigations concerning the impact grinding characteristics of these cultivars. The initial moisture content of kernel ranged from 7.4 % to 7.7 % (w.b.). The SKCS (type 4100, Perten Instruments North America Inc., Reno, USA) was used to determine the hardness (*HD*), kernel weight (*KW*), moisture (*MC*), and diameter (*KD*) from the analysis of individual kernels (AACC Method 55-10, 2002). The kernels were also evaluated for bulk density (BD) (AACC Method 55-31, 2002).

The preliminary cleaned samples of individual wheat varieties (moisture content of 7.4 – 7.7 % w.b.) were ground by using the laboratory knife mill (GRINDOMIX GM 200, Germany). The 50-g samples were weighted just prior to grinding. The mill speed was adjusted to different levels: 4000, 5000, 6000, 7000 and 8000 rpm for size reduction. The mill was equipped with a computer system that allowed the recording and analysing the grinding energy consumption. The amount of energy consumed during grinding was obtained by means of a multimeter (VC 870, VOLTCRAFT®, Germany) and a computer system that recorded the data measured by the transducer. The grinding energy was calculated by using special computer software. The energy required to run the mill with no load was determined and subtracted from the total energy to obtain the grinding energy. The unloaded grinder current was monitored prior to grinding and remained constant over all testing. The specific grinding energy ($E_r$) was determined as the ratio of the grinding energy to the mass of the material taken for grinding. The sieving analysis was used to determine the particle size distribution of the pulverized material, by using a laboratory screen (Thyr 2, SASKIA, Germany), and separated into fractions using sieves of sizes, 0.800, 0.700, 0.600, 0.500, 0.400, 0.300, 0.200 and 0.100 mm. On the basis of the particle size distribution, the average particle size ($d_p$) was calculated (Velu *et al.*, 2006). The grinding ability index ($E_f$) was calculated as a ratio of the grinding energy to the surface area of the pulverized material. The surface area of the pulverized material was evaluated according to the procedure described by Jha and Sharma (2010). The Sokołowski's grinding index ($K_s$) was calculated on the basis of the size reduction theory described by Sokołowski (1996). Details of the procedure used in determining these indices can be found in Dziki (2011). The distribution of the particle size was evaluated thrice, and the values of grinding indices were calculated from the average particle size.

## RESULTS AND DISCUSSION

Knowledge of the grinding properties of grain is essential to adjust the correct parameters of grin- ding and sieving machines. It is the best way to produce higher and better quality flour. Wheat kernel properties are presented in Tables 1. The (*HD*) ranged from 74 to 89 for all wheat cultivars. According to the classification of (*HD*) proposed by (Williams, 2000), most of the wheat cultivars tested can be classified as hard wheat.

Table.1. Wheat cultivars properties

| Cultivar | *HD* | *KW* (gm) | *MC* (%) | *KD* (mm) |
|---|---|---|---|---|
| Ardente | 80 | 42.83 | 7.7 | 2.95 |
| Armet | 74 | 45.58 | 7.4 | 3.08 |
| Elsadur | 76 | 45.02 | 7.6 | 3.04 |
| Komnata | 78 | 42.53 | 7.6 | 3 |
| Wintergold | 89 | 34.04 | 7.7 | 2.75 |

Table 2. The coefficients of correlation between knifes speeds and energy indices.

| Cultivar | $E_r$ | $E_f$ | $K_s$ |
|---|---|---|---|
| Ardente | 0.92 | - 0.2 | 0.78 |
| Armet | 0.96 | 0.74 | 0.93 |
| Elsadur | 0.94 | 0.9 | 0.76 |
| Komnata | 0.97 | 0.97 | 0.97 |
| Wintergold | 0.93 | 0.65 | - 0.41 |

Table 2 shows the relationship between grinding indices and knifes speed for ground hard wheat used and it was found a positive correlation between the specific grinding energy and speed of knifes for all wheat cultivars. It was found also a positive correlation between knifes speeds and grinding ability index for (Armet, Floradur, Komnata and Lupidur) cultivars whereas in case for (Ardente) cultivar the correlation was negative (- 0.2). from the other hand, the negative correlations between knifes speed and Sokołowski grinding index was obtained only for (Wintergold) cultivar (- 0.4), while there were positive correlations for the rest cultivars used.

Table. 3. Particle size distribution (%) of the ground wheat samples.

| Revolution of speed (rpm) | Cultivar | Rang of class (mm) | | | | | |
|---|---|---|---|---|---|---|---|
| | | > 0.8 | 0.8-0.6 | 0.6-0.4 | 0.4-0.2 | 0.2-0.1 | < 0.1 |
| **4000** | Ardente | 69.69±2.8 | 7.77±0.12 | 6.75±0.19 | 8.70±0.30 | 5.54±0.08 | 1.56±0.03 |
| | Armet | 72.76±1.65 | 7.57±0.12 | 6.73±0.23 | 8.55±0.14 | 4.40±0.20 | 0.00±0.00 |
| | Elsadur | 68.48±2.45 | 8.02±0.33 | 7.26±0.23 | 10.09±0.33 | 5.65±0.16 | 0.51±0.01 |
| | Komnata | 65.41±2.28 | 8.17±0.21 | 8.12±0.09 | 10.40±0.28 | 7.32±0.13 | 0.60±0.01 |
| | Wintergold | 68.23±1.47 | 7.62±0.12 | 7.32±0.25 | 9.51±0.18 | 5.48±0.19 | 1.84±0.04 |
| **5000** | Ardente | 52.22±1.36 | 13.45±0.41 | 11.34±0.25 | 13.80±0.24 | 7.69±0.21 | 1.52±0.02 |
| | Armet | 56.79±0.97 | 12.85±0.36 | 10.80±0.34 | 12.31±0.40 | 6.33±0.09 | 0.93±0.02 |
| | Elsadur | 51.73±1.60 | 13.02±0.25 | 11.82±0.17 | 14.76±0.51 | 8.08±0.18 | 0.60±0.01 |
| | Komnata | 47.51±1.46 | 14.15±0.46 | 12.53±0.41 | 15.96±0.35 | 8.66±0.23 | 1.21±0.04 |
| | Wintergold | 51.36±2.52 | 13.43±0.50 | 12.08±0.38 | 14.69±0.40 | 7.25±0.19 | 1.21±0.03 |
| **6000** | Ardente | 31.09±0.88 | 19.94±0.68 | 17.35±0.28 | 19.59±0.38 | 10.05±0.25 | 2.00±0.04 |
| | Armet | 36.49±0.59 | 19.28±0.46 | 16.15±0.19 | 18.06±0.43 | 7.64±0.16 | 2.39±0.03 |
| | Elsadur | 31.08±1.23 | 19.45±0.72 | 17.41±0.34 | 20.09±0.67 | 10.29±0.37 | 1.70±0.02 |
| | Komnata | 26.42±0.71 | 19.67±0.37 | 18.45±0.44 | 21.75±0.54 | 10.79±0.20 | 2.94±0.05 |
| | Wintergold | 30.36±1.05 | 19.59±0.61 | 17.73±0.50 | 19.99±0.42 | 10.47±0.31 | 1.87±0.05 |
| **7000** | Ardente | 12.98±0.43 | 21.76±0.53 | 23.09±0.18 | 25.56±0.22 | 13.52±0.12 | 3.11±0.12 |
| | Armet | 16.72±0.57 | 23.31±0.66 | 22.44±0.25 | 23.76±0.38 | 11.53±0.16 | 2.25±0.07 |
| | Elsadur | 12.45±0.36 | 22.43±0.32 | 23.05±0.40 | 26.90±0.41 | 13.38±0.19 | 1.80±0.05 |
| | Komnata | 8.89±0.20 | 20.43±0.16 | 24.26±0.27 | 27.79±0.69 | 14.61±0.22 | 4.03±0.11 |
| | Wintergold | 11.07±0.17 | 21.25±0.38 | 23.68±0.24 | 27.18±0.45 | 13.49±0.28 | 3.36±0.09 |
| **8000** | Ardente | 4.60±0.11 | 17.34±0.24 | 26.54±0.82 | 31.34±1.12 | 16.15±0.44 | 4.05±0.03 |
| | Armet | 6.07±0.14 | 17.75±0.18 | 23.66±0.59 | 25.46±0.74 | 14.16±0.30 | 12.91±0.40 |
| | Elsadur | 4.14±0.09 | 16.22±0.22 | 26.87±1.03 | 33.44±1.17 | 16.92±0.26 | 2.43±0.06 |
| | Komnata | 2.30±0.05 | 13.11±0.37 | 26.47±0.95 | 35.04±0.94 | 17.40±0.41 | 5.71±0.14 |
| | Wintergold | 3.57±0.10 | 15.13±0.42 | 26.43±0.86 | 32.99±1.08 | 16.63±0.33 | 5.27±0.16 |

Table1 shows the sieve analysis results of ground material where found that increased speed of knifes from 4000-8000 rpm has influenced of decreasing number of coarse particles (above 0.8 mm) for all wheat cultivars used. From the other hand, it was found the highest mass fraction of fine particles (below 0.1 mm) increased with the same ranges of increasing knifes speeds for all wheat cultivars, Moreover, it was observed that fine mass fraction (below 0.1 mm) of Armet cultivar gave substantially and distinguished increasing when increased knifes speed from 7000-8000 rpm and it ranged from ( 2.25-12.91mm).

Fig.1. presents the results where the speed of knifes increased from 4000 to 8000 rpm, the average particle size decreased. The same tendency was found for all kind of wheat cultivars. This parameter decreased from 0.85 to 0.38 mm.

The results of specific grinding energy of the wheat cultivar of the studied wheat were shown in Fig. 2. The obtained data clearly revealed, that increasing speeds of knifes caused an increase in specific grinding energy for all wheat cultivars. The values of this parameter ranged from 5.53 $kJkg^{-1}$ to 25.02 $kJkg^{-1}$. The same tendency was found for all kind of wheat samples.

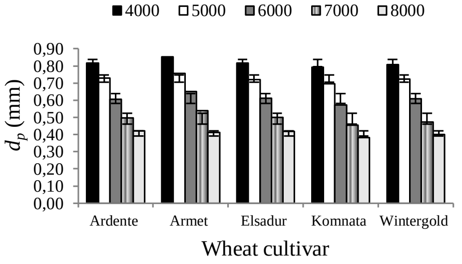


Fig.1. Average particle size ($d_p$) of hard wheat by using knife mill for different speeds.

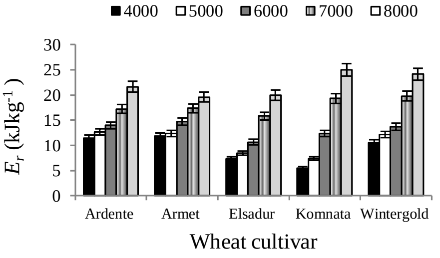


Fig.2. Specific grinding energy ($E_r$) of hard wheat y using knife mill for different speeds.

The data in Fig. 3 shows that there is a significant influence of changing speeds of knifes on the obtained results. The grinding ability index varied with increasing speeds of knifes from 0.95 to 2.09 $m^2 \cdot kJ^{-1}$. Fig. 4. shows the Sokołowski's grinding index ($K_S$). the Sokołowski grinding index ranged from 11.90 $kJkg^{-1}mm^{0.5}$ to 26 $kJkg^{-1}mm^{0.5}$.

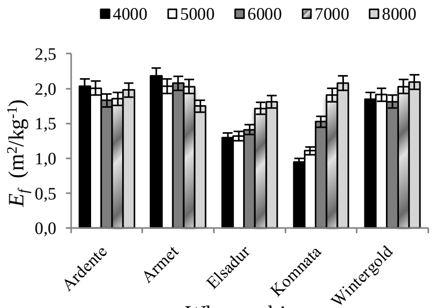


Fig.3. Grinding ability index ($E_f$)of hard wheat by using knife mill for different speeds.

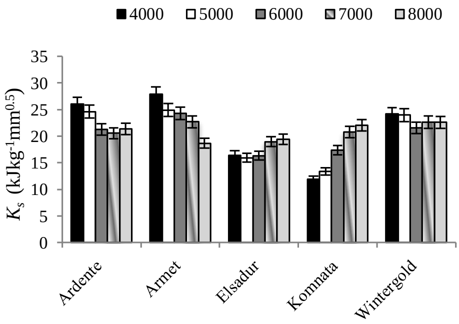


Fig.4. Sokołowski's grinding index (($K_S$) of hard Wheat by using knife mill for different speeds.

## CONCLUSION

On the basis of the results obtained it was found that an increase of the speed of knifes from 4000 to 8000 rpm caused an increase in specific grinding energy and decrease of average particle size for all wheat cultivars. It was observed that other indices of grinding, such as grinding ability index and Sokołowski's grinding index, were changing when speed of knifes increased. On the other hand, the results of changing speed of knifes has influenced values of mass fraction at different range of class, it was noticed that fractions below 0.1 have increase dramatically when speed increased from 4000 – 8000 rpm for all wheat cultivars used. Especially Armet cultivar has clearly shown tangible increased from 0.0 to 12.91 mm. It was also found that for all wheat cultivars used, the lowest values of average particle size were observed with increased knifes speed. Moreover, the significant correlations were found, in most cases, between grinding energy indices and speeds of knifes.

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# 4.6. COMPARISON BETWEEN CHAMBERS AND WINDROWS COMPOSTING SYSTEMS FOR MANURE TREATMENT

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**Keywords:** composting, aeration, windrows, reactor chambers

## ABSTRACT
Composting process is one of the best technologies for farmyard manure treatment. However, it can be done in different ways. The aim of this research was to compare manure composting processes running in two different technologies: open windrows and closed, insulated bioreactor chambers. The results have shown strong temperature growth in the case of cow and pig manures can be observed in both systems (bioreactor chambers as well as open windrows). Also, deep weight losses were found in both chambers and open windrows systems. The results have shown increasing of density much higher in case of open windrow composting comparing to process happened inside reactor chambers. Dry matter content tended to strong growth in case of open windrows composting.

## INTRODUCTION

Farmyard manure is the mixture of animal excrements with litter, which is usually cereals straw. Litter farming, which results in the production of farmyard manure, requires much greater involvement of human labour than breeding on grates (Janczak *et al.,* 2017). In this second case, slurry production is a simpler and cheaper process. Due to the high cost of human labour in Western Europe, the liquid manure system definitely dominates in animal husbandry (Cáceres *et al.,* 2015; Cáceres *et al.,* 2018). In turn, in Poland, where until recently the cost of human labour in agriculture was low, the production of manure exceeds the amount of manure produced several times. As a consequence, out of nearly 100 million tons of livestock manures produced in Poland, nearly 80 million is farmyard manure, and only less than 20 million is slurry (Kozłowski *et al.,* 2019). This is a completely different situation than in Western Europe, where manure production, apart from small farms, is much less common than liquid manure systems (Scarlat *et al.,* 2018).

There are several different technologies for manure management. However, it seems that only two are reasonable: composting and anaerobic digestion (Lin *et al.,* 2018). Composting process is related with the decomposition of organic matter and its transformation in divers valuable products (Czekała *et al.,* 2017; Czekała *et al.,* 2019; Cerda *et al.,* 2018). This technology is usually realized within open windrows (wiht usage of specialized tractor aerator or manure spreader) or in big scale composting chambers with forced aeration.

However, many specialists have different opinions about both technologies (Sołowiej *et al.,* 2017; Czekała *et al.,* 2019; Ermolaey *et al.,* 2019). Some of them underline that closed chambers make easier control of the whole process (Jiang *et al.,* 2019). And other researches showed the big advantages of windrows composting, especially easier mechanization processes and deep mass losses (Bhattacharjee *et al.,* 2016). However, there is not enough research related with the impact of different technologies on cow and pig manures.

The aim of this research was to compare manure composting processes running in two different technologies: open windrows and closed, insulated bioreactor chambers.

## MATERIALS AND METHODS

In this study, two different composting systems were analysed:

a) Chamber system (ChS): composting of manure realized inside bioreactor chamber with an insulation layer and continues aeration.

b) Windrows system (WS): composting of manure which was realized in windrows aerated temporary with machinery usage (manure spreader and loader);

The experiments were made in two places: open windrow composting (WS) trials were realized in the medium-size agricultural farm placed in South-West from Poznań (Wielkopolska) and composting in bioreactor chamber system (ChS) was made in Ecotechnologies Laboratory (EL) at Institute of Biosystems Engineering, Poznań University of Life Sciences. Ecotechnologies Laboratory is the biggest Polish composting and biogas laboratory (with over 20 bioreactors for composting process optimization and 250 different fermenters).

The materials tested during the experiments were cow manures (from different dairy farms) and pig manures (from university experimental farm and private farm). Two experiments were made (with windrows and chamber systems). During the experiments, we have used follow manures:

a) Experiment with chamber system:

CM1 Cow Manure 1 (from experimental university farm in Przybroda),

CM2 Cow Manure 2 (from experimental university farm in Brody),

PM Pig Manure (from experimental university farm in Złotniki).

b) Experiment with windrow system:

PMA Pig Manure Autumn composting (in privet farm in Wielkopolska South-West),

PMW Pig Manure Winter composting (in privet farm in Wielkopolska South-West).

In the chamber system experiment, the tested manures were taken from fresh windrow and transported to EL. The samples for basic physical and chemical analysis were taken. After that the manures were put inside the bioreactor chambers (fig. 1). After filling, the chambers were closed and the aeration system was turned on.

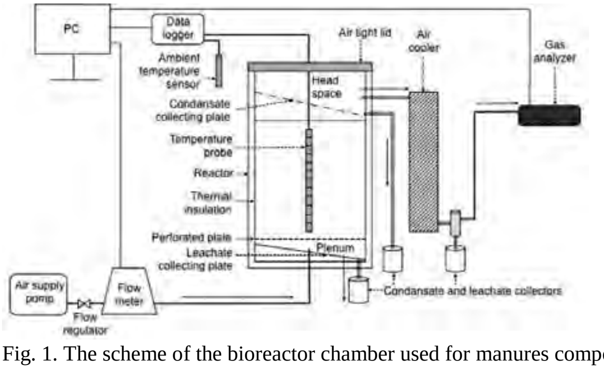


Fig. 1. The scheme of the bioreactor chamber used for manures composting process (Janczak *et al.*, 2017)

In case of windrows composting, the manures were loaded on manure spreader and the spreader moved to the balance in order to check the manure weight. Then the creation of windrow was done by spreader which moved very slowly (1 m each 15-20 seconds). This let us to create the windrows with height up to 1.4 m which is enough for correct composting process. In both composting systems, the material was mixed (ChS manually, WS by spreader usage) in the second week of composting.

In both cases of composting, the whole material was analysed for weight, volume and basic physical and chemical parameters. The dry matter content was made with the Polish Norm PN-75 C-04616/01 (by drying samples, in 3 repetitions, in 105$^{o}$C by 24 hours), organic matter content was analysed with the norm PN-Z-15011-3 by combustion of dry samples (in 3 repetitions) in 525$^{o}$C within 3 hours.

**RESULTS**

The results have shown that for both systems – chamber system (ChS) as well as windrows system (WS), the temperatures during thermophilic composting phase largely exceeded level of 70$^{o}$C (fig. 2 and fig. 3). This is very important from a sanitary point of view because manure being under temperature over 70$^{o}$C for at least one hour is treated as material free from dangerous microorganisms.

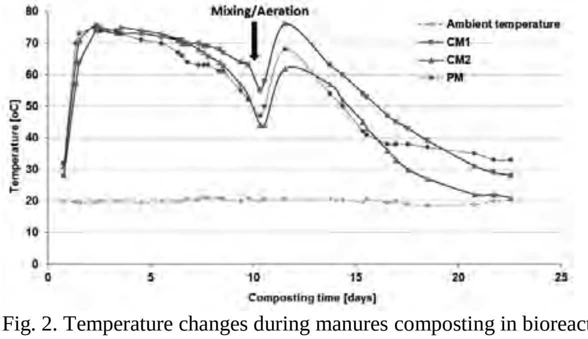


Fig. 2. Temperature changes during manures composting in bioreactor chambers

The analysis of fig. 2 shows clearly that in case of both manures (cow and pig) it was possible to reach a long thermophilic phase with the maximum temperature inside the reactor reaching 75$^{o}$C. It has to be also underlined that the mixing of the composted material made on the 10$^{th}$ day of the process had a very strong impact on the second growth of temperature (average increasing was over 20$^{o}$C).

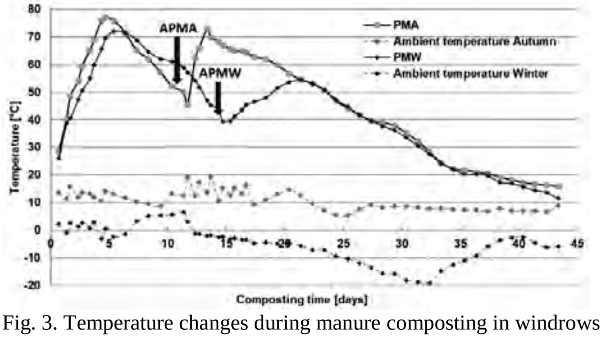


Fig. 3. Temperature changes during manure composting in windrows during Autumn and Winter seasons; APMA – Aeration of Pig Manure in Autumn, APMW - Aeration of Pig Manure in Winter

The effect of secondary temperature growth (after mixing) concerns also windrow composting (fig. 3). However, it has to be underlined that the composting process has huge energetic potential. The outside temperature during winter composting experiment (PMW) was below 0°C within more than 30 days, reaching in coldest days -19°C. But even under such low temperature, the tested windrow kept the long thermophilic phase. The growth of temperature was related with strong water vapour and $CO_2$ emissions, which had the direct impact on reduction of composted materials mass (tab. 1.).

Tab. 1. Weight changes during manures composting process in bioreactors

| Parameter | CM1 | CM2 | PM | Unit |
|---|---|---|---|---|
| Initial weight | 43.9 | 40.47 | 40.73 | kg |
| Final weight | 24.74 | 22.57 | 24.56 | kg |
| ***Loss of weight*** | ***43.64*** | ***44.23*** | ***39.70*** | ***%*** |

The weight losses were between 39.7 and 44.23% and those values are quite typical for composting process run in correct conditions. It has to be noted that pig manure had a little bit smaller mass losses comparing to cow manure.

Tab. 2. Weight changes during manures composting process in windrows during Autumn and Winter experiments

| Parameter | PMA | PMW | Unit |
|---|---|---|---|
| Initial weight | 2630 | 2781 | kg |
| Final weight | 1392 | 1724 | kg |
| ***Loss of weight*** | ***47.07*** | ***38.01*** | ***%*** |

The pig manure composted in windrows has shown big differences between autumn and winter process (tab. 2.). It should be closely related with outside temperature because temperature below 0°C influenced on creation icy surface on windrow surface which decreased the evaporation process and, in consequence – lower mass losses.

Tab. 3. Density changes during manures composting process in bioreactors

| Parameter | CM1 | CM2 | PM | Unit |
|---|---|---|---|---|
| Initial density | 302.76 | 305.43 | 313.31 | $kg/m^3$ |
| Final density | 309.25 | 300.93 | 350.86 | $kg/m^3$ |
| ***Changes*** | ***2.10*** | ***-1.50*** | ***10.70*** | ***%*** |

The bioreactor chambers were completely closed and only one gas outlet let to evacuate the gases from aerated materials. However, part of evaporated water had condensed on the bioreactor ceiling and dropped again to the composted material. However, the special system (condensate collecting plate – fig. 1) let to keep the moisture and density on the similar level (tab. 3.).

Tab. 4. Density changes during manures composting process in windrows during Autumn and Winter experiments

| Parameter | PMA | PMW | Unit |
|---|---|---|---|
| Initial density | 341.5 | 331.10 | $kg/m^3$ |
| Final density | 623.6 | 497.4 | $kg/m^3$ |
| ***Changes*** | ***45.24*** | ***33.43*** | ***%*** |

The windrows composting had strong influence on density increase. It was related with initial porous structure (after windrows formation by spreader) which reached the height up to 1.4-1.5 m. Then, within the temperature growth and decomposition of straw (structural material for windrow), the whole windrow tended to collapse and reach the height on level 0.5-0.7 m. The consequence is strong growth which can be observed in table 4.

Tab. 5. Dry mass changes during manures composting process in bioreactors

| Parameter | CM1 | CM2 | PM | Unit |
|---|---|---|---|---|
| Initial dry mass | 24.26 | 18.19 | 24.59 | % |
| Final dry mass | 21.99 | 25.28 | 25.59 | % |
| ***Changes*** | ***-10.32*** | ***28.05*** | ***3.91*** | ***%*** |

Dry mass changes during composting experiment have different ways and are difficult to explain (tab. 5., tab. 6.). Those difference should be related with different dynamic of temperature growth which means different intensity of organic matter decomposition.

Tab. 6. Dry mass changes during manures composting process in windrows during Autumn and Winter experiments

| Parameter | PMA | PMW | Unit |
|---|---|---|---|
| Dry initial mass | 26.15 | 24.24 | % |
| Dry final mass | 48.24 | 33.43 | % |
| ***Changes*** | ***45.79*** | ***27.49*** | ***%*** |

In the case of both composting experiments (autumn and winter), it can be observed clear growth of dry matter content. This phenomena is much stronger than in the case of composting chamber system. It is related with the fact that in an open windrow system, the water vapour and $CO_2$ can easily move to the natural environment comparing to closed chamber system. So in case of losing mass necessity (for some organic waste), the open windrow biowaste composting seems to have much bigger potential than composting in bioreactor chambers on a large scale.

## CONCLUSIONS

On the base of research made in this paper, the following conclusions were formulated:

- The strong temperature growth in the case of cow and pig manures can be observed in both systems (bioreactor chambers as well as open windrows).
- The deep weight losses are characterized for composting process and can be found in both, chambers and open windrows systems.
- The real-scale windrows have a much bigger tendency to increase the density comparing to the bioreactor chamber. However, with the huge size, industrial scale chambers (i.e., 500 $m^3$), the effect of density growth can also be increased.
- Open system composting has much bigger potential for dry matter increasing because of much intensive evaporation effect during the thermophilic phase.

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# 4.7. THE INFLUENCE OF METAL NANOCOLLOIDS ON SELECTED FACTORS OF THE QUALITY OF PUMPKIN LEAVES

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**Keywords:** process of fertilization, nanocolloids, pumpkin seedlings, carotenoids, chlorophylls

## ABSTRACT

One of the elements of sustainable agriculture is taking care of the development and quality of the obtained crop yields by applying the fertilization process. Therefore, the paper attempts to determine the effect of three concentrations (0.005%, 0.01% and 0.015%) of silver and copper nanocolloid solutions (AgNC and CuNC) applied as foliar spray to pumpkin leaves of 'Miranda' cultivar. Collected material was analyzed towards the content of basic pigments in the form of carotenoids and chlorophylls (chl *a* and chl *b*). Plants were grown in hydroponic cultivation and samples were collected on 22nd and 29th days of plant growth. Based on the results obtained, it was found that the plant, after using silver and copper nanocolloid solutions, reacts strongly to the administered substance by triggering the defence mechanisms. The confirmation of this thesis was that on the first day of sampling and analysis after the use of AgNC, there was some decrease in the content of chlorophylls *a* and *b*, and in the second term, in both cases, the increase of this pigment levels in pumpkin leaves. Similar situation was also recorded for the content of carotenoids.

## INTRODUCTION

Nanoparticles of metals (AgNP, AuNP, CuNP, and ZnNP) (Dumont *et al.*, 2015) and metal oxides (e.g. $nCeO_2$, nCuO, $nTiO_2$, and nZnO) are increasingly introduced into agricultural processes and products through the use of e.g, pesticides (Khot *et al.*, 2012) and herbicides (Dubas and Pimpan 2008). The presence of nanoparticles in the soil environment raises a number of concerns as to their potential impact on soil ecosystems and the quality of the food produced. As suggested by Ma *et al.*, (2015), there are two paths through which nanoparticles can transfer inside the plant, specifically from the root to the leaf, or from the fruit or the leaf to the root. Both of the same have been discussed in publications pertaining to hydroponic (Hernandez-Viezcas *et al.*, 2016) or soil culture (Rico *et al.*, 2015) cultivations.

Plants constitute important receptors of the terrestrial compartment condition, so when NPs are present in the soil, they become a potential path of nanoparticle intake, translocation and bioaccumulation within the food chain (Garcia-Gomez *et al.*, 2015). Excessive use of nanoparticles can have a direct, toxic impact on plant tissues, including of chlorosis, root development, rate of photosynthesis, production of reactive oxygen species (ROS), or occurrence of oxidative stress (Xu *et al.*, 2018). The analysis of plant photosynthetic capacity is one of the most convenient parameters allowing the detection of nanoparticle-induced stress. Numerous literature reports mention a correlation between NPs and energy transfer effectiveness in isolated environments, which indicates an impact on the photosynthetic processes taking place in the studied plants. In the case of zNnO, the influence on photosynthesis varied depending on the plant species (Zhao *et al.*, 2013; Dimkpa *et al.*, 2012) but was also affected by the concentration of the compound used and the stage of the plant's development. Zhao *et al.*, (2015) concluded that the use of nZnO (24±3 nm) at 800 $mg \cdot kg^{-1}$ resulted in a decrease in the chlorophyll content in corn after 20 days of cultivation. The impact of new nano-fertilizers on the yield and quality of products, as well as the related risks to human health and the natural environment, remain largely unknown. The aim of this study was to examine plant chlorophylls and carotenoids content in pumpkin seedlings after application of spraying (stressors) to plants grown in hydroponic conditions (AgNC silver and CuNC copper nanocolloids).

## MATERIALS AND METHODS

The analysis consisted in confirming the content of nanocolloid in the preparations. It was carried out at the Central Laboratory of Electron Microscopy, UMCS in Lublin. The AFM atomic force microscope from Veeco (USA) NanoScope V was used to map the solid surfaces in three dimensions in the magnification range from 2000 to 500,000 times. The reliability of measurements is in accordance with the PN-EN ISO/IEC 17025 standard. Preparations for AFM microscopy were obtained by applying a drop of solution to a mica plate adhered to a metal disc and evaporating the solution. The measurements were carried out at room temperature. Records obtained using AFM were processed in the Nanoscope Analysis software (Bruker).

In the experiment, non-encapsulated seeds of Polish pumpkin cultivar 'Miranda' were used. Nano-materials for the study were two commercially available products in 1L bottles represented by silver and copper nanocolloids at a concentration of $\geq 0.1\%$ (1000ppm) for silver (1KAg) and $\geq 0.1\%$ (1000ppm) for copper (1KCu) produced by ITP-SYSTEM Ltd. in Dąbrowa Górnicza, Poland.

In order to carry out the experiment to determine the impact of abiotic stress on the plant, pumpkin seeds were placed in a 70% ethanol solution for surface sterilization (30 s). They were then transferred to a 1.5% solution of sodium hypochlorite (NaClO) for 15 min. After this time, the seeds were washed five times in distilled water and then laid on round plastic trays 30 cm in diameter lined with a paper towel. Each tray contained about 500 seeds. They were moistened by pouring about 100 ml of distilled water into each tray, then covered with aluminium foil and inserted into the phytotron FD 711 DD INOX to germinate under the following conditions: relative humidity 60% at 20/18 °C day/night, in the dark. Seeds were ventilated daily. The germination process lasted 7 days.

The nanocolloids silver and copper solution (50, 100 and 150 ml) was prepared at room temperature. Measured proportions of nanocolloids were added in addition to 1 litre of sterile distilled water (SDW) and stirred at room temperature for 15 min. The concentration of AgNC and CuNC after addition to 1 litre of SDW was 0.005%; 0.01% and 0.015%.

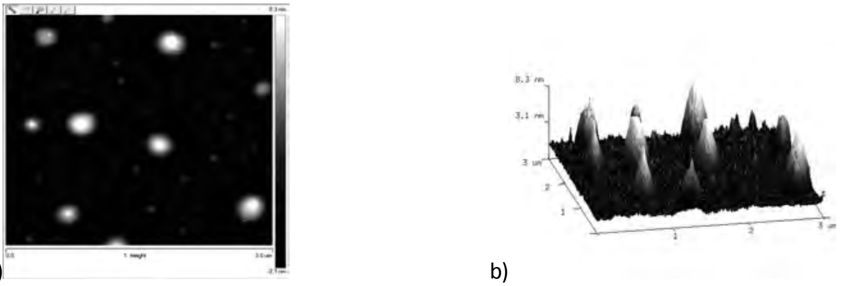
After germination of seedlings to a similar size with well-developed roots and having about 1.5cm length, seedlings were transferred to a modified, aerated Hoagland medium with optimum pH 6. Plants were grown in phytotron for the next 21 days under the following conditions: relative humidity 60%, temperature 20/18 °C day/night, photoperiod 18/6h day/night. After 21 days, the seedlings were sprayed with a prepared variant of nanocolloids in amount of about 4 ml (AgNC and CuNC at 3 different concentrations: 0.005%; 0.01% and 0.015%). After spraying, the samples were grouped in variants to avoid possible contact with plants treated with other concentrations. Analytical material was collected on day 22 (after first spraying with nanocolloid) and on day 29 of the plant life. For the biochemical analysis, the first leaves were separated from each of 30 plants, then their central parts were separated by weighing 0.5 g samples and then frozen at -60 °C.

Determination of chlorophylls (chl) *a* and *b* and carotenoids (car) in pumpkin seedlings (green leaves) was performed by spectrophotometric method using Jaco V-630 double beam spectrophotometer with UV-VIS beam. The results are expressed in $\mu g \cdot ml^{-1}$ and estimated for the average of three replicates according to the procedure by Lichtenthaler and Buschmann (2001).

Achieved results were analysed statistically by considering all variables, for which the mean values ± SD were calculated. For the content chlorophylls and carotenoids results were expressed as mean ± standard deviation (n=9). Statistical significance of differences among treatments were determined using one-way analysis of variance and covariance (ANOVA) followed by Tukey's at a significance level of $P<0.05$.

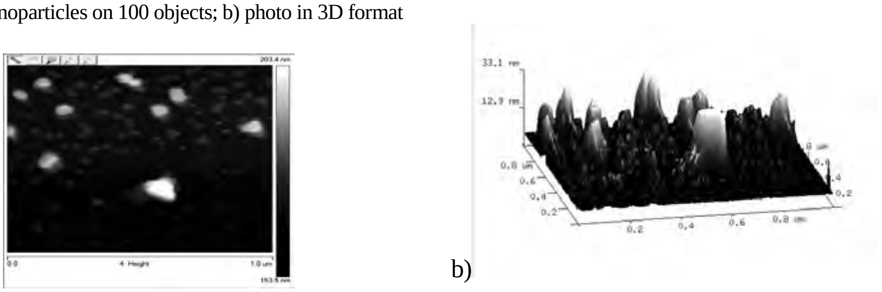
**RESULTS**

The average area of the analysed zone for the silver nanocolloid was 14559.980 $nm^2$ (Figure 1). The minimum particle height in the nanopreparation was 1.11 nm, while the maximum was 21.38 nm. In the case of observed particles of the copper nanocolloid, the area under study was 2505.493 $nm^2$ (Figure 2). The minimum average height of visible nanoparticles was 20.319 nm and maximum 64.942 nm.



a) b)

Fig. 1 AFM analysis results for AgNC: a) image in 2D format according to particle height and distribution of nanoparticles on 100 objects; b) photo in 3D format



a) b)

Fig. 2 AFM analysis results for CuNC: a) image in 2D format according to particle height and distribution of nanoparticles on 100 objects; b) photo in 3D format

The content of pigments in pumpkin leaves after application of nanocolloids is shown in Table 1. In the experiment, for which the application of the silver nanocolloid was assumed, the content of chlorophyll *a* (chl *a*) and *b* (chl *b*) in the control sample of plants at day 22 was respectively 32 $\mu g \cdot ml^{-1}$ (chl *a*) and 12.36 $\mu g \cdot ml^{-1}$ (chl *b*). In the case of carotenoids (car), their amount in the control for the 22 day of plants growth was 4.52 $\mu g \cdot ml^{-1}$. The chlorophyll content after AgNC application was reduced in each of applied concentrations. The achieved values were lower than those obtained in the control sample by 25.94%, 9.06% and 22.06%. The amount of chl *b* was also reduced by a 20.23%, 21.28% and 12.14% as compared to the control. On the first day after spraying with silver nanocolloid, a decrease in the content of carotenoids in pumpkin leaves was also observed. Its content has decreased respectively by 46.02%, 8.85% and 20.58%.

Values of the amount of pigments in control samples on the 29th day of plant growth were respectively 25.84 $\mu g \cdot ml^{-1}$ (chl *a*), 9.98 $\mu g \cdot ml^{-1}$ (chl *b*) and 2.68 $\mu g \cdot ml^{-1}$ (car). The content of analysed pigments in leaves was increased in each of the applied concentrations. In the case of chl *a*, the increase, in comparison to the control group, was 4.6%, 31.7% and 33.2%, respectively. The content of chl *b* was higher by 11%, 31% and 35.7%, respectively. The amount of carotenoids in leaves was higher respectively by 4.8%, 98.8% and 84.3%.

For variants and plants samples, where the copper nanocolloid (CuNC) was applied, the obtained amounts of pigments in control samples for the 22nd day of plant growth were equal to 24.79 $\mu g \cdot ml^{-1}$ (chl *a*), 10.19 $\mu g \cdot ml^{-1}$ (chl *b*) and 3.51 $\mu g \cdot ml^{-1}$ (car). For the amount of chlorophyll *a* and *b*, their growth was observed at all applied concentrations. For chl *a*, the amounts recorded were higher than those in the control sample by 24.5%, 29.5% and 33.6%. An increase of 8.7%, 23.2% and 25.9% was observed for chl *b*. Application of the copper nanocolloid and carrying out analyses at day 22 of plant life showed that the amount of carotenoids increased only at 0.005 and 0.01 % concentration by 16.3% and 4%, respectively. After applying the concentration of 0.015%, a 44% reduction in the content of carotenoids in the analysed material was observed.

In the case of analyses performed at the 29th day of plant life, the content of pigments in the control sample was 24.5 $\mu g \cdot ml^{-1}$ (chl *a*), 8.91 $\mu g \cdot ml^{-1}$ (chl *b*) and 3.42 $\mu g \cdot ml^{-1}$ (car), respectively. After applying the concentration of 0.005 %, in both cases, the chlorophyll *a* and *b* amounts slightly decreased by 0.16% (chl *a*) and 1.35% (chl *b*). At other concentrations, an increase in the content of this pigment was noted for chl *a* 13.7% and 9.2%, while for chl *b* 18.5% and 9.3%. Content of carotenoids has also changed. For concentrations of 0.005 and 0.01 %, reductions of 19.3% and 28.6% were observed. For 0.015%, a slight increase by 3.5% was recorded.

Table 1. Content of chlorophylls and carotenoids in leaves of pumpkin.

| Day of growth | Nanocolloid | Pigments | Control | 0.005 | 0.01 | 0.015 |
|---|---|---|---|---|---|---|
| | | $\mu g \cdot ml^{-1}$ | | % | | |
| 22 | AgNC | chl *a* | 32.0±0.56A | 23.7±1.40aA | 29.1±0.39aA | 24.9±1.02aA |
| | | chl *b* | 12.3±0.55A | 9.86±1.23aA | 9.73±0.59aA | 10.8±0.21aA |
| | | car | 4.52±0.16A | 2.44±0.35aA | 4.12±1.03A | 3.59±0.34aA |
| 29 | | chl *a* | 25.8±0.24A | 27.0±0.79A | 34.4±0,76aA | 34.4±1.34aA |
| | | chl *b* | 9.98±0.51A | 11.0±0.76aA | 13.8±0.13aA | 13.5±0.76aA |
| | | car | 2.68±0.51A | 2.81±1.19A | 5.33±1.32aA | 4.94±0.20aA |
| 22 | CuNC | chl *a* | 24.8±0.71A | 30.9±0.55aB | 32.1±0.80aB | 33.2±0.63aB |
| | | chl *b* | 10.1±0.69B | 11.7±0.95B | 12.5±0.87aB | 12.8±1.05aB |
| | | car | 3.5±0.21A | 4.08±1.11B | 3.86±0.48A | 1.96±0.48aB |
| 29 | | chl *a* | 24.5±1.56B | 24.4±1.68B | 27.8±1.46aB | 26.7±0.97aB |
| | | chl *b* | 8.91±0.44B | 8.79±0.66B | 10.5±0.06aB | 9.74±0.86B |
| | | car | 3.4±0.48A | 2.76±0.83A | 2.4±1.00aB | 3.54±0.50B |

Mean values ± SD (n=9); a - significant difference in relation to the corresponding control ($P<0.05$); A, B - significant difference in relation to the corresponding concentration in days ($P<0.05$)

## DISCUSSION

The pigment content analysis conducted in the present study revealed that on the 22nd day, the content of the concentration of the analysed pigments in the leaves of pumpkin grown in a hydroponic cultivation after the application of nanocolloids (silver and copper) was reduced in all experimental variants. The application of silver nanocolloid (AgNC) resulted in a decrease of the pigment content with the increasing concentration of the solution used (e.g.: in the case of chl *a* from 23.7 $\mu g \cdot ml^{-1}$ for the lowest concentration to 24.94 $\mu g \cdot ml^{-1}$ for the highest*).* In the case of foliar application of NKCu, the plant's reaction was the opposite – the higher the solution's concentration, the higher the pigment content (e.g.: in the case of chl *a* from 30 $\mu g \cdot ml^{-1}$ for the concentration of 0.005 % to 33 $\mu g \cdot ml^{-1}$ for 0.015 %). The obtained results indicate that the application of nanoparticles at the early stage of plant development inhibited the production of chlorophylls and carotenoids, but at the later stages of plant growth the plants' defence mechanisms were able to better handle the interference (stress) resulting from the application on the $29^{th}$ day of plant growth. The obtained results were consistent with those reported by other authors. Mahmoodzadeh *et al.,* (2013) paid special attention to the fact that higher accumulation of chlorophyll in plant leaves may result from a complementary interaction and amounts of other immanent nutrients such as magnesium, iron or sulphur. Content of carotenoids in plant leaves is considered one of the fundamental photosynthetic pigments that are strong ROS quenching substances, namely singlet oxygen ($^1O_2$) by intercepting the triplet-chlorophyll (Young 1991). They also act as pigments that absorb light, photons and transfer the excitation energy to chlorophyll, which finally reaches the reaction site. Carotenoids also serve as precursors to signalling molecules that influence plant development and biotic/abiotic stress responses (Li *et al.,* 2008). Lidon and Henriques (1991) found that applying CuNP changes the chlorophyll content and changes the structure of chloroplast and tylacoid membrane in spinach, rice, wheat and bean leaves in experimental growth conditions. In experiments performed Taran *et al.,* (2017) reported 13% increase in chlorophyll content in wheat plants of 'Stolichna' cv. originated from grains soaked with CuNPs as compared to the control. Moreover, chl *a* to chl *b* ratio in leaves of wheat seedlings changed due to the influence of combined action of CuNPs with ZnNPs. Analyses of carotenoids content in leaves of 'Stolichna' cv. decreased by 10% after application of NP (Taran *et al.,* 2017). They observed remarkable increase in chlorophyll content in the subapical leaves of soybean plants, although it did not lead to an increase in photosynthetic productivity. Trujillo-Reyes *et al.,* (2014), when analysing the chlorophyll content in lettuce leaves after application of nanoparticles with $CuSO_4 \cdot 5H_2O$ and Cu/CuO NPs at 10 and 20 $mg \cdot l^{-1}$ concentration found that the amount of chlorophyll decreased respectively by 17%, 13% and 14% in relation to values achieved for the control. In studies carried out by Hatami and Ghorbanpour (2013), addition of AgNP at concentration of 80 $mg \cdot cm^{-3}$ contributed to the decrease in pigments content in plasticids in pelargonium cultivars. Applying AgNPs by Farghaly and Nafady (2015), invoked considerable stimulation of chl *b* and car pigments fraction, except from chl *a*, in tomato plant. Treatment of wheat seedling with AgNPs did not show any significant improvement as compared to the control sample. It can be agreed with the findings of Pandey *et al.,* (2014) that the chlorophyll content increased with increasing the AgNP concentration, but the effect of CuNPs on chlorophyll might be different. These differences may result from differences in the reactivity of released ions from CuNPs and Cu released by CuO (Trujillo-Reyes *et al.,* 2014).

## CONCLUSIONS

The use of modern chemical fertilizers is the most important in plant nutrition and protection. Mixed fertilizers can be formulated in hundreds of ways. Applied of modern chemical fertilizers with nanocolloids ensure growth and protection plants. The content of pigments (chl *a*, chl *b* and car) on day 22 of plant growth in pumpkin leaves after application of silver nanocolloids (AgNC) in all considered concentrations was lower than in the control sample. On day 29, the plant coped with unfavourable effects of the nanocolloid and the content of all pigments increased. After application of the CuNC at 22 day of plant life, the content of chl *a* and chl *b* was higher than in controls at each concentration. However, the amount of carotenoids was reduced along with the increasing concentration of copper nanocolloid. At 29 day of plant life, the content of chl *a* and chl *b* and for car was higher than in the control only at a higher concentration.

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# 4.8. THE EFFECT OF DIGESTATE FERTILIZATION ON QUALITY AND STRENGTH ON RAPESEEDS

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**Keywords:** digestate, spring rape, strength, sustainable agriculture

## ABSTRACT
The main direction of digestate management, after taking into account its physicochemical properties, should be a bio-fertilizer use. The digestate taken from the agricultural biogas plant was tested for the content of macronutrients and heavy metals. The content of macronutrients was also tested in soil before and after digestate application. The digestate was used for winter oilseed rape. Analysis of fat and protein content in seeds showed good quality of winter oilseed rape. It was found possible to use digestate as fertilizer. The paper presents results of tests on compressive strength and elastic deformation of three rapeseed cultivars (Bios, Feliks, Markus). Each of the cultivars was cultivated by three methods, i.e. fertilization with digestate, NPK fertilizers and a control combination without any fertilization. Based on the research, it was found that the use of digestate and compound fertilizer shows higher compression strength of single seeds (16.18 N; 14.75 N) and elastic deformation (0.315 mm; 0.302 mm) than control combinations (12.93 N; 0.254 mm).

## INTRODUCTION

Agricultural production, which aims to produce food with good quality parameters, must be carried out in accordance with the requirements of environmental protection. It is important to maintain the safety of the fertilizers use in agricultural environment with particular regard to nitrogen fertilizers. Fertilizers used in liquid form get into the soil solution faster and are better absorbed by plants.

Anaerobic fermentation is a promising process in agricultural practice. It can reduce the negative impact of waste on the environment. One of the by-products generated during anaerobic fermentation is digestate (Makádia *et al.,* 2016). During anaerobic fermentation, total nitrogen is preserved, and complex organic nitrogen compounds are mineralized to the ammonium form (Wysocka-Czubaszek, 2019). Taking into account its physicochemical properties, one should strive to use digestate as a bio-fertilizer (Kowlaczyk-Juśko *et al.,* 2015). Vázquez-Rowe *et al.,* (2015) and Wysocka-Czubaszek (2019) also pay attention to the use of digestate as a fertilizer instead of mineral fertilizers. A biogas plant located in agricultural area should receive organic products from farmers. In contrast, farmers, taking care of the quality of soil on their farm, should receive plant digestate from the biogas and use it for fertilizing purposes (Kowalczyk-Juśko *et al.,* 2015, Tao *et al.,* 2014). The digestate used as a fertilizer improves soil fertility, quality and resistance of plants to biotic and abiotic factors (Kouřimská *et al.,* 2012). Kouřimská *et al.,* (2012) in their research state that the use of digestate increases the quality and yield of vegetables. In turn, Chiew *et al.,* (2015) report that the use of digestate as a fertilizer increases the content of macronutrients and microelements in soil and plants.

Storage of rapeseed is subject to the risk of uncontrolled and adverse reactions. The most influential factor on rape seed spoilage during storage is humidity, which should be 6-9% (Szwed *et al.,* 1995). Rape seeds require post-harvest processing during the technological process, where it is necessary to dry them artificially affecting the quality of the oil obtained (Stępniewski *et al.*, 2003). Significant differences in physical characteristics of rapeseed compared to cereal must be taken into account when adapting or relying on storage systems for cereal grains. The size and strength of rapeseed are factors that can affect their suitability for storage and processing. Degree of mechanical damage to individual rapeseeds is determined by their strength properties, which are associated with varietal characteristics, growing conditions, degree of maturity, seed moisture content, seed temperature, as well as combined harvesting and post-harvest treatment, for example the level and type of dynamic load, seed spatial orientation at loading, drying technology and seed storage conditions and time (Calisir *et al.*, 2005; Herak *et al.*, 2015; Tańska *et al.*, 2008).

The purpose of this study is to determine the impact of liquid (digestate) and mineral fertilizers on the quality and strength of rapeseed.

## METHODS

Digestate obtained from the biogas plant in Piaski (Lubelskie Province) was applied on experimental fields for winter rape cultivation. For the sake of comparison, all the plants mentioned above were sown and fertilized with mineral fertilizers as well. The experimental fields are located in Gospodarstwo Doświadczalne w Czesławicach Uniwersytetu Przyrodniczego w Lublinie, Lubelskie Province. Three varieties of spring rapeseed (Bios, Feliks and Markus) from the Plant Cultivation Station Czeslawice Sp. z oo. were subjected to tests. The seeds were sown on experimental plots in south-eastern Poland in Lublin province in 2016–2017.

Digestate was tested for the content of macroelements and heavy metals. Soil samples were examined for the content of macroelements as well. The tests were conducted before and after digestate application. Laboratory tests were performed at the District Chemical-Agricultural Station in Lublin and in the Central Agro-ecological Laboratory at the University of Life Sciences in Lublin.

After harvesting, the seeds were cleaned and then left under laboratory conditions at 20 °C surrounded by about 70% humidity to equilibrate humidity for a month. The humidity of tested seeds was 7%, and then 100 seeds were randomly selected depending on the type of crop, which was weighed using the scales (Radwag) with an accuracy of 0.1 mg.

The uniaxial compression tests between two parallel planes were performed using a Zwick/Roell Z005 testing machine equipped with a compression head with a maximum force of 50 N. During testing, the speed of moving plate was constant and amounted to 3 mm/min. The measurement was carried out until the seed crack, recording changes in the loading force as a function of the displacement of the measuring head.

The crack point corresponding to a clear decrease in pressure force on the load-deformation characteristics was determined automatically using Zwick's TestXpertII.V3.5 software. Value of the force destroying the granule was assumed to be the force (FC), at which the seed crack together with the accompanying elastic deformation (dL) occurred.

## RESULTS

The biogas plant (a biogas combined heat and power plant) is located in Piaski Commune, Lubelskie Province. The electric power is 0.99 MW, and the thermal power

– 1.1 MW. The annual electricity production – approximately 8 400 MWh. The generated biogas is desulfurized, dewatered, cooled and pumped by means of an underground gas pipeline into a cogeneration engine which generates electricity and heat in a combined process. The following are used as an input into the digestion process: green waste matter, maize silage, beet pulp, stillage, whey.

The digestate was taken from the Piaski biogas plant, which was poured manually on the surface of the experimental plots for rapeseed cultivation, in the amount of 180 l/ 50 $m^2$. The digestate was tested for macronutrients and heavy metals before use. The pH was 8.50. The content of macronutrients in the digestate was: nitrogen - 3.05 g/l, phosphorus - 0.09 g/l, potassium - 5.25 g/l, calcium - 0.25 g/l, magnesium - 0.039 g/l. Heavy metal content in the digestate sample tested was below the measuring method range. Before sowing and after harvesting of winter oilseed rape, soil analysis for acidity and macronutrients content was performed (Table 1).

Table 1. Tests for pH and macronutrients content in soil

| Feature examined | before using digestate | after using digestate |
|---|---|---|
| Acidity [pH] | 7.56 | 7.63 |
| Phosphorus [mg / 100 g soil] | 31.40 | 37.30 |
| Potassium [mg / 100 g soil] | 7.20 | 10.04 |
| Magnesium [mg / 100 g soil] | 13.40 | 13.86 |

Analyzing the test results, the soil pH increased from 7.56 to 7.63. An increase in the content of selected macronutrients was also noted. The phosphorus content increased by 5.90 mg per 100 g of soil, potassium by 2.84 mg per 100 g of soil and magnesium by 0.46 mg per 100 g of soil.

In 2018, winter rape seeds were collected from a plot fertilized with digestate with a moisture content of 5.67% and from the plot fertilized with mineral fertilizers with a moisture content of 6.04%. Table 2 presents results regarding the yields obtained and the weight of one thousand seeds.

Table 2. Changes in yield and mass of one thousand seeds

| | Yield ($t \cdot ha^{-1}$) | | | Weight of one thousand seeds (MTN) (g) | | |
|---|---|---|---|---|---|---|
| | Bios | Feliks | Markus | Bios | Feliks | Markus |
| digestate fertilization | 3.10 | 2.99 | 3.17 | 5.85 | 5.87 | 5.85 |
| fertilizing with mineral fertilizers | 3.01 | 3.00 | 3.14 | 5.84 | 5.86 | 5.85 |

For the control object, the yield was 2.87 $t \cdot ha^{-1}$ and the weight of thousand seeds - 5.82 g. For other winter rape seed cultivars, the yield fluctuated around 3 $t \cdot ha^{-1}$. The weight of a thousand seeds ranged from 5.85 g to 5.87 g. Analyzing the obtained test results, slight discrepancies were found regarding the impact of the fertilizer type on the yield and weight of a thousand seeds. This suggests that the use of digestate as a fertilizer has a positive effect.

Table 3 presents results of tests regarding fat and protein content in winter rapeseed.

Table 3. Changes in fat and protein content in winter rapeseed in individual experiment variants

| | Fat content (%) | | | Protein content (%) | | |
|---|---|---|---|---|---|---|
| | Bios | Feliks | Markus | Bios | Feliks | Markus |
| digestate fertilization | 42.95 | 42.97 | 42.95 | 21.38 | 21.35 | 21.39 |
| fertilizing with mineral fertilizers | 42.78 | 42.88 | 42.80 | 21.40 | 21.38 | 21.42 |

For the control object, the fat content was 42.67% and the protein content 21.28%. For other winter rapeseed cultivars, the fat content ranged from 42.78% to 42.95%, and the protein content 21.35% - 1.42%. Analyzing the obtained test results, a similar fat content was found in winter rape seeds depending on the type of fertilizer used. Tested fat content indicates good quality of harvested seeds.

Test results regarding the strength of winter rapeseed fertilized with digestate and mineral fertilizers are presented in Table 4.

Table 4. Strength properties and size of tested rapeseeds.

| Variety | Kind of Cultivar | Strength properties | Mean value (N/mm) | Standard Deviation (N/mm) | Minimum value (N/mm) | Maximum Value (N/mm) | CV (%) | Mean Diameter of Seeds (mm) |
|---|---|---|---|---|---|---|---|---|
| Bios | Control | Fc | 13.34 | 6.05 | 3.99 | 25.49 | 45.35 | 1.95 ± 0.149 |
| | | dL | 0.279 | 0.084 | 0.120 | 0.426 | 30.0 | |
| | NPK | Fc | 14.75 | 5.46 | 6.31 | 26.71 | 37.02 | 1.89 ± 0.126 |
| | | dL | 0.301 | 0.097 | 0.106 | 0.452 | 32.1 | |
| | Digestate | Fc | 16.40 | 5.14 | 6.14 | 29.81 | 31.34 | 1.89 ± 0.144 |
| | | dL | 0.307 | 0.075 | 0.176 | 0.446 | 24.5 | |
| Feliks | Control | Fc | 12.95 | 4.95 | 3.89 | 22.23 | 38.22 | 1.91 ± 0.151 |
| | | dL | 0.270 | 0.074 | 0.166 | 0.428 | 27.3 | |
| | NPK | Fc | 16.25 | 5.12 | 3.86 | 26.45 | 31.51 | 1.85 ± 0.181 |
| | | dL | 0.299 | 0.078 | 0.075 | 0.464 | 26.2 | |
| | Digestate | Fc | 18.53 | 5.11 | 5.63 | 27.72 | 27.58 | 1.90 ± 0.158 |
| | | dL | 0.357 | 0.112 | 0.159 | 0.620 | 31.5 | |
| Markus | Control | Fc | 12.50 | 5.67 | 3.19 | 24.40 | 45.36 | 1.89 ± 0.152 |
| | | dL | 0.213 | 0.062 | 0.107 | 0.361 | 29.0 | |
| | NPK | Fc | 13.27 | 6.06 | 4.34 | 24.77 | 45.67 | 1.81 ± 0.158 |
| | | dL | 0.306 | 0.108 | 0.069 | 0.531 | 35.4 | |
| | Digestate | Fc | 13.62 | 4.20 | 8.96 | 25.49 | 30.84 | 1.81 ± 0.145 |
| | | dL | 0.281 | 0.094 | 0.102 | 0.547 | 33.7 | |

*$F_c$ – compressive force, dL – elastic deformation*

Based on Table 4, it can be observed that the use of digestate in the cultivation of rapeseed for both the Bios and Feliks cultivars contributes to an increase in the static strength of their seeds compared to the control combination. The highest compressive strength value for the Bios cultivar was 29.81 N and the smallest was 5.63 N (Feliks cv.). Average strength in all cultivars - 16.18 N. However, the average elastic deformation values were the largest of all recorded ones, with an average of 0.315 mm (data not shown). Although in the case of the Markus cultivar, the highest average elastic deformation was recorded in traditional cultivation. Among the considered variants, the largest deformation value was recorded in the Feliks cv. with the use of digestate (0.620 mm). The lowest value was observed in the Markus cv. in traditional cultivation (0.069 mm). Given dimensions of seeds when using digestate, their size ranged from 1.81 to 1.90 mm. It was a group between the largest seeds from control crops (from 1.89 mm to 1.95 mm) and the smallest from crops using compound fertilizer (from 1.81 mm to 1.89 mm).

For crops with the use of mineral fertilizer, the lowest value of force needed to crush rapeseed was 3.86 N in the Feliks cv., and the highest - 26.7 N in the Bios cv. Average strength in all cultivars - 14.75 N. Elastic deformations occurring with the cultivars covered by the tests showed increased values in relation to the control combination and were on average 0.302 mm (data not shown).

Considering the case in the absence of any form of fertilization, it was observed that in all rape cultivars, the average compressive strength was in turn the lowest, the average - 12.93 N. This may indicate that the application of both forms of fertilization has an impact on physical properties of seeds. Markus cv., that reached 3.19 N and was the lowest of all seeds tested, showed minimal compressive strength. However, the Bios cultivar achieved the highest strength of 25.4 N.

Comparing the obtained test results to tests performed by Tańska and Konopka (2008), in which no digestate was used, the values of rapeseed strength in terms of their size ranged from 10 N to 18 N, while large seeds (with a larger mass) showed significantly less elastic deformation than medium seeds, but not so much as the small ones. Referring to the tests carried out, in the three cases considered, values obtained with the use of compound fertilizer were similar and ranged from 7 N to 21 N. Rape seeds in cultivation treated with digestate, the values of which were between 7 N and 24 N, maintained their compressive properties in a similar range. Higher elastic deformation values were recorded for crops using digestate and compound fertilizer than control combinations. Both forms of cultivation also showed higher compression strength of individual seeds.

## CONCLUSIONS

This investigation revealed that post-digestion liquid contains large amounts of macroelements. However, no heavy metals were found in digestate. The examination of soil samples before and after digestate application showed increase in the content of macroelements in the soil, which implies a good fertilizing value of digestate.

The investigation results related to winter rape confirmed the efficiency of post-digestion liquid application as a fertilizer. Consequently, post-fermentation residues from biogas plants can be used as a fertilizer.

Fertilizing fields with digestate brings numerous benefits, e.g. reduction of demand for plant protection products (destruction of weed seeds during fermentation), or destruction of possible pathogens. Digestate utilization as a fertilizer brings tangible benefits in agricultural production, but it is also a product the application of which can reduce the negative effects of mineral fertilization and contribute to development the sustainable agriculture.

The rapeseed cultivars tested after using digestate and compound fertilizer showed higher compression strength of single seeds (16.18 N; 14.75 N) and elastic deformation (0.315 mm; 0.302 mm) than control combinations (12.93 N; 0.254 mm).

In the conducted tests, the range of average size rape seed diameters of all cultivars and forms of cultivation ranged from 1.81 mm to 1.95 mm. This indicates their good suitability for industrial purposes.

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## 4.9. TEXTURE CHANGES IN PEAR CULTIVARS DURING STORAGE

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**Keywords:** pear, mechanical properties, storage, time, sustainable agriculture

## ABSTRACT

In Poland, pears are stored in cold storage plants with normal atmosphere, less often with a controlled atmosphere. Estimation of physical parameters permits the determination of the current state of the fruit and the prediction of allowable periods of commercial turnover after storage. The objective of the study was to characterise, on the basis of experimental studies, the firmness of the flesh and the skin strength in the puncture test of pear cultivars Hortencia, Konferencja, Lukasówka, and Xenia held in cold storage plant with normal atmosphere (NA). In the course of cold storage of pears there takes place an unfavourable change in the analysed parameters of their texture. The dynamics of changes in the analysed values characterising the texture was related to the varietal traits of the fruits. Well-balanced management of raw materials fits in the concept of sustainable agriculture.

## INTRODUCTION

In 2018, apple harvest in the European Union countries amounted to 12.5, while pear harvest - 2.4 million tons (Freshmarket.pl, 2019). Such high fruit harvest creates sales problems and reduces fruit prices. The low price of the fruit may cause the interest of the orchard farmers to produce fresh juices on the farm. In some countries (Austria, Germany) orchard farm are equipped with a complete line of pressing and gentle juices preservation. Lately the development of a service using the mobile pressing is observed. Consumers expect juices to have pro-health and appropriate physical properties. (Kobus, Nadulski, Wilczyński, Starek, Zawiślak, Rydzak, Andrejko 2019). Over the last years, new techniques have been applied to extract fruit juices (Nadulski, Kobus, Wilczyński, Zawiślak, Grochowicz, Guz 2015, Kobus, Nadulski, Wilczyński, Kozak, Guz, Rydzak 2019). The major factor that determines the usefulness of pome fruit for consumption and processing is its quality related, among others, to texture (Zerbini 2002). It is important to have fruits in commercial turnover before their firmness drops to a level that would be unacceptable to the consumer or have too low quality for processing. Therefore, it is necessary to acquire knowledge on changes in the textural properties of particular pear cultivars in the course of storage in cold storage plants with normal and controlled atmosphere (Taniwaki, Hanada, Tohro, Sakurai, 2009).

In practice, the estimation of textural properties of fruit is conducted primarily with the use of empirical tests consisting, among other things, in the determination of fruit firmness with the Magness-Taylor method and of skin strength in the skin puncture test, as well as imitation application of the TPA test (Bourne, 2002). The textural properties of pome fruits depend to a large extent on pre-harvest and post-harvest factors, and the time of harvest of the fruits has a significant effect on the storage capacity of the fruits and on their properties during storage (Mitcham, Mattheis, Bower, Biasi, Clayton, 2001; Gómez, Wang, Pereira 2005; Wawrzyńczak, Rutkowski, Kruczyńska 2006; Eissa, Alghannam, Azam, 2012).

The objective of the study was to characterise, on the basis of experimental studies, the firmness of the flesh and the skin strength in the puncture test of pear cultivars Hortensia, Konferencja, Konferencja and Xenia held in cold storage. The scope of work included determining the firmness for flesh tissue and skin puncture force.

## MATERIAL AND METHODS

The experimental material consisted of fruits of four pear cultivars *(Pyrus L.*): Hortensia, Konferencja, Konferencja, Xenia). The material originated from a specialist orchard farm belonging to the Association of Fruit Producers “Stryjno Sad”. The material selected for the tests was of similar fruit size, healthy, without mechanical damage.

The material used in the experiments was stored for 150 days in a cold storage plant with normal atmosphere (NA). The first series of tests was performed immediately after the harvest, and subsequent tests at 30 days intervals. In the storage plant the temperature was maintained at 1.7-2.5°C and humidity at the level of 86-92%.

The textural tests were performed with the use of the Texture Analyser TA-TX2, Stable Micro Systems Ltd. (Great Britain), equipped with measuring head with operation range up to 0.5 kN. The tests were made using a penetrometer with diameter of 8 mm and a cylindrical tip with convex face (conforming to the Magness-Taylor apparatus) for the penetration of pear flesh, and a penetrometer with diameter of 5 mm and a flat-faced cylindrical tip for the pear skin puncture tests. The penetration tests were conducted on fruits with a layer of skin removed to achieve penetration of 8 mm. The skin puncture test was made on the largest-diameter perimeter of the fruits, until the penetrometer penetrated the fruit flesh to the depth of 8 mm. Statistical analysis of the results was made using the software package Statistica 12.0 (StatSoft Inc., Tulsa, OK, USA), using the analysis of variance and regression analysis.

## RESULTS

Out of the examined pears, Hortensia (37.4 N) had the lowest firmness after harvest, while Conference (58.6 N) – the highest. According to Wawrzyńczak's (2006) research, the firmness of pear flesh after harvest depends primarily on the variety and harvest time. Pear storage in the storage plant with normal atmosphere caused a big loss of fruit flesh firmness at the end of the period of storage (Fig. 1). The greatest loss of firmness of 62.8% was recorded in the case of fruits of cv. Hortensia, and the lowest – 30.4% - in the case of cv. Xenia. The firmness of the flesh of fruits of cultivars Konferencja and Lukasówka decreased by approximately 40-44%. In the case of Hortensia and Conference cultivars, during the first three months, the firmness of pear flesh remained at a similar level, and only at the end of the storage process a significant decrease was observed. According to Johnson and Luton (1996), firmness of pears after storage in a cold store should amount at least to 40 N.

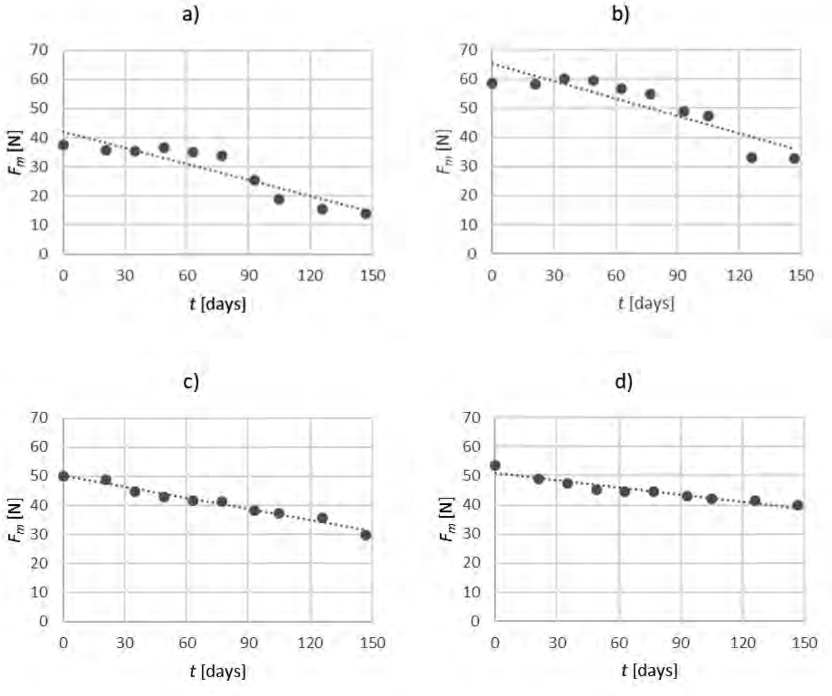


Fig. 1. Mean values of force $F_m$ (firmness) for flesh tissue of pears of cultivars Hortencia (a), Konferencja (b), Lukasówka (c), Xenia (d) in relation to the time of storage in cold storage plant with normal atmosphere (NA)

Force $F_m$ (firmness) for flesh tissue of pear during the storage were described by means of linear regression equations, obtaining good fit of the equations to measured values (Tabe 1).

Table 1. Regression equations for penetrometric test for flesh tissue of pear storage in cold storage plant with normal atmosphere (NA)

| Parameter | Cultivar | Regression equation | $R^2$ |
|---|---|---|---|
| Force $F_m$ [N] (firmness) | Hortensia | $F_m = -0.184t + 41.904$ | 0.847 |
| | Konferencja | $F_m = -0.162t + 61.398$ | 0.611 |
| | Lukasówka | $F_m = -0.127t + 50.076$ | 0.970 |
| | Xenia | $F_m = -0.082t + 50.976$ | 0.903 |

In the course of fruit storage in the cold storage plant with normal atmosphere a distinct decrease was recorded in the value of force required to puncture the skin (Fig. 2). At the end of the period of storage the value of the force required for pear skin puncture, in the case of all pear cultivars tested, decreased to the level of 14.4-32.4 N. The greatest decrease of skin strength was noted in the case of pears cv. Hortencia and Lukasówka, for which it amounted to approx. 55%, while in the case of the remaining cultivars the decrease was in the range of 23.8-45.4%. The development of peel's strength of the examined fruit indicates that it is a varietal characteristic.

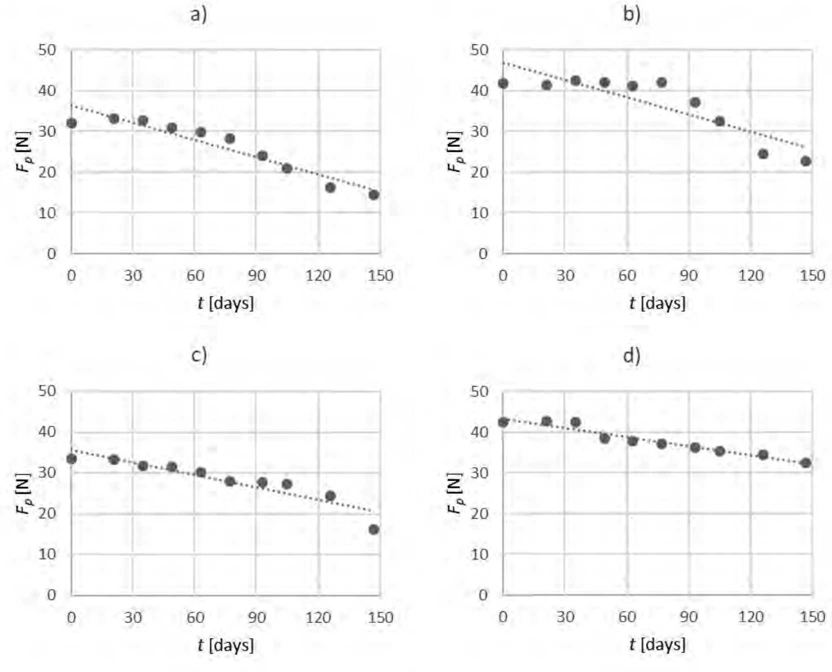


Fig. 2. Mean values of skin puncture force $F_p$ for pears of cultivars Hortencia (a), Konferencja (b), Lukasówka (c), Xenia (d) in relation to the time of storage in cold storage plant with normal atmosphere (NA)

Force $F_p$ (puncture force) for skin of pear during the storage were described by means of linear regression equations, obtaining good fit of the equations to measured values (Tabe 2).

Table 2. Regression equations for penetrometric test for flesh tissue of pear storage in cold storage plant with normal atmosphere (NA)

| Parameter | Cultivar | Regression equation | $R^2$ |
|---|---|---|---|
| Force $F_p$ [N] (puncture force) | Hortensia | $F_p = -0.140t + 36.295$ | 0.899 |
| | Konferencja | $F_p = -0.140t + 46.845$ | 0.749 |
| | Lukasówka | $F_p = -0.101t + 35.625$ | 0.850 |
| | Xenia | $F_p = -0.074t + 43.293$ | 0.938 |

In conclusion it can be stated that pear flesh firmness and skin puncture force depend significantly on the time of fruit storage. In addition, statistical analysis of the results showed that the range and character of changes in the parameters tested depended also on the varietal traits of the fruits.

## CONCLUSIONS

In the course of cold storage of pears there takes place an unfavourable change in the analysed parameters of their texture. Pear storage time have a decisive effect on the preservation of the texture. The dynamics of changes in the analysed values characterising the texture was related to the varietal traits of the fruits. Among the pear cultivars under study the smallest range of changes in the analysed texture parameters was determined for cultivars Xenia and Konferencja. Awareness of alterations that occur in the fruit texture during storage process enables to make rational decisions in the matter of emptying the cold storage plant and directing the fruit for sale or processing, which is important in the context of sustainable agriculture. Well-balanced management of raw materials fits in the concept of sustainable agriculture.

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# 4.10. THE EFFECT OF CARROT STORAGE ON THE PROPERTIES OF CARROT-APPLE JUICE

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**Keywords:** ultrasound, apple, carrot, juice, organic food

## ABSTRACT
Organic farming is the foundation of sustainable development, especially when its products are later used as raw materials in various production processes. In research apple juice from Ligol and Gala Must varieties and carrots of the Bolero and Norway varieties grown in an organic way was used. The prepared juices were mixed together, obtaining the entire spectrum of mixtures, from pure apple juice to carrot juice and with intermediate concentrations every 20%. Norway variety carrots have been stored for five weeks. The juices from those carrots were tested with weekly intervals. For all prepared samples, the velocity and attenuation coefficient of the ultrasonic wave were measured at 25°C, 30°C, 35°C, also the dry matter was determined. A significant relationship between wave velocity and concentration or temperature has been shown. In addition, the way carrots are stored affects the properties of the juice made from it.

## INTRODUCTION

Ultrasounds, as a medium that has impact on the processed biological material, are widely used at the initial stage, preceding the treatment or, if possible, during it (Mason *et al.*, 1996). Ultrasound treatment is applied to change the properties of the material, i.e. to reduce the duration of the process, which contributes to lower energy-consumption or improvement of the quality of the final product (Pinheiroa *et al.*, 2015).
Ultrasounds may also be used as information carrier, which provides information about the material being processed. For this purpose, it is required that the energy of the wave be small enough not to destroy the object it penetrates (Mamvura *et al.*, 2018). During wave propagation, its parameters change, which makes the assessment of material properties possible. Factors such as temperature, density, deposits of other materials and their size (Shukla *et al.*, 2010) have impact on such ultrasound parameters as velocity and attenuation coefficient, which may be determined relatively easily (Coupland, 2004). Application of mechanical waves also allows for monitoring processes, and controlling them based on the obtained data or determining the optimum moment of their termination (Nassar *et al.*, 2004). Mizrach (2007) successfully used ultrasounds for the assessment of tomatoes ripeness. Kuo *et al.* (2008) demonstrated strong relation between wave velocity and viscosity as well as sugar content in orange juice. Ultrasounds have great potential and widespread applications. Their application may have impact on the development of sustainable agriculture by the assessment of the effects of its implementation.

## MATERIAL AND METHODS

The research material constituted apples of Ligol and Gala Must varieties as well as carrots of Bolero and Norway varieties from organic farming. All apples and carrots of Bolero variety were stored in cold storage conditions (cooler) at the temperature of 2°C and air humidity of 80% from the moment they were obtained. Carrots of Norway variety were stored in two separate batches: one batch in cold storage conditions and the other batch in the room temperature of 22°C and humidity of 45%. A juice extractor was used to extract juices, which were diluted with distilled water to the concentration of 70% w/w. Then the juices were mixed in order to obtain mixtures of juices with the content of carrot juice in apple juice amounting to 0%, 20%, 40%, 60%, 80% and 100%. A full spectrum of mixtures of juices of the following varieties: Ligol-Bolero, Gala-Bolero and Gala-Norway was obtained. For carrots of Norway variety additional examinations were performed during the period of storage, i.e. four weeks in cold storage conditions and two weeks in room temperature conditions. Each sample of the juice was examined by ultrasounds. Velocity and attenuation coefficient of ultrasonic wave of 2 MHz frequency were determined. Two transducers working based on echo technique on fixed length of the wave was 0.123m and 0.088m. For all mixtures of juices and carrots roots dry substance contents were determined using dryer.

## RESULTS AND DISCUSION

One of the most frequently used methods of agricultural produce storage is storing them in lower temperature and in controlled atmosphere. During examinations, carrots of Norway variety were stored in lowered temperature, without control of air composition. It resulted in rapid loss of moisture in carrot, in particular for samples stored in room temperature. Dry substance content in carrot root increased from 11% at the beginning of the research to 17% for carrots stored in room conditions for two weeks and to 22% for carrots stored in cold storage conditions for the period of four weeks. Loss of moisture in carrot roots was significant, and it was necessary to use more material to prepare a sample of juice of the same volume. Initially, dry substance content in juices amounted to 7%. After two week-storage of carrots in room temperature, the content of dry substance in the extracted juices was at the level of 10%, and after four-week storage in cold storage conditions it amounted to 12%.

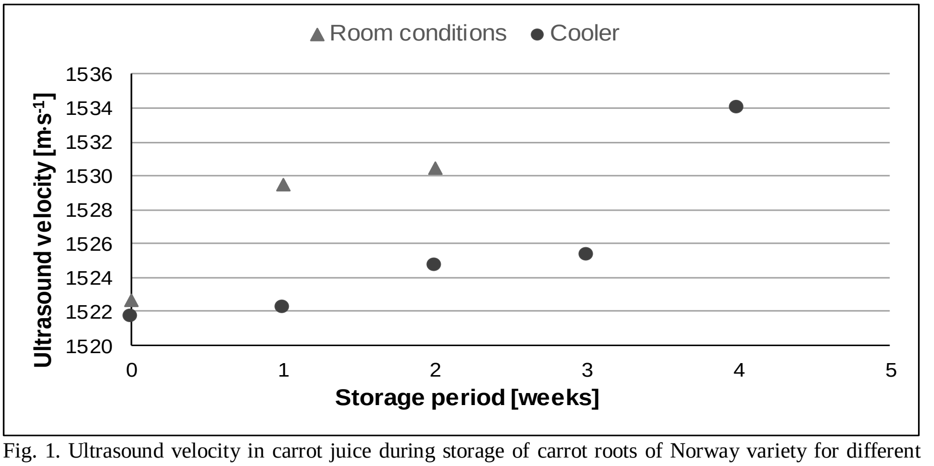


Fig. 1. Ultrasound velocity in carrot juice during storage of carrot roots of Norway variety for different methods of storage.

The ultrasound velocity which was determined for samples of juices extracted from the carrots is shown in Figure 1. It may be observed that the velocity increases with storage time. It is most likely connected with the increasing content of dry substance in juices prepared every consecutive week.

Apple-carrot juices were extracted from apples of Ligol and Gala Must varieties with dry substance contents of 12% and 15%, respectively, and carrots of Bolero variety with dry substance content of 8%. For mixtures of juices the presented concentration indicates the share of carrot juice in the mixture. The dependence between the ultrasound velocity and the concentration of the mixture obtained from the varieties of Ligol and Bolero is presented in Figure 2. Successive series of data are measurements performed in different temperatures. The results are described by the linear function, for which the parameter $R^2$ reached values at the level of approx. 0.975. With the increase of carrot juice share, the velocity of the wave decreased, while it increased with the increase of temperature. The impact of temperature on wave velocity increases slightly with the addition of carrot juice. It is indicated by the value of the slope coefficient of the presented model, which assumes the following values: -0.090, -0.075 and -0.071 for temperatures of 25, 40 and 35°C, respectively. It means that wave velocity in carrot juice increases faster during heating than in apple juice.

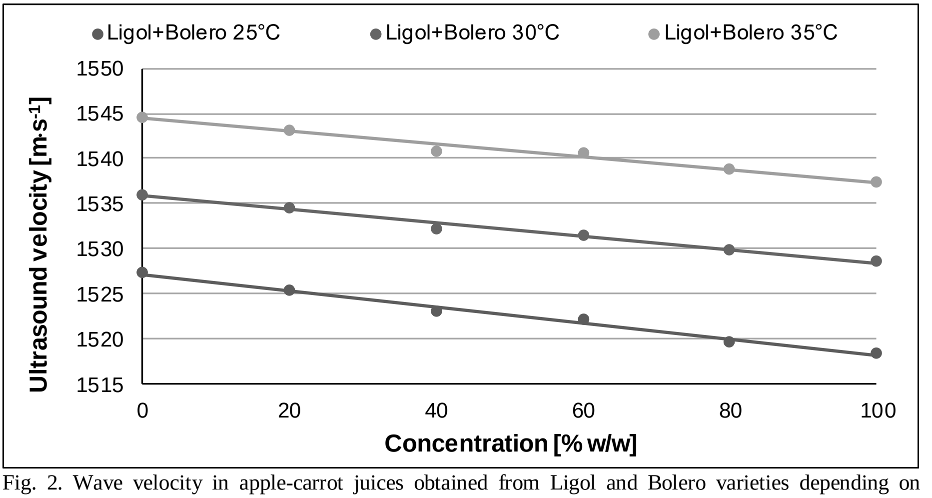


Fig. 2. Wave velocity in apple-carrot juices obtained from Ligol and Bolero varieties depending on percentage share of mixture components in different temperatures.

Wave velocity for juice extracted from apples of Gala Must is only slightly higher than for Ligol variety. Consequently, taking the mixture that consists of Gala and Bolero varieties into consideration, slopes of straight lines describing the dependence of wave velocity on concentration will be different. Slope coefficients for the linear model amount to: -0.130, -0.118 and -0.104 for temperatures of 25, 30 and 35°C, respectively. Particular attention ought to be paid to juices extracted from Gala and Norway varieties, which is marked by dashed line in Figure 3 (slope coefficients -0.077, -0.069, -0.054, for temperatures 25, 30 and 35°C). Wave velocity for juices from carrots of Norway variety is greater than for juices from carrots of Bolero variety. Considering wave velocity determined after four-week storage of carrots of Norway variety, wave velocity in apple juice would be smaller than wave velocity in carrot juice. It would result in reverse slope of the straight line describing empirical measurements.

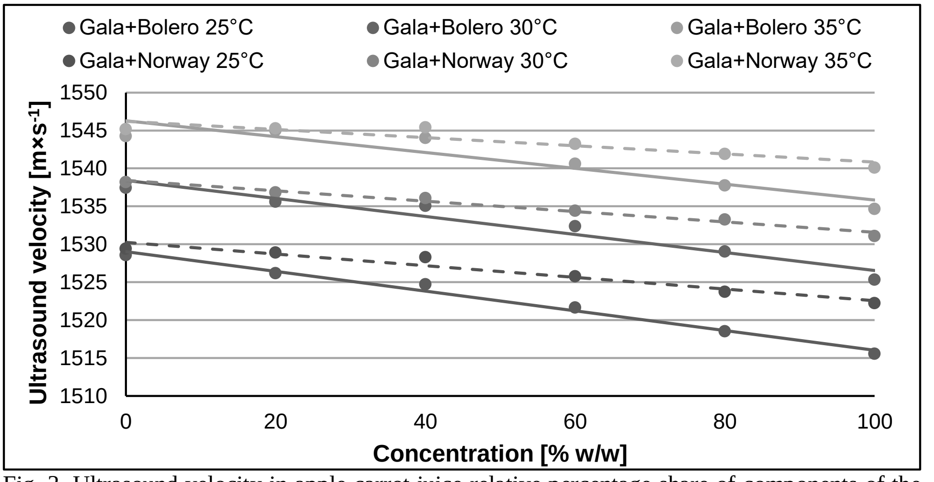

Fig. 3. Ultrasound velocity in apple-carrot juice relative percentage share of components of the mixture at different temperatures.

Attenuation coefficient for juices, which was determined during carrot storage, did not demonstrate significant changeability. A similar situation was observed for mixtures of juices. However, in this case, the following trend was observed: the attenuation coefficient decreased with higher carrot juice share. Higher value for apple juice can most likely be attributed to air vesicles (Segers *et al*., 2016), which form in the process of juice extraction in a juice extractor.

## CONCLUSIONS

Due to seasonality, agricultural products require storage. The longer the storage period the higher the storage costs. Just as loss of product quality is undesirable, the familiarity with the impact of storage on the quality of the final product may be valuable information. Such information may help in e.g. optimization of the process as a whole, from obtaining raw material to its processing.

Ultrasound application made it possible to exhibit the dependence between the properties of carrot juice and the storage period of ecological carrot of Norway variety. This dependence may be related to the change in the dry substance content in juice, which increased with carrot storage duration. This requires further research, in particular, as regards the assessment of valuable nutrients loss.

Mixtures of apple-carrot juices were characterized by different velocity depending on the variety used to produce juice. Percentage share of components of the mixture of juices and temperature also had a significant impact. Ultrasounds may be successfully used to assess properties of fruit-vegetable juices. It may be a valuable tool to optimize processes of obtaining and processing agricultural food products. In particular, when the products come from ecological farming, the time required to obtain the results and non-invasive method of measurements are of considerable significance.

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# 4.11. THE EFFECT OF ORGANIC FARMING ON CARROT JUICE PROPERTIES

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**Keywords:** ultrasound, juice, organic food

## ABSTRACT

Organic farming as a component of sustainable development is an important area where quality assurance and control is a very important factor. Carrots of Naval and Nerac varieties were used in the research. Each of them was cultivated in a conventional and ecological way. Juice was prepared from the roots and the test samples were diluted to 50%, 60%, 70% and 80%. For the material prepared in this way, colour measurements, as well as velocity and attenuation coefficient of the ultrasonic wave with a frequency of 2 MHz were made. The results obtained for carrots from conventional and organic crops differ significantly. The wave speed is higher for juices from conventional crops. Individual colour components also indicate different properties of juice from different crops.

## INTRODUCTION

Sustainable development involves more ecological economy, which uses resources more effectively, is more environmentally-friendly and more competitive, Anuszewska *et al.* (2011). In the United Nations Organization documents "sustainable development" is defined in detail as: "(…) a development that satisfies the basic needs of all people and preserves, protects and restores the health and integrity of the Earth's ecosystem, without threatening to meet the needs of future generations and without exceeding the long-term limits of Earth's ecosystem capacity", source – the Internet. The essential barrier in undertaking pro-ecological activities is the lack of financial resources and effective production technologies, hence, the necessity to implement innovations in this respect. An important factor is quality control. Therefore, an attempt has been made to use ultrasounds and colour measurements for this purpose. Ultrasounds are a valuable tool used to determine properties and assess the condition of the object being studied. They enable the performance of non-destructive measurements, and the time required to obtain the results is very short. So far, they have been mostly used to examine construction materials, and, consequently, there are no comprehensive studies related to their application for the assessment of biological materials. The monographs on this subject include Opieliński (2011) and Bushong (1991).

## MATERIAL AND METHODS

The research material were carrots of Naval (Na), and Nerac (Ne) cultivars, both from conventional (C) and organic (O) agricultural systems. The carrots were stored in cold storage conditions at the temperature of 2°C and the air humidity of 85%. A juice extractor was used to prepare juices from the carrots. The extracted juices were then mixed with the distilled water to obtain the following concentrations: 50, 60, 70 and 80% w/w. The samples were examined at the temperatures of 22, 25, 30, 35, 40°C using ultrasounds. The measured parameters included ultrasound velocity and attenuation coefficient with the frequency of 2MHz. Two transducers working based on echo technique with the wave path lengths of 0.123m and 0.088m were used. Moreover, for all samples of juices, carrots roots and waste products left over from juice production, dry substance contents were determined using the dryer method. Data on colour of juice samples were obtained from their digital images acquired by Cannon flatbed scanner, CanoScan 5600F. Images were acquired in the AdobeRGB colour space, with resolution of 300 dpi. The algorithms for image processing and were implemented in ImageJ v1.52q environment (Rasband 1997-2018, Abramoff et al 2004, Schneider *et al.* 2012). RGB colour components, read in each image piksel, were linearized according to formula (1), and recalculated into components XYZ using the conversion matrix in formula (2).

$$V = v^{\gamma} \tag{1}$$

where $v \in \{r, g, b\}$ and colour components are in range [0-1], $V \in \{R, G, B\}$, $\gamma$ = 2.19921875.

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} \begin{bmatrix} 0.5767309 & 0.1855540 & 0.1881852 \\ 0.2973769 & 0.6273491 & 0.0752741 \\ 0.0270343 & 0.0706872 & 0.9911085 \end{bmatrix} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \tag{2}$$

The above conversion matrix results from the values of chromatic coordinates of primary colours (R, G, B) and white point (*W*), corresponding to the standard illuminant D65 and the 2° standard observer (Adobe Systems Inc. 2005). Based on the XYZ colour components, CIELab components as well as chroma *C* and hue *h* were determined for each pixel (CIE Standard. 2004), and then averaged over the entire image. Multi-way ANOVA was used to analyse the significance of colour differences in populations, determined by cultivar and agricultural system. The analysis was performed using Statistica 13.3 (TIBCO, 2017). In case of significant interactions Tukey multiple comparison tests were used to compare means. All the analyses were performed at the significance level $\alpha = 0.05$. Bars on the means plot denote mean ± standard error.

**RESULTS AND DISCUSION**

Numerous factors dependent on the properties and the condition of the material may have impact on the velocity of the ultrasonic wave. Fig. 1 presents the dependence between the wave velocity and the carrot juice concentration extracted from organically cultivated carrots of Naval cultivar. For each temperature presented in the graph as a separate series of data, the results were described by the linear function. In the examined range of concentrations and temperatures, this function sufficiently describes the character of changes, and the lowest value of the coefficient of determination $R^2$ for all the measurements amounted to 0.97. The velocity of the wave increases with the increase of the temperature and the concentration. However, the increment of the wave velocity resulting from the higher concentration is slower for the samples in higher temperature. Such properties are described by the slope of the applied linear model, and were observed for each cultivar, irrespective of the agricultural system. It is connected with different properties of juice components. In the temperature range of 20÷40°C, wave velocity in water increases approximately by 11 $m*s^{-1}$ with the increase of the temperature by 5°C, and the character of the changes is not linear. With the increase of juice concentration, the increment of the velocity during temperature increase by 5°C decreases, and reaches approximately 8.2 $m*s^{-1}$, with the concentration equal 80%. Wave velocity depends on juice concentration and its temperature; interaction occurs between these parameters. The values of the coefficient of the linear model for all the measurements are presented in table 1.

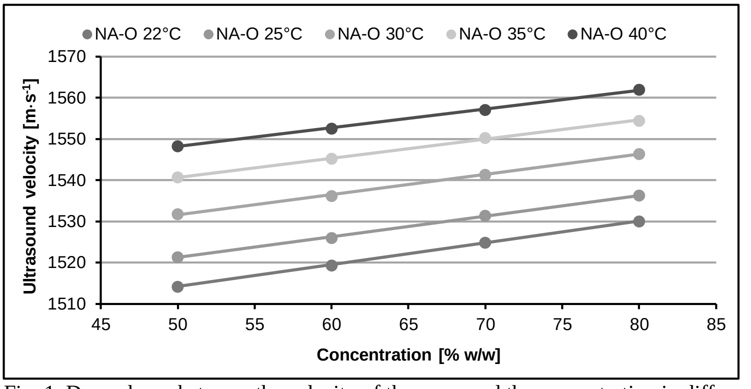


Fig. 1. Dependence between the velocity of the wave and the concentration in different temperatures of juice from the organically cultivated carrot of Naval variety.

Table 1. Values of coefficients of the linear model in the form $y = ax + b$ (a and b are coefficients of the model) that describes changes of the wave velocity depending on concentration at constant temperature.

| Temperature [°C] | NA-O | | | NA-C | | |
|---|---|---|---|---|---|---|
| | a | b | $R^2$ | a | b | $R^2$ |
| 22 | 0.527 | 1487 | 0.994 | 0.426 | 1448 | 0.975 |
| 25 | 0.502 | 1496 | 0.986 | 0.439 | 1495 | 0.977 |
| 30 | 0.489 | 1507 | 0.985 | 0.433 | 1506 | 0.977 |
| 35 | 0.465 | 1517 | 0.985 | 0.389 | 1518 | 0.973 |
| 40 | 0.454 | 1525 | 0.973 | 0.39 | 1525 | 0.973 |
| Temperature [°C] | NE-O | | | NE-C | | |
| | a | b | $R^2$ | a | b | $R^2$ |
| 22 | 0.508 | 1487 | 0.986 | 0.3597 | 1489 | 0.973 |
| 25 | 0.474 | 1496 | 0.981 | 0.361 | 1497 | 0.980 |
| 30 | 0.458 | 1507 | 0.982 | 0.354 | 1508 | 0.982 |
| 35 | 0.4497 | 1516 | 0.972 | 0.345 | 1517 | 0.978 |
| 40 | 0.440 | 1525 | 0.977 | 0.324 | 1527 | 0.970 |

The possibility of identification of the agricultural products cultivation system may be desirable in numerous situations, in particular, when the results are available within a short period of time. Figure 2 presents an example comparison of the dependence of ultrasonic wave velocity on the concentration of juice from carrots cultivated using different methods; it only includes measurements performed at the temperature of 25 °C. For the whole studied range of concentrations and temperatures, greater wave velocity was observed for the samples obtained from organically cultivated carrots rather than conventionally cultivated ones. Moreover, with the increase of the concentration, at the constant temperature, the differences become greater. On the other hand, the comparison of the wave velocity for juices with constant concentration shows that the differences become smaller with the increase of the temperature.

Attenuation coefficient, determined for all juices, does not show a significant dependence between the concentration or the temperature. However, a decreasing tendency of the coefficient may be observed as the solid phase content increases. It may be connected with the process of solid phase sedimentation occurring in the sample. It was not possible to fully avoid the impact of the effect of sedimentation on the performed measurements in the measurement chamber.

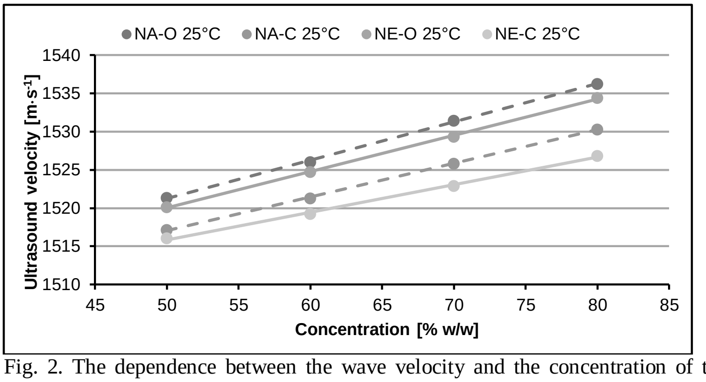

Fig. 2. The dependence between the wave velocity and the concentration of the carrot juice at the temperature of 25 °C for different cultivars and agricultural systems.

The content of dry substance, which was determined for all juices corresponds with the concentration of the prepared samples and is within the range of 5.8% - 8.8% for juices with the concentrations of 50% and 80%, respectively. Solid phase content in the samples with different concentrations does not differ significantly statistically. The differences in the dry substance content for carrot root and waste left over from juice production are significant for the agricultural system and insignificant for the cultivar. Organically cultivated carrots contain twice as much dry substance as conventionally cultivated carrots. The determined contents of dry substance are presented in table 2.

Table 2. Dry substance content in carrot roots and waste left over from juice extraction.

| Cultivar | Dry substance content [%] | |
|---|---|---|
| | Waste | Root |
| NE-O | 16.2 | 14.0 |
| NE-C | 8.4 | 5.2 |
| NA-O | 17.9 | 13.7 |
| NA-C | 9.0 | 6.5 |

The analysis revealed that all the examined colour components were significantly affected by cultivar (Fig. 3a-e).

Juice obtained from carrots of Naval cultivar was lighter and had significantly greater contribution of red (by 7%) and yellow (by 2%) components in the general colour sensation, which was also more intensive (saturation higher by 4%) in comparison with Nerac cultivar. The hue of juice obtained from Naval cultivar was shifted towards orange, while the hue of juice from Nerac cultivar was greenish-yellow. A significant impact of agricultural system was only observed in case of Lab components and hue parameter (Fig. 4a-d).

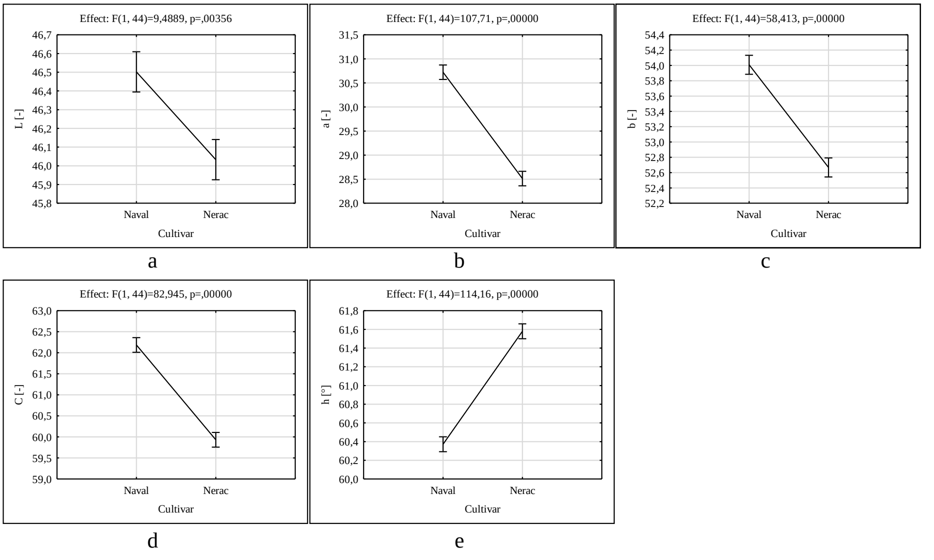


Fig. 3. The effect of cultivar on colour components of carrot juice.

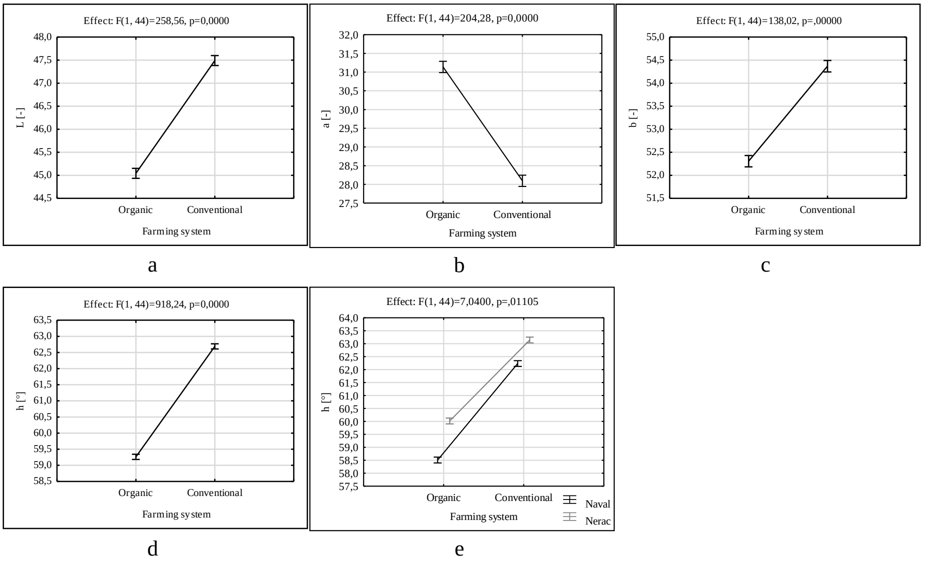


Fig. 4. The effect of agricultural system on colour components of carrot juice (a-d) and the effect of cultivar × agricultural system interaction on the hue of carrot juice (e).

Juices obtained from organically cultivated carrots were darker (lightness lower by 5%). The contribution of red component in general colour sensation of these juices was 10% higher, and yellow component was 4% lower compared with juices obtained from conventionally cultivated carrots. Therefore, it may be assumed that the organic agricultural system stimulates obtaining juice with intense orange hue, while the colour of juice from conventionally cultivated carrots is rather yellow. It is essential in case of applying colour standards for food products such as pomace juices, naturally muddy or clarified juices. The effect was even stronger in case of Naval cultivar, which was confirmed by significant cultivar×agricultural system interaction observed for hue (Figure 4e).

## CONCLUSIONS

The results of the performed research related to ultrasonic wave velocity and carrot juice colour indicate significant differences between conventional and organic farming. Additionally, differences resulting from carrot cultivars were observed. This may become the basis for the development of fast and reliable method for the identification of the agricultural system as well as the quality control of agricultural products. Development of such a system for agricultural products assessment would require further research involving the impact of environmental factors such as climate and soil. Also, the scope of research would require extending by a representative, in terms of number, group of the examined cultivars and set out standards that describe characteristic features of such a group related to wave velocity and selected colour components. A significant impact of the farming system was only observed in the case of Lab colour components. However, the ultrasonic attenuation coefficient, which was determined for all the examined juices, does not exhibit a significant dependence between the concentration or the temperature and does not provide grounds for the identification of the cultivar and the agricultural system.

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# 4.12. THE IMPACT OF TWO YEARS OF PLANT PROTECTION IN THE GERANIUM WITH SPECIAL EMPHASIS ON GREENHOUSE WHITEFLY (*Trialeurodes vaporariorum*) AND THE WESTERN FLOWER THRIPS (*Frankliniella occidentalis*)

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**Keywords:** Geranium, plant protection, Trialeurodes vaporariorum, Frankliniella occidentalis, horticulture

## ABSTRACT

Our study was carried out in 2014 and 2015 in a horticulture in Kecskemét, Hungary. The main plant of horticulture is geranium (*Pelargonium*). In each year we performed insecticide control on 1,000-1,000 pieces of geraniums. The greatest damage was caused by the greenhouse whitefly (*Trialeurodes vaporariorum*) and the western flower thrips (*Frankliniella occidentalis*). In the first year we used 8 insecticides and in 2015 we used 9 insecticides. In 2014, 51% of the tested geraniums were infected with pest insects (27% *F. occidentalis*, 24% *T. vaporariorum*), and one year later, 550 of the 1,000 geraniums were infected (30% western flower thrips, 25% greenhouse whitefly). To enhance the efficacy of the insecticides, the Silwet adhesive was used.

## INTRODUCTION

The geranium (*Pelargonium*) is part of the *Geraniaceae* family. Among the genus of the geranium there are annual or perennial herbaceous species, rarely woody (semi-shrubs or shrubs) (Nagy, 1975; Honfi *et al*., 2011). The most common species is the garden geranium (*Pelargonium hortorum*) (Szántó *et al*., 2003). To Europe, the first geranium (*Pelargonium triste*) was imported by the Dutch around 1600 from South Africa.

Today, the cultivated geranium species are of hybrid origin. The bloom depending on the variety and the season lasts 20-40 days. It is an extraneous pollinating plant. The geranium home country (South Africa), pollen mediated by the birds, while in Hungary the need for artificial pollination when the core recovery. Generally, fertility is poor. The germination strength is 71%.

The types of geranium are divided into two major groups according to the propagation method: F1 hybrids can be grown from seed heterosis and vegetative shoots propagated heterozygous varieties (Armitage and Kaczperski, 1992; Hass-Tschirschke, 1994; Burri, 2004). Heterosis breeding of varieties mainly deal with the United States. Horticulture varieties grown in Europe did not extend to plant cultivation. Vegetative propagated varieties can be grouped by growth. Small individuals grow to 20-30 cm (for example: variety of Radio, variety of Friesdorf). Middle-height individuals are 30-40 cm high (e. g. variety of Adonis, variety of Rubin). High individuals are 40 cm high (for example: variety of Hungaria) (Nagy, 1975).

The temperature requirement of the geranium moves within wide limits. Optimum temperature is 16-18 °C day and night of 12-14 °C vegetative periods. During cuttings it is 20 °C, but it can withstand 25-30 °C during the summer planting. It then blooms with the most intense water supply. The optimum temperature of the hybrid varieties is 18-24 °C (Dobay, 1998).

In addition to the optimal light conditions, the geranium develops and blooms favourably. With 25,000 lux illumination both in cultivation and outdoors, there is rapid growth, rich in flowering, rich in branching, stem does not stretch. It does not damage the 50,000 lux light when the required water content is available in the soil (Nagy, 1991).

Most of the geranium species live in their natural habitat in a dry, whimsical precipitation distribution area. Relative humidity should not exceed 70-75% in the glasshouse and foil. Particularly in the cool, dark, winter months, night and morning condensation are dangerous. If the temperature reaches the dew point, the water will precipitate on the glass, foil and drop into the plants, leading to the spread of the Botrytis (Glits and Folk, 2000). Winter irrigate geranium enough for 2-3 weeks.

The geranium species live in their original habitat on sandy humusous soil. In cultivation, soil is not particularly demanding, just like other ornamental plants. The soils in the pH range of 6.3-7.2 are ideal. Nitrogen, phosphorous and potassium-rich, but excessive N content causes strong vegetative development, hindering flowering. The N deficiency causes short leaves with small leaves. Lime-rich sensitive, it induces chlorosis in plants. In the soil, the salt concentration cannot rise above 0.5% otherwise the lower leaves will be smothered by salt suffocation. Effective defence is frequent, abundant, relieving irrigation. Rooting medium consists of 70-80% peat, 20-30% clay minerals, 10-20% bark + 2.5-3 kg / $m^3$ carbonated lime + 0.5 kg / $m^3$ complex fertilizer (Nagy, 1975).

Land disinfection is inevitable because the source of soil used in propagation and cultivation is very high. In addition to soil-fungi, bacteria and weeds, we find viral infected plant parts in the soil. The soil is disinfected by steaming at high temperatures at 92-95°C for 4-6 hours (Gerbár, 1992).

Among the most commonly used geranium pests to count the greenhouse whitefly (*Trialeurodes vaporariorum*) during the cutting propagation and growing. In summer, on the leaves of the geranium the Silver Y (*Autographa gamma*), on the geranium flower the cotton bollworm (*Helicoverpa armigera*) causes harm. Of the flower of geranium, it is regularly damaged by Western flower thrips (*Frankliniella occidentalis*) (Glits *et al*., 1997).

## MATERIAL AND METHOD

The experiment was set up in a gardening during in 2014 and 2015 in Kecskemét (Bács-Kiskun County), Hungary. The gardener was founded in 1978, initially for gerbera (*Gerbera*) and yucca (*Yucca*) were their main crops, but switched to the geranium (*Pelargonium*) cultivation as a result of market. In horticulture, there are about than 80 variety geranium of the standing, running, semi-trailer types and English gnawing. The *Pelargonium* was different sizes and colours. These are the 6-pack, 10 to 14 cm pot made commodity.

The cuttings are taken from parent plants from excellent propagation material and rooted in a computer-controlled greenhouse with soil heating. This way they can provide high quality cuttings for customers.

The gardening distributed by Klasmann-Deilmann GmbH, Germany Company, Klasmann TS 3 types of peat used in the cultivation of geranium. The composition of Klasmann TS 3 is a medium decomposed white filler, 0-25 mm; chemical properties: pH ($H_2O$, v / v 1: 2.5) 6.0; Nutrient content (g / l): 1.0 and added nutrients: Nitrogen (mg N / l) 140; Phosphorus (mg $P_2O_5$ / l) 100; Potassium (mg $K_2O$ / l) 180; Magnesium (mg Mg / l) 100; Fe 13% EDTA. Physical properties: dry matter content <10%, water capacity 75-80%, air capacity 10-15% (http[1]).

The colour trap (blue, yellow) is placed in the greenhouse to indicate the presence of pest insects.
Table 1 summarize the insecticides were used during the experiment (2014-2015).

Table 1. Insecticides during the experiments.

| Year | Insecticide | Active ingredient |
|---|---|---|
| 2014 | Actara | Thiamethoxam |
| | Cyperkill | Cypermethrin |
| | Danadim | Dimethoate |
| | Mospilan | Acetamiprid |
| | Spin tor | Spinozad |
| | Sumi-alfa | Esfenvalerate |
| | Vertimec | Abamectin |
| | Warrant | Imidacloprid |
| 2015 | Actara | Thiamethoxam |
| | Chess | Pymetrozine |
| | Cyperkill | Cypermethrin |
| | Danadim | Dimethoate |
| | Mospilan | Acetamiprid |
| | Naturalis | Beauveria bassiana |
| | Spin tor | Spinozad |
| | Sumi-alfa | Esfenvalerate |
| | Warrant | Imidacloprid |

## RESULTS AND DISCUSSION

During the experiment, the most common damages were caused by pests of greenhouse whitefly (*Trialeurodes vaporariorum*) and the Western flower thrips (*Frankliniella occidentalis*). The following pests were also found in the greenhouse: rose aphid (*Macrosiphum rosae*), mites (*Acari spp.*), bradysia (*Bradysia spp.*). The chemical protection was carried out from March to November in both years.
The 27% of the total geranium (1,000) damaged by *F. occidentalis* in 2014. The damage was 24% by *T. vaporariorum* in the same year.

In 2015, the greenhouse whitefly and the Western flower thrips damaged more geraniums than in 2014. The 30% of the total *Pelargonium* damaged by *Frankliniella occidentalis* and the damage was 25% by *Trialeurodes vaporariorum*.

The Mospilan, Admiral and Cyperkill insecticides were the most effective against of *Frankliniella occidentalis*. In addition to the insecticides, we also used an adhesion enhancer, Silwet. The Admiral insecticide was the most effective against of *Trialeurodes vaporariorum*.

## CONCLUSION

Our study was carried out in 2014 and 2015 in a horticulture in Kecskemét, Hungary. The main plant of horticulture is geranium (*Pelargonium*). During the experiment, the most common damages were caused by pests of greenhouse whitefly (*Trialeurodes vaporariorum*) and the Western flower thrips (*Frankliniella occidentalis*). The chemical protection was carried out from March to November in both years. The following pests were also found in the greenhouse: rose aphid (*Macrosiphum rosae*), mites (*Acari spp.*), bradysia (*Bradysia spp.*), but their damage is not significant.
In 2014 we used 8 insecticides: Actara, Cyperkill, Danadim, Mospilan, Spin tor, Sumi-alfa, Vertimec and Warrant. In 2015 we used 9 insecticides: Actara, Chess, Cyperkill,

Danadim, Mospilan, Naturalis, Spin tor, Sumi-alfa and Warrant. The Mospilan, Admiral and Cyperkill insecticides were the most effective against of *Frankliniella occidentalis*. The Admiral insecticide was the most effective against of *Trialeurodes vaporariorum*. In addition to the insecticides, we also used an adhesion enhancer, Silwet.

The 27% of the total geranium (1,000) damaged by *F. occidentalis* in 2014. The damage was 24% by *T. vaporariorum* in the same year. In 2015, the greenhouse whitefly and the Western flower thrips damaged more geraniums than in 2014. The 30% of the total *Pelargonium* damaged by *Frankliniella occidentalis* and the damage was 25% by *Trialeurodes vaporariorum*.

In addition to chemical protection, biological and mechanical protection should be applied in the future.

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# 4.13. STEM RUST RETURNS, OLD – NEW RYE PATHOGEN

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**Keywords:** stem rust, rye, leaf-segment test

## ABSTRACT
Rye can be infected by stem rust caused by *Puccinia graminis* f. sp. *secalis.* For many years infections rye by stem rust was negligible, but for certain years this disease has been epidemic. The increase in temperatures during the growing season caused an increase in the importance of this disease. The breeding of rye-resistant varieties to the stem rust is the best way to reduce this disease. For sustainable production, new varieties of rye (stem rust – resistant varieties) will be needed, which will be better adapted to changing socioeconomic and climatic environments and ensure good yield in terms of quality and quantity.

## INTRODUCTION
### Rye – meaning and production
Rye (*Secale cereale* L.) is the second most commonly used cereal (after wheat) which grains are used in the production of bread. Rye is considered as a highly versatile crop, for example as a green plant, it is used as a livestock pasture and green manure in crop rotations, as grain it is used for livestock feed and feedstock in alcohol distilling and as a flour it is used for baking breads and other baking products. Rye is also planted for prevent wind erosion in southern Australia, as pasture crop in Argentina (Chaves et al., 2008) and for biogas and bioethanol production in Germany. Rye is an important crop for farmers in many countries, because of its winter hardiness, ability to grown in poor soils or baked products (Bushuk, 2001). The main rye growing areas within the EU are located in Poland (873,222 ha), Germany (537,300 ha), Spain (108,080 ha) and Denmark (111,400 ha) (FAOSTAT 2017). 13,7 million tons of rye were produced worldwide in 2017, of which 81,6% within the Europe (Fig. 1). Germany (2.74 million tons) and Poland (2.67 million tons) were the largest producers of rye in the world in 2017 (Fig. 2) (FAOSTAT 2017).

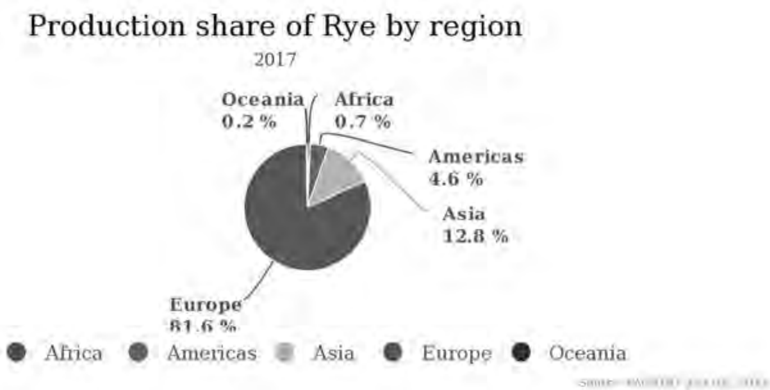


Fig. 1. Production share of rye by region in 2017.

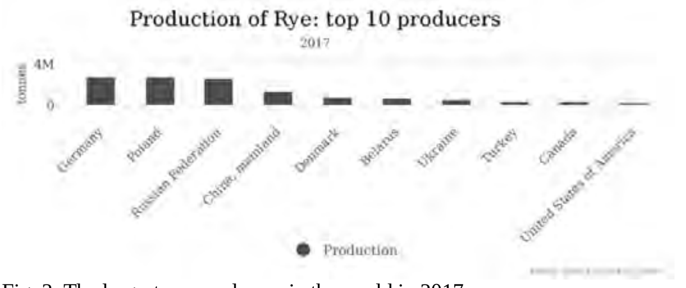


Fig. 2. The largest rye producers in the world in 2017.

**Rye rust**

Rye can be infected by three different types of rusts: leaf rust, caused by *P. recondita* f. sp. *secalis* Roberge, crown rust, caused by *P. coronata* var. *hordei* Jin & Steff. and stem rust caused by *Puccinia graminis* f. sp. *secalis* Erikss. & Henning.

**Disease symptoms**

At the beginning of infection discoloration on the infected tissues are visible. With the progress of infection the stem rust of rye is present as elongated pustules, which erupt through the surface of tissue. Pustules contain brick, red uredinospores (ellipsoidal). Pustules appear alone or in clusters and are mainly formed on stem, but may also occur on leaves and leaf sheaths (Fig. 3).

Fig. 3. Stem rust of rye.

Teliospores (dark, shiny, ellipsoidal, clavate, spindle shaped) are formed as plants mature. Teliospores are germinate and produce haploid basidiospores in the spring. Basidiospores infect the alternative host and spermagonia are formed. Next spermacia copulate and aecia (diploid generation) are formed. Aecia are formed on the lower side of alternative host leaves. The aeciospores infected rye. Next uredia are formed and new uredinal stage is started (Ishokova et al., 2002).

The spores of the fungus are mostly dispersed by wind over long distance. The alternate hosts of this fungi can be *Berberis vulgaris*, *B. canadensis* (Chaves, 2008).
Stem rust favors to develop hot days (25-30°C), mild nights (15-20°C) and wet leaves from rain or dew.

**Economic significance**

Stem rust it is considered as the one of the most destructive disease in rye, because no resistance cultivars are available (for instance in Germany and Poland). This disease can leads to increased water loss, decreased the amount of metabolites available for grain filing (Solodukhina & Kobylianskiĭ, 2000), which has a significant impact on the quality and quantity of the yield obtained. An epidemic can destroy a whole field even three weeks before harvest. *P. graminis* f. sp. *secalis* may cause yield losses up to 30-50%, even though it occurs late in the growing season. For example stem rust infection caused yield losses of 50-60% in Russia in epidemic years (Solodukhina & Kobylianskiĭ, 2000).

**Ecology**

For many years infections rye by stem rust was negligible, but for certain years this disease has been epidemic. For example the most serious epidemics in rye were in northern Europe (Roelfs, 1985).
The increase in temperatures during the growing season caused an increase in the importance of this disease, its occurrence to a greater extent in Europe. In the last years, rye stem rust regularly occurred in continental growing areas like Brandenburg (Germany), Pannonicum (Austria), and northern Poland. In the hot summer of Belarus and Russia, stem rust is a pertinent disease. In Southern Germany and Austria it is observed increasing number of years with epidemic of stem rust of rye that may be caused by warmer summer temperatures. Protection against stem rust of rye is particularly needed in hot-summer climates.

**Protection**

Understanding the epidemiology of disease is essential before starting any control strategy. Symptoms of stem rust of rye infection are visible in the later stages of plant development, hence the use of earlier fungicidal treatment against both brown rust and stem rust of rye at the same time is ineffective. The breeding of rye-resistant varieties to the stem rust is the best way to reduce this disease. Using of resistant cultivars is relatively inexpensive for rye producers and is reported to be more environmentally friendly than any other control strategies. Field test using adult plants have been used for first resistance genes for stem rust of rye identification. This method called "gold standard" is quite laborious, time and space consuming. A leaf – segment test (LST) is a high-throughput techniques. Thanks LST more populations and genetic resources could be analyses, in results the effort for identification of resistance genes would be considerable reduced. LST are also cheaper, faster and what important can be conducted in wintertime ahead of the growth period. Furthermore LST are potentially non-destructive and the resistant single plants can be further cultivated and used for breeding (Rahmatov et al., 2016). In the rye case resistance genes have been characterized up to now by field testing in several environments (Solodukhina & Kobylianskiĭ, 2000, Miedaner et al., 2016).
In addition rye may be important due to the source of resistance genes for other plants, e.g. for the related *Triticae* species.

## CONCLUSIONS

It is important to understanding mechanisms of plant resistance to stem rust. Especially known what genes control the events that prevent or delay the development of the infection structures of rust fungi. Genomic studies of the stem rust-rye interaction are great challenges for the future to reduce the infection by this disease. For sustainable production, new varieties of rye (stem rust – resistant varieties) will be needed, which will be better adapted to changing socioeconomic and climatic environments and ensure good yield in terms of quality and quantity.

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# 4.14. APPLICATION OF HERBAL ADDITIVES TO DEVELOP NEW TYPES OF NATURAL SNACKS: PROCESSING ASPECTS

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**Keywords:** gluten-free snacks, extrusion-cooking, process efficiency, energy consumption, herbal supplements

## ABSTRACT

Herbal supplements can be used as natural additives in gluten-free cereal crisps. The aim of the study was to produce extruded corn-based crisps supplemented with the addition of linden inflorescence (*Tiliae inflorescentia*) or elderberry (*Sambucus nigra*) flowers and fruits, or chamomile flowers (*Matricaria chamomilla)* in amounts of 1-5% and to evaluate the effect of herbal additives on the extrusion-cooking process. The research included measurements of energy consumption (SME) and of the efficiency of the extrusion-cooking process. Our work shows that increasing the amount of herbal additives increased SME values and reduced the process efficiency. Elderberry fruit turned out to be the most promising addition because it did not significantly negatively affect the examined processing aspects.

## INTRODUCTION

Functional food items on the market enriched with vitamins, nutraceuticals and herbs include puffed cereals, bread and drinks. These products can contribute to improving the quality of life, because they play important roles in the prevention of chronic diseases (Blicharski *et al.,* 2017). One of the many methods employed in producing such food items is extrusion-cooking. Its popularity is due to low energy consumption need coupled with high processing efficiency and the possibility to use a wide variety of raw materials and additives. The extrusion-cooking method is especially appropriate for functional food production, and instant gruels, pasta or snacks prepared with this method have a great potential to be good source of natural antioxidants (Oniszczuk *et al.,* 2015a).

Study findings have confirmed that a high-temperature short-time extrusion process has no negative impact on the antioxidant activity of polyphenolic compounds, present both in the raw products as well as gruels enriched with *Tilia*. Hence, extrusion-cooking could be used for the production of a wide range of products containing antioxidant active polyphenols (Wójtowicz *et al.,* 2017) derived from, for example, Silver linden *Tilia argentea Desf*. leaves (used to treat respiratory diseases and colds) (Toker *et al.,* 2005).

Chamomile is another well-known medicinal plant that could be processed via the extrusion-cooking process. It is known to hold a number of medicinal properties, e.g. anti-inflammatory, sedative, antispasmodic, spasmolytic, antimicrobial and antiseptic effects. Moreover, chamomile is attributed to have anti-carcinogenic properties, and as a potential diet enrichment supplement, could prevent cardiovascular diseases (Oniszczuk *et al.,* 2015b).

Previous research has shown that snacks enriched with *Sambucus* flowers and prepared by the extrusion process, have a great potential to be a good source of natural antioxidants and may be a convenient, health-promoting product useful in the prevention of lifestyle diseases (Oniszczuk *et al.*, 2017).

The aim of the study was to produce extruded corn-based crisps with the addition of linden inflorescence or elderberry flowers and fruits or chamomile flowers, and to study process efficiency and SME.

## MATERIALS AND METHODS

In this study, corn grit purchased on the local market (distributor: Awiko, Lublin, Poland) was used as a base ingredient in snack formulation, while dried linden inflorescence, elderberry flowers and fruits, and chamomile flowers were the additives (Kawon-Hurt, Gostyń, Poland). The herbal supplements were first ground with the laboratory grinder (Grindomix GM 200, Retsch, Germany). Blends of corn grits and herbal additives in amounts from 1 to 5% were subsequently prepared and mixed. The blends were moistened to 13% of moisture content. A single screw extruder type TS-45 (ZMCh Metalchem, Gliwice, Poland) with a ratio of the screw length to its diameter L/D= 12 was then used to create the corn-based snack goods at a screw speed of 120 rpm. Herein, extrudates were shaped with a single-open forming die of 2.5 mm diameter.. The maximum temperature of processing in the each sections of the extruder during processing was set at 130-140-142˚C. The snacks were cut for 3 cm pieces, collected, cooled down to ambient temperature and stored at room temperature. During processing, the extrusion process output was measured as a ratio of the obtained extrude mass per time unit (Matysiak *et al.,* 2018). Energy consumption as specific mechanical energy (SME) was determined according to the formula of Kręcisz el. al. (2015):

$$SME = \frac{n*P*O}{n_{max}*100*Q} \text{ (kWh kg}^{-1}\text{)} \quad (1)$$

where: $n$ - screw rotations (rpm), $P$ - electric power (kW), $O$ - engine load (%), $n_{max}$ - maximum screw rotations (rpm), $Q$ - process efficiency (kg $h^{-1}$).
Statistical analysis was performed using Statistica 13.3 software (StatSoft, US). The results were presented as box-and-whiskers plots. Homogeneous groups were determined using the Tukey post-hoc test.

## RESULTS AND DISCUSSION

The processing efficiency during the extrusion-cooking of corn-based snack supplemented with different herbal additives is presented in Figure 1. We found that with an increase in the content of the additive, as compared to the basic corn snack, a decreased efficiency was noted for snack supplemented with linden inflorescence, elderberry flowers and chamomile flowers (Fig. 1a, 1b, 1d). This effect is thought to have come about because the increased amount of fibrous fractions derived from herbal additives makes it difficult to obtain the proper expanded structure of snack products (Han *et al.,* 2018, Makowska *et al.,* 2015, Wójtowicz *et al.,* 2018). We also saw that the addition of linden inflorescence and chamomile flowers in a small amount (1 and 2%, respectively) significantly affected extrusion-cooking efficiency (Fig. 1a, 1d). Indeed, the lowest process efficiency (20.5 $kgh^{-1}$) was obtained during the production of corn-based crisps with 4% of linden inflorescence addition. In contrast, in the case of the elderberry fruit enriched corn snack (Fig. 1c), increasing the amount of additive to 4% in the recipe increased processing efficiency of snacks as compared to the basic corn-based snack control. However, elderberry fruits added in amounts from 1 to 5% insignificantly affected the extrusion-cooking efficiency (Fig. 1c). The maximum value (33.32 kgh$^{-1}$) of processing output was observed during the production of corn-based snacks enriched with 1% elderberry fruits. These values were comparable to the results presented by Lisiecka and Wójtowicz (2019) for corn-based snacks enriched with fresh vegetables where the highest values, above 34 kgh$^{-1}$, were noted for corn-based snacks with 2.5% leek content and for corn-based snacks with 5.0% of beetroot and onion produced at 120 rpm.

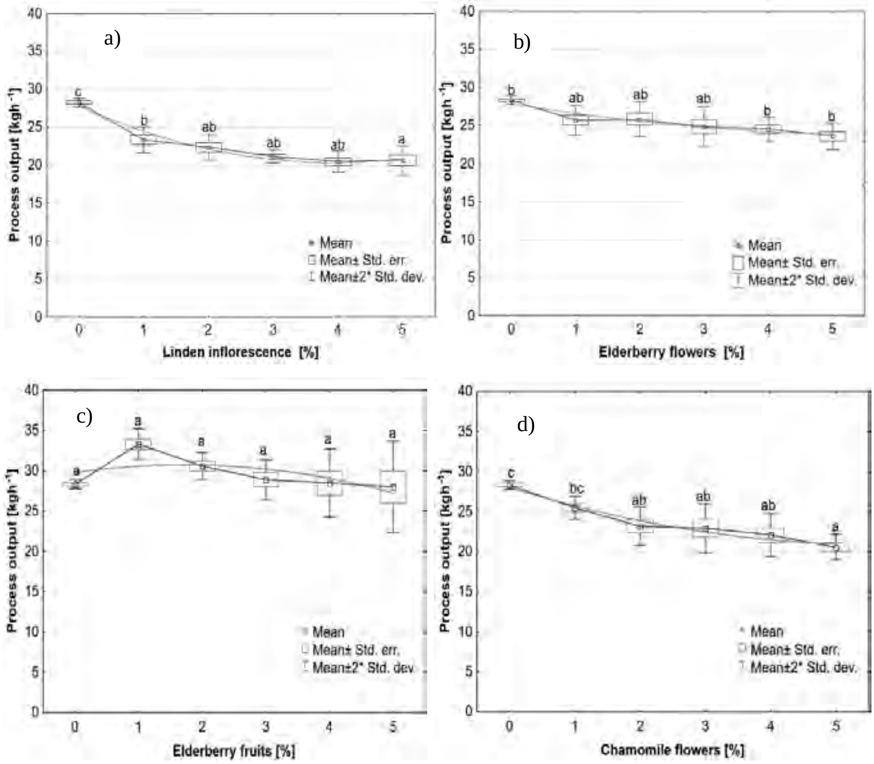


Fig. 1. The results of processing efficiency during the extrusion-cooking of corn-based snacks supplemented with various herbal additives: a) linden inflorescence, b) elderberry flowers, c) elderberry fruits, d) chamomile flowers; (n=3); $^{a-c}$ – means followed by the same letters indicate insignificant differences (p<0.05)

Energy consumption is one of the most important aspects of food processing, especially for producers. A corresponding amount of energy supplied during processing is responsible for the starch conversion during the extrusion-cooking. Higher SME is often connected with a better degree of starch gelatinization, because the mechanical energy promotes rupture of intermolecular hydrogen bonds (Pardhi *et al.,* 2019). The effect of processing variable conditions on specific mechanical energy requirements during the extrusion-cooking of various products has been reported by many researchers (Altan *et al.,* 2008, Comacho-Hernandez *et al.,* 2014, Kręcisz, 2016, Stojceska *et al.,* 2009). The effect depends on the extruder type and L/D configuration, raw materials used and processing conditions, especially initial moisture content and screw speeds (Kręcisz *et al.,* 2015, Matysiak *et al.,* 2018). The results of SME corn-based snack production with different herbals addition are presented in Fig. 2. With the increased amont of herbal additives an increased SME values were noticed during the extrusion-cooking of snacks supplemented with linden inflorescence, elderberry flowers and fruits and chamomile flowers, while the lowest value (0.09 kWhkg$^{-1}$) of SME was observed during the production of corn-based snacks without additives.

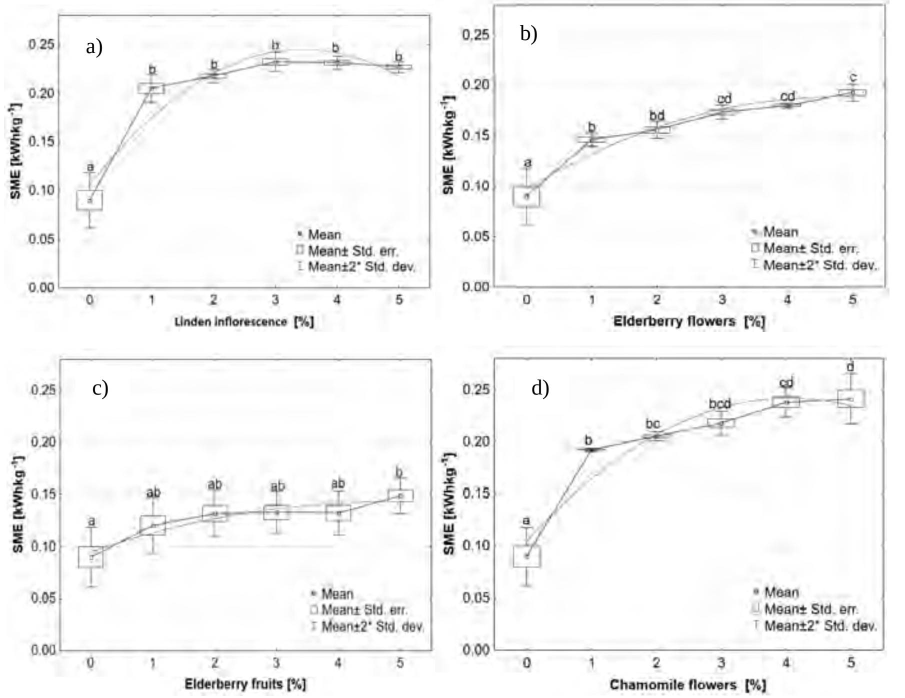


Fig. 2. The results of specific mechanical energy consumption during the extrusion-cooking of corn-based snacks supplemented with various herbal additives: a) linden inflorescence, b) elderberry flowers, c) elderberry fruits, d) chamomile flowers; (n=3); $^{a-c}$ – means followed by the same letters indicate insignificant differences ($p<0.05$)

There are some reports indicating that replacing starch with fiber-rich additives increases SME, as fiber from additives binds the water and thus enhances the products' viscosity during the extrusion-cooking (Singha *et al.*, 2018). In our study, the highest SME (0.24 kWhkg$^{-1}$) was obtained during the production of corn-based snacks with 5% chamomile flower addition (Fig. 2d). The results showed that even 1% of linden inflorescence, elderberry flowers and chamomile flowers had a significant effect on increasing energy consumption (Fig. 2a, 2b, 2d). The smallest differences were observed when elderberry fruits were added in the recipe (Fig. 2c), but for all the tested samples, the addition of the chosen herbs had a significant effect on SME values. A possible explanation lies in the work of Kręcisz *et al.*, (2015), who found SME values from 0.09 to 0.11 kWhkg$^{-1}$ for corn-rice instant gruels, wherein lower values may be the result of the higher initial moisture content of raw material blends.

## CONCLUSIONS

Studies have shown the possibility to fortify corn-based crisps up to 5% of the recipe with herbal additives, i.e. linden inflorescence, elderberry flowers, elderberry fruits and chamomile flowers. Our work revealed that the addition of elderberry flowers and fruits in amounts up to 5% had negligible effect on the results of process efficiency, which makes these additives recommended as a source of nutritionally valuable components in supplementing corn-based snacks. The addition of elderberry flowers and fruits also had no negative effect on the amount of products obtained. Furthermore, while all herbal additives increased the energy consumption during processing of supplemented corn-based snacks, the elderberry fruit addition in amounts from 1 to 4% did not significantly affect the energy consumption during the extrusion-cooking process. All the herbal additives used were suitable for obtaining enriched snacks, but the elderberry fruit addition seems to be the best because this additive had no significant effect on the tested processing aspects as compared to the other herbs that were tested.

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## 4.15. USE OF SELECTED CEREAL BRAN DEPENDING ON THE CONTENT OF SELECTED ELEMENTS

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**Key words:** cereal bran, sustainability, elemental analysis.

## ABSTRACT

Bran is a product made of non-waste milling of cereals. Sustainable development in the field of new technologies is increasingly used in food production. Raw materials and cereals are a natural source of fibre, several vitamins (mainly from B, C and E groups) as well as macro and micro elements crucial for maintaining correct body functions. Depending on the content of specific elements they possess uniquely precious properties which may be a determinant of their further use in practice. The objective of this work was to define usefulness of the selected ecological cereal brans on the basis of the conducted mineral analysis CP OES. The following macro elements have been marked and interpreted: Calcium (Ca), Phosphorus (P), Potassium (K), Magnesium (Mg), Sodium (Na), as well as microelements, that is: Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Selenium (Se) Zinc (Zn). Furthermore, attention was paid to harmful elements occurring in alarming volumes, such as: Nickel (Ni), Lead (Pb), Aluminium (Al), whilst others, such as: Cadmium (Cd), Arsenic (As), which were located below the limit of quantification.

## INTRODUCTION

New technologies in the processing of agricultural produce allow reducing the generated waste, which contributes to the reduction of disposal costs. Some of the resulting by-products have a number of valuable nutritional values, which affects their further use (Sobczak, et. al. 2015, Kozak et. al. 2017). Mineral substances enter an organism through oral route or in the form of supplementation. Human organism is unable to synthesize them, thus one ought to ensure that they are systematically provided in adequate proportions and volumes. Shortages of macro or micro elements lead to deficiency symptoms. Due to the contents in an organism and the level of daily demand, minerals may be divided into two basic groups:

- Macro elements comprised by: Calcium (Ca), Phosphorus (P), Magnesium (Mg), Sodium (Na), Potassium (K) and Chlorine (Cl). They are characterized by high contents in an organism, exceeding 0.01%, while demand for them exceeds 100 mg per day.
- micro elements, thus trace elements, such as for instance: Iron (Fe), Copper (Cu), Zinc (Zn), Manganese (Mn), Fluorine (F), Iodine (I), Cobalt (Co), Molybdenum (Mo), Selenium (Se), Chromium (Cr). They are present in human body in volumes less than 0.01%, upon demand exceeding 100 mg/person/day (Ziemlański 2001).

Macro and micro elements participate in certain crucial for life metabolic processes, such as: electrolytic economy, hormonal economy haematopoiesis, metabolic transformations, as well as correct functioning of the nervous and skeletal systems (Somer 2000, Ziemlański 2001).The objective of this work was to define usefulness of the selected ecological cereal brans on the basis of the conducted mineral analysis CP OES.

## MATERIAL AND METHODS

Research material consisted of 5 types of cereal bran (buckwheat bran, spelt bran, oat bran, wheat bran, rye bran), originating from Polish ecological crops. Samples were mineralized in the closed system with the use of Anton Paar microwave oven. Grinded in sample mortar they were subsequently moved to Teflon films (150-300 mg per sample). Then, HNO3 and HCl were added in the ratio 3:1. The following mineralization programme was applied: Step 1 - 10’ in 350 W, Step 2 – 35’ in 650 W, Step 3 – cooling of vessels. Mineralized samples were filtered through a falcon filter. The obtained solutions were diluted in ultra-pure water up to 50ml.The ICP OES analysis was carried out on Spectro Blue spectrometer. The following patterns were applied in order to prepare a calibration solution: Bernd Kraft Der Standard Spectro Genesis ICAL and VHG SM68-1-500 Element Multi Standard 1 in 5% HNO3. Measurements of samples were carried out three times. Tests were performed within Regional Centre Research of Environment, Agriculture and Innovative Technology EKO-AGRO-TECH Pope John Paul II State School of Higher Education in Biala Podlaska, Poland.

## RESULTS

The following micro elements were detected in the composition of the tested cereal: Calcium (Ca), Phosphorus (P), Potassium (K), Magnesium (Mg), Sodium (Na) in volumes specified in table 1. Elements from the group of micro elements were also marked, that is: Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Selenium (Se) Zinc (Zn), which have been presented in table 2. Furthermore, attention was drawn to harmful elements occurring in alarming quantities, such as: Nickel (Ni), Lead (Pb), Aluminium (Al), the contents of which has been presented in table 3, whilst the contents of Cadmium (Cd) and Arsenic (As) in all tested samples was at the level below the limit of quantification.

Table 1. Contents of macro elements in selected cereal bran expressed in [ppm]

| Type of bran / element | Ca | P | K | Mg | Na |
|---|---|---|---|---|---|
| Buckwheat bran | 203.41 | 4760.07 | 3032.73 | 1788.66 | 152.69 |
| Spelt bran | 403.18 | 7186.45 | 4253.78 | 2015.33 | 333.26 |
| Oat bran | 463.31 | 4621.96 | 2390.88 | 1277.10 | 27.57 |
| Wheat bran | 895.00 | 9629.21 | 7433.68 | 3235.26 | 296.57 |
| Rye bran | 627.05 | 4783.33 | 4027.48 | 1425.32 | 322.07 |

The largest content of Calcium (Ca) was noted in wheat bran (895.0 ppm), whilst the lowest in buckwheat bran (203.41 ppm). The largest volume of Magnesium (Mg) was noted in wheat bran (3235.26 ppm), as well as spelt bran (2015.33 ppm), whereas the lowest contents was noted in oat bran (1277.10 ppm), (Table 1). Sodium (Na) was marked in large volumes in spelt bran (333.26 ppm), whereas the smallest volumes of this element were found in oat bran (27.57 ppm), (table 1).Wheat bran turned out to be a perfect source of potassium (K) (7433.68 ppm), but significant levels of this element were also reported in spelt bran (4253.78 ppm) and rye bran (4027.48 ppm). The smallest amounts of potassium were found in oat bran (2390.88 ppm), (table 1). The largest contents of phosphorus (P) were marked in case of wheat bran (9629.21 ppm) and spelt bran (7186.45 ppm). The smallest volumes of this component were reported in oat bran (4621.96 ppm), (Table 1). The largest volumes of iron (Fe) were noted in wheat bran (96.57 ppm), and the smallest - in buckwheat bran (32.55 ppm), (Table 2).

Table 2. Contents of micro elements in the selected cereal expressed in [ppm]

| Type of bran / element | Co | Cr | Cu | Fe | Mn | Se | Zn |
|---|---|---|---|---|---|---|---|
| Buckwheat bran | <0.001 | 0.18 | <0.001 | 32.55 | 16.72 | 0.00 | 22.84 |
| Spelt bran | <0.001 | 0.39 | <0.001 | 58.96 | 28.08 | 0.39 | 25.89 |
| Oat bran | <0.001 | 0.23 | <0.001 | 37.85 | 46.49 | <0.001 | 17.99 |
| Wheat bran | <0.001 | 0.26 | <0.001 | 96.57 | 88.68 | <0.001 | 47.10 |
| Rye bran | <0.001 | 0.21 | <0.001 | 52.16 | 61.03 | <0.001 | 36.58 |

Whilst, copper (Cu) as well as cobalt (Co) was marked below the limit of quantification, amounting to 0.001 ppm in all tested brans (table 2).The highest contents of magnesium (Mn) was observed in wheat bran (88.68 ppm), while the lowest in buckwheat bran (16.72 ppm), (table 2). Selenium (Se) was reported in spelt bran at the level of 0.39 ppm, whilst in the remaining samples - below 0.001ppm, (table 2). Chromium (Cr) was observed on the highest level in spelt bran (0.39 ppm), while the lowest contents occurred in buckwheat bran (table 2).The smallest contents of heavy metals was noted in cereal bran, where only the content of aluminium (Al) amounted to 22.29 ppm, while the remaining elements such as: Ni, Pb, As, Cd were below the limit of quantification, (table 3).

Table 3 Contents of heavy metals in selected cereal expressed in [ppm]

| Type of bran / element | Ni | Pb | As | Cd | Al |
|---|---|---|---|---|---|
| Buckwheat bran | 1.26 | 1.61 | <0.001 | <0.1 | 16.54 |
| Spelt bran | 0 | 1.79 | <0.001 | <0.1 | 10.15 |
| Oat bran | 0.93 | <0.001 | <0.001 | <0.1 | 13.55 |
| Wheat bran | 0.79 | <0.001 | <0.001 | <0.1 | 27.36 |
| Rye bran | 0 | <0.001 | <0.001 | <0.1 | 22.29 |

## DISCUSSION

Tests concerning the contents of elements with a wide range of material of plant origin have been the subject of interest in many scientific centres. Contents of elements in cereal was marked on a world scale. Cereal products are a rich source of mineral components for a human body (Awika, 2011, Dewettinck *et al.,* 2008; Poutanen, 2012, Jâkobsone et. al., 2015). The contents of minerals in cereal products depends on many environmental factors. According to the literature, the most crucial of them include type of soil and climate. Furthermore, issues related to crops, phase of plant development, maturity are of importance (Smith *et al.,* 2012).The contents of elements in plant material is significant mainly due to food aspects concerning the contents of macro and micro elements and, in particular, such elements as: Fe, Ca, Cu and Zn (Kashian and Fathivand, 2015, Żukiewicz-Sobczak *et al.*, 2017, Kozak *et al.*, 2016). Within own tests, from amongst the indicated elements, only copper (Cu) occurred below the limit of traceability (0.001 ppm). One ought to remember that micro elements perform substantially important functions in a human body, though they are in fact needed in trace amounts. On account of this, if the required level is exceeded, they become toxic for the organism. According to multiple authors, these elements include: Cadmium (Cd) and Lead (Pb) (Al-Gahri and Almussali, 2008). Within the tested bran no Cadmium was detected, whilst alarming volumes of lead in buckwheat bran were noted at the level of 1.619 ppm and rye bran - 1.793 ppm.

## CONCLUSIONS

Protection of natural resources as well as rational waste management leads to optimization of many technologies in agri-food production. Based on the definition of sustainable development, environmental protection strategies involving continuous, integrated and preventive operation in product production processes. Such activities lead to increased production efficiency as well as reduced risk to people and the natural environment. Sustainable production aims to produce goods that use processes that reduce pollution. In connection with this idea, the production of bran in the non-waste use of cereals has the hallmarks of sustainable development. Occurrence of selected cereal bran depending on the contents of the selected elements may constitute a broad spectrum of applications. Cereal with rich composition of macro and micro elements, such as wheat may be a precious material for production of functional food and special designation food. Other, less rich in terms of components bran, such as buckwheat bran may find their use as supplementation of a daily diet or addition to animal feed on farms. Similar dependencies ought to be considered in terms of possible applications.

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# 5. MANAGEMENT AND ECONOMICS

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## 5.1. PERFORMANCE OF A CHESTNUT VACUUM HARVESTER – FIRST RESULTS

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**Keywords**: mechanization, chestnut orchard, harvester work rate.

## ABSTRACT

In Portuguese chestnut producing regions, harvest is mostly manually. Nowadays it's difficult to find available labour. Harvest mechanization is a solution if some difficulties of actual harvesting systems, are solved. Currently the equipment available is not completely suitable to work under high humidity conditions and high concentration of leaves and chestnut burrs, conditions that can jeopardize equipment performance. Another difficulty is pointed out by the agro-industry that complains that chestnut mechanically harvested appear with stone, branches and other materials that depreciate their value. It is important to improve harvesting procedures. Equipment performance knowledge is an important step to find solutions for problems mentioned. In 2018 harvesting season, field trials took place in a chestnut orchard in Northeast of Portugal to get information of equipment performance. This paper presents work rate preliminary results of one vacuum harvester.

## INTRODUCTION

In Portuguese chestnut (*Castanea sativa*) producing regions, harvest is mostly manually, collecting from the soil previously fallen chestnuts.

In the last decades chestnut harvesting machines are available in the market, in continuous technological evolution. The use of this equipment has reduced the harvesting time and the associated costs. It is also an answer to the lack of labour required for manual harvesting. Consequently it has been an alternative to traditional manual harvesting (Monarca, D. *et al.,* 2014a).

There are two main categories of chestnut harvesting machines: vacuum-type harvesters and mechanical pickers (Monarca, D. *et al.,* 2014a). These two types of equipment are commercially available trailed, mounted and self-propelled.It is expected that mechanical harvesting provides an improved quality of chestnuts, because a better work rate can reduce the time in which the fruits stay on the ground. The chestnuts must not remain too long in contact with the ground to prevent its desiccation, contamination by fungi and the risk that they might be attacked by rodents.However, for farmers fully enjoy these advantages, some aspects of the operation need to be improved: to reduce fruits damages caused by equipment and to improve equipment performance under high humidity conditions common during harvesting season.Chestnuts harvested with the equipment currently available in the market may not have better quality than the fruits manually harvested. In addition to the chestnut, some stones, branches and other inert are harvested, that by abrasive effect, damage the integrity of the chestnut and depreciate its commercial value, especially for fresh consumption. The percentage of damaged fruit is higher when harvested mechanically than when harvested manually. The most common damage assessment refers to: petiole absence, superficial scratches, visible strokes and tears in the epidermis, and deep abrasions affecting a thicker layer of the epidermis (Monarca, D. *et al.,* 2003; Monarca, D. *et al.,* 2005; Monarca, D. *et al.,* 2014b).

It is important to improve harvesting procedures and to improve the quality of work done by machines. Equipment performance knowledge is an important step to find solutions for problems mentioned.

## MATERIAL AND METHODS

### Field trials sites

Field trials took place in November 2018 in Northeast Portugal (41º 39' 35"N 6º 50' 46"W - altitude 885 m) over an area of 4275 $m^2$ with a slight slope (up to 5%) in an orchard of "Judia" cultivar, 25 to 35 years old, tree spaced 9.5 m x 9.5 m (site 1) (Figure 1). In this site was collected data to evaluate equipment work rate and work speed.

Fig. 1. Site 1.

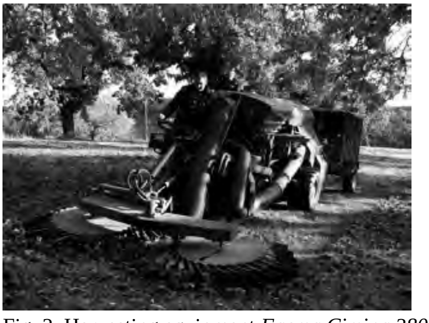

Fig. 2. Harvesting equipment *Facma Cimina 380*.

In a site 2, similar and near site 1, but with an area of 4250 $m^2$, was collected data to evaluate work speed.

### Harvesting equipment used

A vacuum self-propelled harvester *Facma Cimina 380* was used (Figure 2). The characteristics of this equipment are in Table 1.

Table 1. Equipment characteristics.

| | |
|---|---|
| Traction | Two rear-wheel drive with hydraulic transmission |
| Length (mm) | 5950 |
| Height (mm) | 1890 |
| Width (mm) | 1770 |
| Harvesting width (mm) | 3000 |
| Weight (kg) | 2630 |
| Power (kW) | 74 |

The equipment has a centrifugal fan to produce the vacuum that picks up the material from the soil surface and is also used to separate the fruit from the burrs, leaves, small branches and others inert (Guyer, D. E. *et al.*, 2012).

### Harvesting methods

The machine collected chestnuts from the soil in the area between rows traveling three times as shown in Figure 3. After the last of these three passes, the machine went to harvest in the next inter row area. Time for harvesting in each inter row includes time spent to turn over inside each inter row. There is a harvest interruption in the turns between inter rows.

Chestnuts collected are temporarily stored in a semi-trailer pulled by the harvesting equipment with a capacity of approximately 1000 kg.

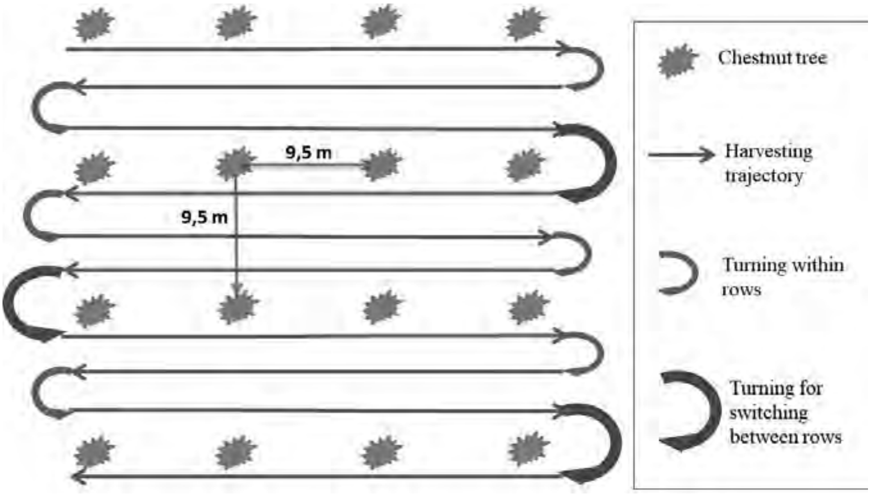


Fig. 3. Trajectories of harvesting equipment.

### Work speed evaluation

The average work speed was evaluated by measuring with a chronometer the time spent by equipment between turns and relating this to the space travelled.

This data was obtained in two sites. Site 1 with three repetitions, and site 2 with four repetitions.

### Equipment work rate evaluation

To evaluate the equipment work rate, time for each elementary operation was measured with a chronometer: harvesting time; inoperative time; turning time within two rows (during which harvesting continues) and turning time for switching between rows (during which harvesting stops). Inoperative time refers to the interruption of work to clear the product flow in the internal equipment parts.

Working rate was evaluated by the ratio worked area / time, in $m^2.s^{-1}$ and $ha.h^{-1}$

The total working time results by the sum of each elementary operation. Total harvesting time is obtained by adding harvest time to turning time within each row.

Total working time, because it includes turning times when harvesting is interrupted and inoperative time, is higher than harvesting time.

Harvesting performance is assessed by field efficiency: ratio between the sum of elementary operation time during harvesting and total working time. Field efficiency is expressed as a percentage, reporting the ratio of the time a machine is effectively operating, to the total time committed to the operation. (Hunt, D. 1983).

## RESULTS AND DISCUSSION

### Work speed

Average work speed: 0.96 km.h$^{-1}$ to 1.47 km.h$^{-1}$ or 0.27 m.s$^{-1}$ to 0.41 m.s$^{-1}$.

Table 2. Work speed in site 1

| Distance (m) | Time (minutes) | Medium work speed (km.h$^{-1}$) |
|---|---|---|
| 40 | 2.55 | 0.96 |
| | 2.73 | |
| | 2.25 | |

Table 3. Work speed in site 2

| Distance (m) | Time (minutes) | Medium work speed (km.h$^{-1}$) |
|---|---|---|
| 169.5 | 6.31 | 1.47 |
| | 7.45 | |
| | 6.6 | |
| | 7.5 | |

### Equipment work rate

Table 4 shows harvesting elementary operations time in field tests.

Table 4. Elementary operations time

| Elementary operations (minutes) | | Total elementary harvesting operations (minutes) | Total elementary non harvesting operations (minutes) |
|---|---|---|---|
| Harvesting | 51.85 | 54.94 | |
| Turning within two rows | 3.09 | | |
| Inoperative | 5.8 | | 12.05 |
| Turning for switching between rows | 6.25 | | |
| Total | | 66.99 | |

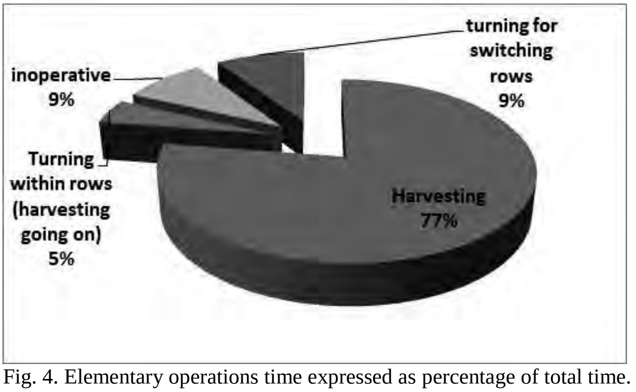


Fig. 4. Elementary operations time expressed as percentage of total time.

Considering 66.99 minutes to complete harvesting in 4275 m$^2$, results in these preliminary tests, a work rate of 0.383 ha.h$^{-1}$ or 1.064 m$^2$.s$^{-1}$.

Field efficiency is 82%. This field efficiency value is satisfactory.
Inoperative time is 8.7% of the total. As observed in field tests, with higher humidity, and with many leaves on the soil, the equipment becomes less efficient or even inoperative as a result of obstruction / clogging of product flow inside equipment. In

these situations, not represented in this paper, a relative increase in inoperative time is expected.

The amount of chestnuts harvested was 700 kg (approximate value), resulting in 630 $kg.h^{-1}$, which is in accordance with references (Monarca, D. *et al.*, 2003; Monarca, D. *et al.*, 2005).

These are preliminary performance results. It is necessary to continue field tests with this equipment and others available in the market.

## CONCLUSIONS

With manual harvesting it is expected to harvest 20 $kg.h^{-1}$ to 30 $kg.h^{-1}$ per person (Monarca D. *et al.*, 2003; Monarca D. *et al.*, 2014a). The results obtained in these preliminary tests point to a remarkable increase in the harvesting work rate with a vacuum harvester. This advantage makes it easier to match the time available to harvest preserving fruit best quality, with the area to be harvested. The reduction in the time necessary makes easier the double harvesting to reduce the period of fruit contact with the moist soil, with advantage for the chestnut sanitary conditions. Double harvesting means to harvest the same area twice. This procedure can be considered necessary because chestnuts are falling to the ground over a period of three or four weeks.

Results show an inoperative elementary operation of 8.7% of total time, necessary to clean the product flow inside of equipment. This slows down the work rate. To solve this problem it is important to improve the chestnut cleaning procedure inside the equipment.

Mechanical harvesting is also a solution to the labour shortage for this operation. In future work, fruit damage should be evaluated and harvesting costs evaluated.

Harvesting costs must be evaluated for a better understanding of mechanical harvesting advantages. Costs of manual and mechanical harvesting must be compared.


## ACKOWLEDGEMENTS

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# 5.2. EFFECTIVE BIOMASS SUPPLY MANAGEMENT AS A FACTOR OF SUSTAINABILITY OF ECOSYSTEMS

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**Keywords**: biofuel, logistics, supply, sustainability, ecosystems

## ABSTRACT
Biomass logistics strategy is an important aspect of biofuels production efficiency growth as well an important factor guarantying sustainability of ecosystems as well. Major factor determining production efficiency is proper organization of biomass transport and storage. The article presents main aspects related to logistics supply, including the organization of supplies in the production of biofuels and an example of a tool designed to support decisions concerning the supply of biomass. Research related to decision support in the supply of raw material contributes to optimize logistics costs, which can have an impact on increased efficiency biofuel production in a context of policies going to ensure sustainability of human being natural environment.

## INTRODUCTION
Fossil fuels are available to be included in emissions and greenhouse services (Kriegler *et al.*, 2017, Riahi *et al.*, 2017) to satisfy priorities of current EU environment policies. In recent years, EU leaders have approved a comprehensive package of measures to address climate change and ensure Europe's security and enough energy supply (Humpenöder *et al.*, 2014). The package, which is the most comprehensive reform of decisions on possibilities so far, aims to ensure the Union's position as a global leader in renewable energy and low-carbon technologies. The result of these arrangements is to be a 20% reduction in greenhouse emissions by 2020, compared to 1990. Such trend will be continued taking attention future regulations. The European Union considers the above objectives, above all it limits the use of energy and increases the consumption of energy from renewable sources (RES). This led to an increase in the production of energy production technologies in the field of renewable resources, including for the dynamic increase in the use of biomass for energy purposes, as a raw material for biofuel production (Ghaley and Porter, 2014). Even more, such the EU policy is included in wider strategy to held sustainable ecosystems for future generations (Helming *et al.*, 2013, Brouwer, 2016, Rötter, 2013).
The energetic use of biomass as a raw material to produce biofuels is justified then, when a positive ecological effect can be applied (reduction of greenhouse effect emissions). In many literature sources, the appropriate location of their production is mentioned as an impact on the efficiency of biofuel production. It must include territory's biomass richness and rational organization of production in terms of transport and storage of raw material (Qin, Liu, 2018, Ko, Lautala and Handler, 2018). The adoption of a logistics strategy for the supply of raw material-biomass is a very complex aspect when planning the production of biofuels. From the perspective of the location of their production, it is important to properly identify the resources of raw materials, as well as the directions of their use, in accordance with the requirements of development. Currently, more and more often, the search for a convenient location uses techniques available in GIS spatial information systems (Panichelli and Gnansounou, 2008, Laasasenaho *et al.*, 2019).
With the growing range of biomass for energy-related purposes, optimization of supply logistics, requires planning, organization and management of resources and transport can be effective method to increase sustainability of ecosystems of rural areas ensuring economic efficiency of farming (Sandhu *et al.*, 2016, Pang *et al.*, 2016).

From the perspective of management and organization of biofuel production, an important aspect to condition its effectiveness in economic and ecological terms is to adopt an appropriate strategy logistics supply of raw material. In a biofuel production company, this task is being carried out as part of procurement logistics, which is the connection between supplier distribution logistics and logistics production. The main problems in this area include continuity of supply and organization of transport biomass. According to the author, it is helpful in the described area of operation of enterprises in this industry can be the development and implementation of systems and tools supporting decisions. Example such a tool was presented in the study.

**Logistics of raw material supply in the biofuel production**

Supply in general is the first and one of the most important links in the logistics chain as well plays a very important role in the functioning of every enterprise. This is since existence the functioning of enterprises is the basic process directly related to the production of products and providing services that require logistical support. In industrial enterprises materials should be provided and made available and other items needed to manufacture the products as per their order or demand to their first use in production or to a supply warehouse. In addition, materials and services purchased from suppliers usually constitute a significant cost item for which it is allocated a significant part of the revenues of each industrial enterprise. Hence, rational choices in the sphere of supply, they are a factor affecting a company's profitability (Yu *et al.*, 2013). In biofuel production raw material is biomass. The use of biomass for energy purposes is associated with the following production processes: biomass production, biofuel production from biomass and production energy from biomass or biofuels. It should be emphasized that these processes are usually carried out by separate business entities. Biofuel is a fuel (a substance which releases under intensive oxidation the amount of heat that arises from biomass processing). There are different types of the raw material for biofuel production plant or animal biomass. We distinguish different types of biofuels made from biomass. They can be state of liquid, solid and gas. Liquid biofuels include higher fatty acid esters, bioethanol, for solid belong pellets and briquettes, biofuel in gaseous form it's biogas. The biofuels listed above also differ in their production technology. Liquid biofuels are received, among others by alcohol fermentation of carbohydrates, butyl fermentation of biomass, or esterification of vegetable oils. Gaseous biofuel - is created, for example, as a result of anaerobic digestion agricultural or vegetable waste from agricultural production. Solid biofuels are generated by mechanical means compacting of crushed biomass. Fuel with a higher bulk density is obtained in this way (Król, 2013, Wang, *et al.*, 2019). In the current reality, biofuel production is based primarily on existing raw materials – agricultural production products or their residues, to a lesser extent on so-called energy crops, and on waste from the production of the wood and food industry (Swain, 2017). Means, that the main producers of biomass used to produce biofuels are farmers. Place of origin biomass is primarily land cultivated by farmers, earmarked for specific plants. Hence, the occurrence of biomass is characterized by high territorial dispersion, which makes it difficult and increases the costs associated with the process of supplying biofuel producers with raw material. The use of agricultural biomass as a raw material has an impact on other aspects that should be considered in biofuel supply logistics. It should be mentioned first that it is limited availability raw materials. It results from the priority of allocating agricultural production space as well as products agricultural for food-related purposes. Competition between food target and production biofuels, in the use of agricultural biomass is the subject of many disputes and discussions. In response to this problem, Directive 2009/28 / EC of the European Parliament was introduced and the Council of 23 April 2009 on the promotion of the use of energy from renewable sources. It aims to promote second generation biofuels, which are obtained from non-constituting materials no competition for food. It provides for financial support for production and use only such bio-raw materials that meet the sustainability criteria described in the directive regarding among other sources of raw material, or the level of reduction of greenhouse gas emissions. Such solutions are to more effectively protect the European Union and domestic market against the import of bio raw materials from countries where there are doubts that they do not meet the criteria of sustainable development, e.g. cutting down tropical forests for the cultivation of plants to produce biofuels. She also assumes detailed regulations regarding the certification of raw materials and biofuels. A certification system is already in force in Poland biomass and biofuel production chain (e.g. ISCC, i.e. International Sustainability & Carbon Certification), which gives the opportunity to distinguish energy carriers produced in a sustainable way using renewable sources. Certified are, among other oilseeds, oils, further intermediates and products (e.g. esters, ethanol, biodiesel). There are five basic aspects to it then evaluated:

- protection of valuable natural areas,
- protection of areas with high carbon resources,
- sustainable agricultural production,
- the volume of greenhouse gas emissions throughout the entire production chain (from agriculture to the final recipient),
- method of managing materials.

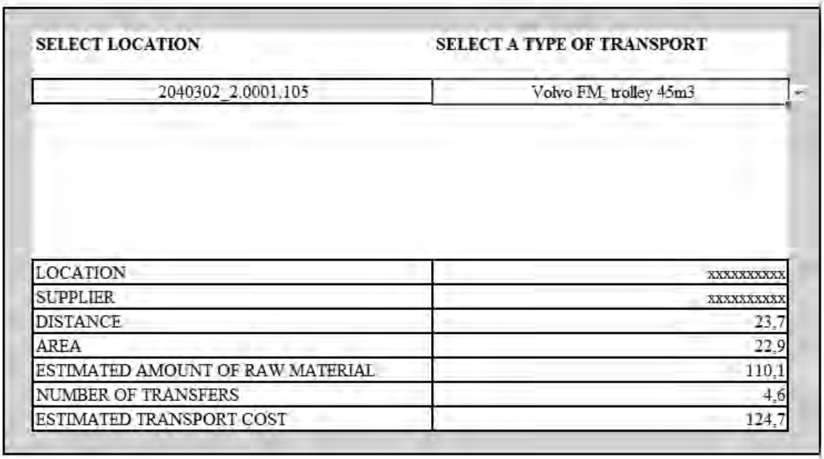
Another aspect is the seasonality of biomass supply, which is usually harvested once a year, in a short time period. It is then necessary to collect, transport and store the appropriate one the amount of raw material to ensure continuity of biofuel production. Due to the natural nature of the biomass production it should also consider the risk associated with adverse weather conditions, which can significantly reduce the level of extracted raw material (Bojar *et al.,* 2014).

Transportation decisions affect the logistics costs of raw material supply. They concern above all everyone choosing the means of transport and routes considering the distance and quality of roads, coin – the case of the spatial nature of biomass production, it is very important. Some types of biomass (e.g. straw, hay, energy crops) are "expensive" to transport due to low bulk density. Often, despite the use of means of transport with a large loading volume, no it is possible to transport the load weight that is permissible for such means of transport (Ko *et al.,* 2018). An example it can be a transport set consisting of a truck tractor and a flatbed trailer with a permissible weight load of 24 tons, which can carry a maximum of about 9-10 tons of straw. Hence, solving transportation problem of biomass raw materials requires suitable tools.

## The findings on decision support concerning raw material supply process in the biofuel production on example of Company X

Described above research problem can be illustrated by a case of Company X. The cost of such load per unit mass are very high. Company X deals with the production of methyl esters of higher fatty acids from oil rapeseed (FAME). Characteristic for the company is "shortening" logistic chain through the independent purchase of raw material, its processing into an intermediate form (oil) and proper biofuel production. The company expanded the scope of its activity through long term investments in the next stages of rapeseed processing, which currently allows it in a more way flexibly adjust sales to the current situation on the rapeseed and its derivatives market. Undertaking deals in the purchase and storage of rapeseed, has a modern rapeseed oil press and an esterification plant (biorefinery) in which rapeseed oil produces higher methyl esters fatty acids that are a biocomponent of transport fuels. As part of the supply of the enterprise cooperates with many suppliers. At the stage of obtaining primary raw material, the suppliers are local farmers from whom the company buys rapeseed directly, as well as dealing companies typically trade in agricultural produce. The company also partly supplies oil rapeseed coming from external suppliers due to higher efficiency of esterification plants than oil mills, as well as in large quantities of methanol and other materials necessary for the production process being carried out by company. The scale of production and supply processes is illustrated by the following data:

- annual production of about 30,000 tons of higher fatty acid methyl esters,
- the process of parallel "batch" transesterification in 6 mixing chambers,
- production of about 100 tonnes of esters per day and about 20 tonnes of glycerin per day,
- daily consumption of about 200 tons of rapeseed for oil production,
- production of about 75 tonnes of rapeseed oil and about 125 tonnes of rapeseed oil cake per day.



| SELECT LOCATION | SELECT A TYPE OF TRANSPORT |
|---|---|
| 2040302_2.0001.105 | Volvo FM, trolley 45m3 |

| | |
|---|---|
| LOCATION | xxxxxxxxxx |
| SUPPLIER | xxxxxxxxxx |
| DISTANCE | 23,7 |
| AREA | 22,9 |
| ESTIMATED AMOUNT OF RAW MATERIAL | 110,1 |
| NUMBER OF TRANSFERS | 4,6 |
| ESTIMATED TRANSPORT COST | 124,7 |

Fig. 1. Screen of report of raw material supply in created tool
Source: own investigation

In cooperation with the company, work began on creating of decision support tool related to the supply of raw material for the production of biofuels for collection and processing data regarding the location of raw materials and their quantity obtainable from local suppliers, as well as supporting decisions related to the organization of transport raw material for storage and use. The tool in the form of an IT application will allow in the enterprise, rationalization of processes related to the supply of biomass as a raw material to produce biofuels. Contains a database including, among others, where resources occur biomass and its properties and means of transport. In addition, it contains calculation algorithms for estimation biomass energy potential, as well as a calculator for biomass transport costs to the production plant biofuels for different supply variants (Figure 1). The tool allows you to identify acquisition sites raw material on numerical maps.

## CONCLUSIONS

In undertaken research there was proof that effective biomass supply management is a factor of sustainability of ecosystems. Energetic use of biomass as a raw material for biofuel production is justified then, when it achieves a positive ecological effect, while striving to achieve the highest efficiency production and economy compared to the use of conventional fuels. In enterprises in this industry, there is a need to support decisions related to supplying raw material, resulting from its limited availability and spatially distributed occurrence. Research related to decision support in the supply of raw material contributes to optimize logistics costs, which can have an impact on increased efficiency biofuel production. In other side presented solutions can support more effective biofuel managing processes. It means that presented solutions simultaneously support sustainability of ecosystems through decreasing not desired effect of fossil fuels burning.

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# 5.3. UNIFICATION OF TECHNOLOGICAL PARAMETERS OF GRAIN LOGISTICS IN CORPORATIONS

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## ABSTRACT

Parameters and regularities of functioning of the grain logistics system have been investigated by means of a vertically integrated structure of the State Food and Grain Corporation, a joint-stock company, as an example. The paper proposes a methodological toolkit for the unification of technological parameters in order to evaluate the efficiency of the logistics system of vertically integrated structures in the grain-product subcomplex of agricultural production, taking into account the diverse activities of the branches through the definition of a logistic grain equivalent as a common basis for the comparison of the production and marketing activities of the daughter enterprises. The use of a unified indicator makes it possible to estimate the real capacity of the corporation's logistics system to further assess the possibilities of using reserves to increase production efficiency, regardless of the sources of income and the intended purpose of the grain mass. There are determined stages of the statistical research of the dependences of the efficiency indicators of logistic systems.

## INTRODUCTION

The economic problems of grain production have been studied in varies works by such scientists as Benson, Clay, Green, Eicher and Staaz, Eide and others (Benson *et al.,* 1986; Eicher & Staatz, 1990; Eide, 1990). Logistics systems have been studied in the works by Bowersox, Kloss, Stok, Lambert and Linders (Bowersox & Kloss, 2008; Stok & Lambert, 2005; Linders & Firon, 1999), as well as Ukrainian scientists such as Velychko, Krikavsky, Chernopiska, Chukhray and others. (Velychko, 2014; Krikavsky & Chernopiska, 2009; Chukhray, 2014) However, these are mainly investigations at a macro and a micro levels, where the logistics systems are formed from independent elements, integrated with an aim to implement the logistic or the marketing functions as, for example, presented by Chukhrai (Chukhray, 2014). The research at a micro level is presented in the works of Perebiynos, Oklander, and Hromov (Perebiynos, 2012; Oklander & Hromov, 2004), in which the intra-production logistics systems as a set of production departments of the enterprise, interconnected by technological operations, is considered.

A mathematical apparatus in the research of economic processes is applied by the Ukrainian scientists Artemenko, Geyets, Ayvazyan, Afifi, Bolch, Huan, Borovikov, Driper, Sysuev and others (Artemenko, 2003; Geyets *et al.,* 2005; Ayvazyan & Mhitaryan, 1998; Afifi & Eisen, 1982; Bolch & Huan, 1979; Borovikov, 2003; Driper and Smit, 1973; Sysuev *et al.,* 2016). Yet these studies focus primarily on the fundamentals of the use of economic and statistical methods, the applied aspects of research remaining unresolved.

The purpose of this paper is to develop methodological toolkit for the unification of technological parameters in order to evaluate the efficiency of the logistics system of vertically integrated structures in the grain-product subcomplex of an agro-industrial complex, taking into account the diverse activities of their structural elements.

## MATERIAL AND METHOD

To achieve this goal, tasks were considered how to determine and estimate the functional parameters and regularities of the grain logistics system, and to study the structure and activities of the most powerful vertically integrated state operator in the grain-product subcomplex of the agro-industrial complex of the joint-stock company "State Grain Corporation of Ukraine". The criteria-based decision making is preceded by application of an economic-statistical method that includes the correlation and regression analysis in order to study the causal relationships between the efficiency indicators of the logistics systems of corporations in the grain-product subcomplex of an agro-industrial complex with the formation of economic and statistical characteristics. In Ukraine the most presentable logistic system is represented by the most powerful state operator on the grain storage market – PJSC "DZPKU", which covers 10% of all the elevator capacities of Ukraine and provides port transhipment of 6% of the grain for export. As a vertically integrated national operator, the corporation controls 10% of the domestic market for cereals, flour and mixed feed. The company has 55 branches, and the elevator capacities are capable of storing grain and oilseeds in the amount of 3.75 million tons. The efficiency of the logistics system as an integral indicator of efficiency is the ratio of the synergistic effect of the entire system to the total costs of all elements of the logistics chain. The capacity of the logistics system is determined by the parameters of technical means that ensure the movement and modification of the material flow all the way from the primary source of the raw materials to consumers of final product. In order to unify the technological parameters of the efficiency estimation of the logistics system, it is necessary to define a common basis for the comparison of numerous and diversified branches of the corporation; and for this we suggest using a natural indicator, which we conventionally called the logistics grain equivalent (Chukhray, 2014).

To study the dependencies of the key efficiency indicators of the logistics system of a corporation, its operation can be described by a set of variables, among which:

-$x^{(1)}, x^{(2)}, \ldots, x^{(p)}$ – the input variables that describe the conditions of operation of the logistics system of the object of study, considering that some of them, as a rule, can be regulated or partially controlled; in economic and mathematical models they are called factor-arguments, exogenous, predictors, independent, explanatory variables;

-$y^{(1)}, y^{(2)}, \ldots, y^{(m)}$ – the output variables that characterise the efficiency of the operation of the logistics system of the object of study; in the corresponding economic and mathematical models they are called endogenous, dependent or resulting variables;

- $\varepsilon^{(1)}, \varepsilon^{(2)} \ldots, \varepsilon^{(m)}$ – the latent, random, residual components that reflect the impact of the unaccounted "at the input" factors, as well as random errors during the measurement of the dependent, resulting variables; in economic and mathematical models they are called, as a rule, the remainder.

The general purpose of the statistical research of dependences of the efficiency indicators of the logistics system of a corporation can be formulated as follows: according to the results of $n$ measurements of variables:

$$\left\{x_i^{(1)}, x_i^{(2)}, \ldots, x_i^{(p)}; y_i^{(1)}, y_i^{(2)}, \ldots, y_i^{(m)}\right\}, \quad i = 1,2, \ldots, n \tag{1}$$

to build on particular objects of research such a vector-valued function

$$f\left(x^{(1)}, x^{(2)}, \ldots, x^{(p)}\right) = \begin{pmatrix} f^{(1)}(x^{(1)}, \ldots, x^{(p)}) \\ f^{(2)}(x^{(1)}, \ldots, x^{(p)} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ f^{(m)}(x^{(1)}, \ldots, x^{(p)} \end{pmatrix}, \tag{2}$$

which could resume the value of the resulting (predicted) variables $Y = \left(y^{(1)}, y^{(2)},...y^{(m)}\right)'$ after the corresponding values of the explanatory (independent) variables $X = \left(x^{(1)}, x^{(2)},..., x^{(p)}\right)'$ as well as possible.

The functions *f(x)*, which in the presented general formulation of the problem describe the behaviour of the conditional average values $y_{cp}(X)$ of a specific predicted efficiency indicator, are called regression functions. Their model presentation is as follows:

$$y = f\left(x^{(1)}, x^{(2)},..., x^{(p)}; \theta\right) + \varepsilon, \tag{3}$$

where, $\varepsilon$ – the residual component which causes a possible error in determining a particular indicator of the efficiency of the logistics system for the known values of factors $x^{(1)}, x^{(2)},..., x^{(p)}$; $f(X;\theta)$ – the function from some well-known parametric family $F = \{f(X;\theta)\}$, for which, however, the numerical values of the parameters (constants that enter its equation) are unknown.

The main task is to select (estimate) the vector parameter $\theta$ and analysis of the accuracy of the obtained calculation formula $\hat{Y}(X) = f(X;\theta)$, taking into account estimation of the forecast intervals. Therefore, in the development of the regression models with an aim to ensure calculation of the forecast indicators, only the values of function *f (X)* are investigated, but not its structure, which primarily determines the ratio of the share of influence of the explanatory variables $x^{(1)}, x^{(2)}, ..., x^{(p)}$ for each of the resulting indicators $y^{(k)}$ $(k = 1,2,...,m)$. To our object of study $O_1$ we assign a set of "input" (explanatory) and "output" (resultant) variables after type (1) (Table 1).

Table 1. Variables of the efficiency analysis of the logistics system

| Analysed variables | Name of the variable | Notation of the variable |
|---|---|---|
| $x^{(1)}$ | average monthly cost of fixed assets, thousand UAH | *X1_VOF* |
| $x^{(2)}$ | number of employees, people | *X2_CHP* |
| $x^{(3)}$ | payroll, thousand UAH | *X3_FOP* |
| $x^{(4)}$ | material costs, thousand UAH | *X4_MAZ* |
| $x^{(5)}$ | capital-labour ratio, thousand UAH·(people) $^{-1}$ | *X5_FOZ* |
| $\mathbf{y}^{(1)}$ | logistic grain equivalent (the annual amount of grain that has passed through the supply chains in the corporation under study), thousand t | *Y1_LZE* |
| $y^{(2)}$ | designed capacity of the system, thousand. t· (month) $^{-1}$ | *Y2_PLS* |
| $y^{(3)}$ | capital-output ratio of the product, thousand UAH·t$^{-1}$ | *Y3_FMP* |
| $y^{(4)}$ | labour productivity, t·(people) $^{-1}$ | *Y4_PRP* |
| $y^{(5)}$ | utilisation factor of logistic capacity | *Y5_KLP* |

On the basis of the analysed logistics system of the object of research and a specific set of variables that characterise the activities of the corporation, the final application goals of our research foresee:

1) to select the most significant input variables that significantly affect the key indicators of the logistics systems in the grain-product subcomplex as an example of the object of research;

2) to develop a methodology for constructing regression models in order to predict unknown values or average values of certain efficiency indicators of the logistics systems in the grain-product subcomplex; to justify the choice of adequate forecasting models of these efficiency indicators for the selected object of research by the values of indicators characterising the efficiency of the used fixed assets, labour and material resources.

The second stage of the study was to collect the necessary statistical information of form (1). After the results of the company a particular vector of the "input" and "output" indicators characterising its activities was determined:

$$O_i \leftarrow\rightarrow \left(x_{it}^{(1)}, x_{it}^{(2)}, \ldots x_{it}^{(5)}; y_{it}^{(1)}, y_{it}^{(2)}, \ldots, y_{it}^{(5)}\right),\ i = 1;\ t = 1,2,\ldots,48.$$

The selection scope was 48 observations. The stages of the correlation and regression analysis (3–7) are implemented on a computer, using the integrated statistical analysis and the data processing system *STATISTICA* (Borovikov, 2003).

## RESULTS AND DISCUSSION

The analysis of the research results allows making the following conclusions.

1. There is a sufficiently strong connection between the investigated variables of the efficiency of the logistics system. The structure of these connections and their density is characterised on the basis of the paired correlation coefficients represented by the correlation matrix (Table 2).

Table 2. The correlation matrix of dependencies between the analysed variables

| | Correlations (data Log - PAT)<br>Marked correlations are significant at p < ,05000<br>N=48 (Casewise deletion of missing data) | | | | |
|---|---|---|---|---|---|
| Variable | X1_VOF | X2_CHP | X3_FOP | X4_MAZ | X5_FOZ |
| Y1_LZE | 0,42 | 0,54 | 0,55 | 0,53 | 0,31 |
| Y2_PLS | 0,40 | 0,49 | 0,33 | 0,60 | 0,32 |
| Y3_FMP | 0,32 | 0,15 | -0,10 | -0,24 | 0,41 |
| Y4_PRP | 0,15 | 0,27 | 0,35 | 0,40 | 0,07 |
| Y5_KLP | 0,16 | 0,24 | 0,30 | 0,29 | 0,10 |

2. The presence of multicollinearity between the explanatory variables (Table 3) provides for the selection of the most informative of them by means of one of the step-by-step regression methods, for example, *Forward stepwise* (step-by-step method of inclusion).

Table 3. The correlation matrix of the explanatory variables

| | Correlations (data Log - PAT)<br>Marked correlations are significant at p < ,05000<br>N=48 (Casewise deletion of missing data) | | | | |
|---|---|---|---|---|---|
| Variable | X1_VOF | X2_CHP | X3_FOP | X4_MAZ | X5_FOZ |
| X1_VOF | 1,00 | 0,93 | 0,66 | 0,46 | 0,97 |
| X2_CHP | 0,93 | 1,00 | 0,81 | 0,59 | 0,81 |
| X3_FOP | 0,66 | 0,81 | 1,00 | 0,50 | 0,52 |
| X4_MAZ | 0,46 | 0,59 | 0,50 | 1,00 | 0,33 |
| X5_FOZ | 0,97 | 0,81 | 0,52 | 0,33 | 1,00 |

3. Calculation of the estimates of the unknown parameters of the regression equations allows one to select the most significant explanatory variables that affect the efficiency indicators of the logistics systems in a grain-product subcomplex (Table 4), and to present the following regression models:

$$Y1\_LZE = -1.055 + 0.631 \times X3\_FOP + 0.222 \times X4\_MAZ;$$

$$Y2\_PLS = 1.363 + 0.097 \times X4\_MAZ + 0.373 \times X2\_CHP - 0.11 \times X3\_FOP;$$

$$Y3\_FMP = 0.17 + 0.443 \times X5\_FOZ - 0.066 \times X4\_MAZ - 0.154 \times X3\_FOP;$$

$$Y4\_PRP = 0.066 - 0.182 \times X4\_MAZ + 0.403 \times X3\_FOP - 0.335 \times X5\_FOZ;$$

$$Y5\_KLP = -1.646 + 1.851 \times Y1\_LZE - 0.252 \times X4\_MAZ - 0.574 \times X5\_FOZ.$$

Table 4. Brief results of regression for Y1_LZE

| | Regression Summary for Dependent Variable: Y1_LZE (data Log - PAT.sta)<br>R= ,62767486 R?= ,39397573 Adjusted R?= ,36704132<br>F(2,45)=14,627 p<,00001 Std.Error of estimate: ,18663 | | | | | |
|---|---|---|---|---|---|---|
| N=48 | Beta | Std.Err. of Beta | B | Std.Err. of B | t(45) | p-level |
| Intercept | | | -1,055 | 0,803297 | -1,31340 | 0,195705 |
| X3_FOP | 0,382838 | 0,134137 | 0,631 | 0,221025 | 2,85409 | 0,006503 |
| X4_MAZ | 0,341176 | 0,134137 | 0,222 | 0,087134 | 2,54350 | 0,014481 |

4. Analysis of the adequacy degree of the obtained regression equations, based on the values of the determination coefficients ($R^2$), the $F$-criterion and the level of its significance $p$, as well as examination of the residuals of the regression models with graphical visualisation of the residual dispersion diagram suggest to confirm that the linear regression models adequately describe the interrelations between the variables.

5. To do statistical research of the dependencies of the efficiency indicators of the logistics systems in a grain-product subcomplex (figure 1 and figure 2), an attempt was made to construct non-linear regression models of the Cobb-Douglas type:

$$Y2\_PLS = 1{,}095 \times X1\_VOF^{-0{,}294} \times X2\_CHP^{1{,}088};$$

$$Y4\_PRP = 0{,}889 \times X4\_MAZ^{0{,}582} \times X5\_FOZ^{-0{,}168}.$$

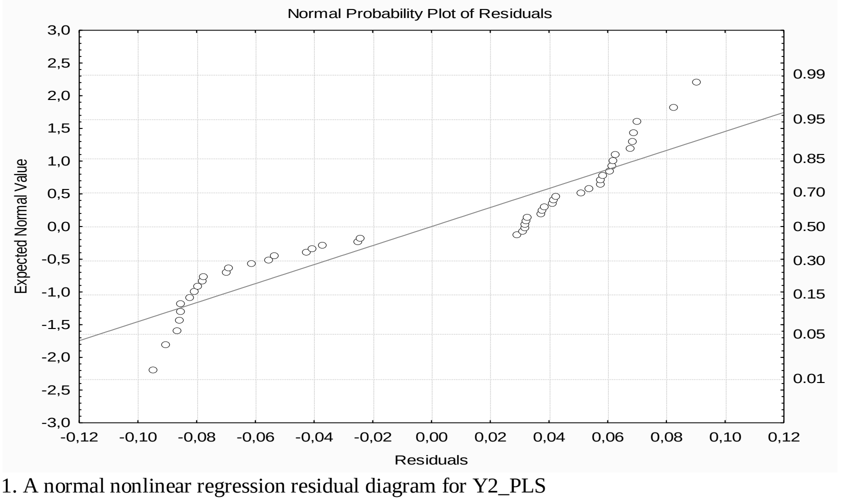

Fig. 1. A normal nonlinear regression residual diagram for Y2_PLS

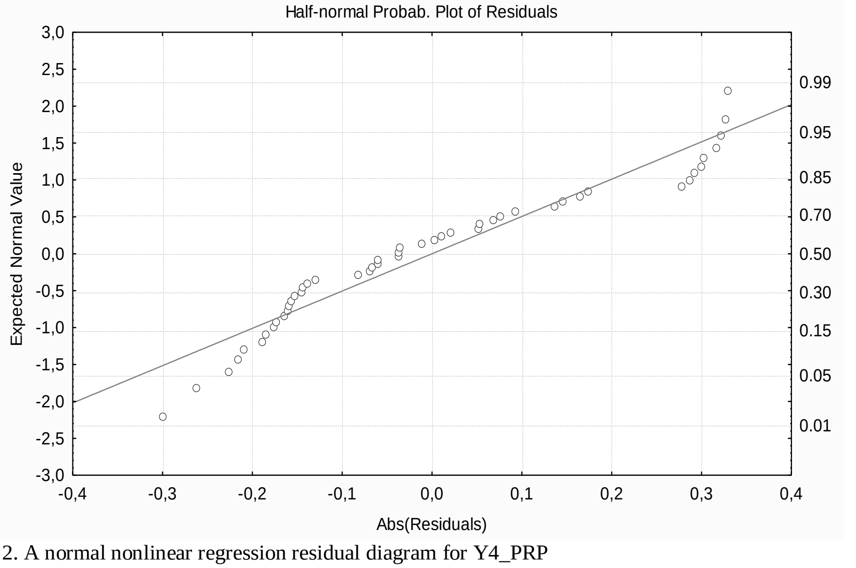

Fig. 2. A normal nonlinear regression residual diagram for Y4_PRP

The analysis of the results of these non-linear models and their normal probabilistic residual diagram allow drawing a conclusion that the degree of their adequacy is significantly inferior to the linear regression models. On the basis of the results of the analysis of the statistical research of the dependencies of certain efficiency indicators of the logistic systems, one can argue that the regression models proposed by us can be used to predict (to recover by anti-logarithmisation translation the results of the inverse logarithmisation by the exponent function) unknown values or average values of particular efficiency indicators of the logistics system of a vertically integrated corporate structure. This, in turn, will make it possible to conduct prospective analysis on the efficiency of the logistics systems in a grain-product subcomplex.

## CONCLUSIONS

The proposed methodological toolkit for the unification of technological parameters in order to evaluate the efficiency of the logistics system of vertically integrated structures in the grain-product subcomplex, taking into account the diverse activities of branches through the definition of a logistic grain equivalent as a common basis for the comparison of the production and marketing activities of the daughter enterprises, allow evaluation of the real capacity of the logistics system of a corporation for further assessment of the possibilities to use the reserves in order to raise the production efficiency regardless of the sources of supply and destination of the cereal masses.

The calculated estimates of the unknown parameters of the regression equations allowed us to identify the most significant explanatory variables that affect the efficiency indicators of the company's logistics system. The linear regression functions witness that the proposed grain logistics equivalent is most affected by the payroll and the material costs.

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# 5.4. REPLACEMENT OF THE MACHINERY PARK IN SELECTED FARMS OF MAŁOPOLSKA REGION

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**Keywords:** agricultural machinery, depreciation, agricultural technique

## ABSTRACT
Studies covered equipment and purchase of farm machines in the selected farms of Małopolskie Voivodeship. It included purchase made with EU aid funds. A period of replacement of the machinery park in selected groups of machines was defined. It was proved that the farms are not able to replace the machinery park in the period determined by a standard, using only purchase, for which they obtained funding.

## INTRODUCTION

After accession to the European Union, Poland obtained a chance for the evolution reconstruction of the agrarian structure and technological modernization of food production and technical infrastructure in the country (Malaga-Tobola, Tabor, & Kocira, 2015). With the moment of accession to the EU, farmers in Poland could have benefit from the aid for investments in the process of modernization of farms from the II pillar of the common agricultural policy. These funds have been an essential element which preconditions the scale and scope of modernization of the Polish agriculture (Kusz, 2014). Investments in farms enable renewal of fixed assets which translates into improvement of production processes, welfare of animals, development of farms and as a result increase in the farm income (Czubak, 2012). Technical infrastructure gets modernised, which is an effect of ultimate purpose of the obtained subsidy for the purchase of, inter alia, agricultural machines, or for construction and equipment of inventory facilities. Each element of the modernization process of the technical infrastructure of farms should be rationally justified (Szelag-Sikora, Cupial, & Niemiec, 2015). Since, the mechanization costs of farm production are one of the main elements of the production costs which precondition engagement of factors included to the so-called productive working capital (direct subsidies) affect the size and quality of production (Mazurek & Lorencowicz, 2017). As a part of the Program for development of Rural Areas 2007-2013 for modernization of farms PLN 1 919 million in the form of a subsidy was designated. It was assumed that participation of farmers will be PLN 2 878 million which in total constituted an expense of PLN 4 797 million designated for modernization of machines and construction investments.

Studies on the level of technical equipment of farms in Poland show that in a great part it depends on the agrarian structure of the region, structure of crops and commodity of farms (Krolczyk, Latawiec, & Kubon, 2014). Agriculture of Małopolskie Voivodeship is a specific example, which is characterised by a considerable agrarian distribution, excess of workforce and low commodity of agricultural production. Farms with the area of 1-5 ha are the most numerous groups and constitute almost 86% in in the structure of farms (Central Statistical Office, 2014). A machinery park is varied due to difficult environmental and soil conditions and specificity of farming on mountainous and sub mountainous areas (Cupial, Kobuszewski, Szelag-Sikora, & Niemiec, 2015). A correct selection of machines in a farm has a great significance, especially in a sustainable agriculture.

The Program for Development of Rural Areas 2007-2013 was designated for farmers, agricultural processing farms and rural communes and small towns. Similarly, as in other programs, funds were given in the form of a subsidy. Farmers and owners of forests could have applied for a subsidy for the purchase of counselling services, modernization of farms and purchase of machines and devices. Also, a group of agricultural producers could have obtained an aid if they started their business activity. A subsidy could have been obtained for the first five years of activity and used for the costs related to administration of a group. Beneficiaries could have obtained also a subsidy for advertising their foods and information on their advantages. Both young farmers who need funds at the beginning of their farming as well as old farmers in the pre-pension age, who decide to resign from farming and wish to transfer them to another farmer. Funds could have been also acquired for forestation and reconstitution of woods destroyed during natural disasters (ARiMR, 2014).

Program for Development of Rural areas 2014-2020 implemented by the Agency for Restructuring and Modernisation of Agriculture assumes a greater pressure on the transfer of knowledge. In the course of negotiations, a budget related to modernization of farms (by EUR 415 million) and payments for area with underdevelopments (by Euro 164 million) were reduced. Out of Euro 579 million of funds obtained, a great part was devoted for bonuses for young farmers (133 million Euro), restructuring of small farms (Euro133 million) and agri-environmental and climatic actions (124 million Euro). The Action "Investments in fixed assets - M04", as a part of which farmers may purchase new machines and devices includes three types of operations: Investments in farms located on the areas of Natura 2000, Investments aiming at protection of water against contamination with nitrates from agricultural sources and Modernization of farms (area A-D) (ARiMR, 2019).

A special pressure was placed on the development of animal production. Moreover, operations concerning the remaining directions of agricultural production, inter alia, as a part of assistance for rationalization of the production technology, introduction of innovations, changes in the production profile, increase of the production scale, improvement of the quality of production, increase of the added value of production. Also, operations related to rational farming will be supported with available water resources to limit negative effects of draught. The number of applications as a part of the Program for Restructuring and Modernization of Agriculture carried out to 31 August 2019 was 13 182 items (The System of Managerial Information Agency for Restructuring and Modernization, 2019).

## RESULTS

Detailed data were collected in farms which use funding as a part of the funds from the Program for Development of Rural Areas 2007-2013. The studies covered 286 farms from the area of Małopolskie Voivodeship. The average area of farms was 18.7 ha. The farms were divided into two area groups below (A) and above the average (B). Analysis was related to the property holding and purchase of machines carried out within 5 years. A replacement value of machines consists of the replacement value of the previously owned machines and the gross value of machines purchased, reduced by the value of the sold and scrapped machines. For the recovery of the level of replacement of the machinery park, the value of the purchased machines was referred to the replacement value of the machinery park (current). On this basis, an assumed period of replacement of the machinery park in selected groups of machines was defined. It should be said here, that although these purchases were aided with the outside funds, in the expenses a considerable share was by the own contribution. According to the principles of the program, funding was 40-60% of the net value of the purchase invoice (Agency for Restructuring and Modernization of Agriculture, 2019). Calculated values do not refer directly to the amount of funds from the Program for Development of Rural Areas but to purchases which a farmer made encouraged by the possibility of using the funds.

Figure 1 presents an assumed period of replacement in particular groups of machines, for all machines and machines along with farm tractors. Moreover, results in small and bigger farms according to the assumed division were showed.

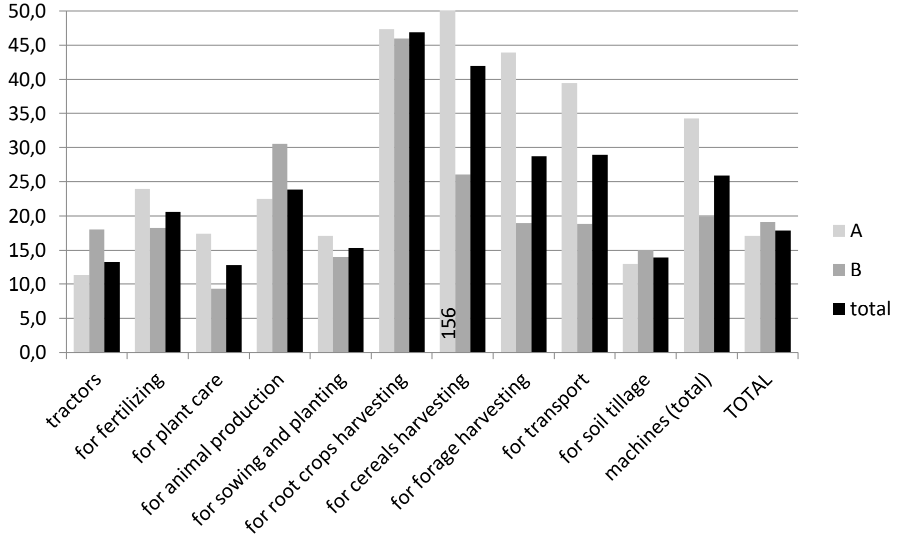


Fig. 1. Estimated period of replacement for purchases aided by funds (thousand PLN]

For machines and tractors the estimated period of replacement for purchases aided with subsidies was 18 years. For the group A farms (below average area) is 17 years and for bigger farms (group B) it is 19 years. In case of agricultural farms (without tractors) it is respectively 26 years and 34 years (group A) and 20 years (group B). Except for cultivation machines and machines for animal production, the estimated period of replacement in small farms is longer than in farms from group B. Purchase of machines designated for harvesting of grains (mainly grain harvesters and presses) is not economically justified in small farms. In case of this group of machines, the index of the estimated period of replacement with the use of subsidies was as long as 156 years.

Compared to the remaining machines, indices calculated for agricultural tractors are better. For tractors in total it is 13 years, for farms from group A - 11 years, and for group B - 18 years. It may be concluded on this basis that farmers in the investigated farms replaced the owned tractors with the use of funding while not exceeding the period of amortization defined in norms. In this context, criteria of access to the program were justifiable and made the power/size of the purchase machines depending on the size of farms. In case of such lack of the type of instructions, smaller farms could in exceptional cases buy machines, the costs of maintenance of which would exceed their financial possibilities.

Figure 2 shows the estimated period of replacement of particular groups of machines to the period of amortisation resulting from applicable norms (Lorencowicz, 2008) (Muzalewski, 2008). Moreover, the limit determined for tractors and farm machines was accepted in the Classification of Fixed Assets and used in accounting.

The calculated values as a rule exceed the age of amortization which is provided in literature as a normative one for particular groups of machines. Therefore, it may be concluded that for replacement of the machinery park with maintaining the normative values of amortization, purchase, to which a farmer will obtain funding, does not suffice. On the other hand, the norm of the Classification of Fixed Assets which is used for calculation of amortization of fixed assets in accounting of enterprises for typical farms has go no application. Such a brief period of amortization can be applied only in large-area farms or in such that provide services. Farm usually use machines much longer than it is defined in depreciation charges. Often it results from lower use than the normative one or from too small use.

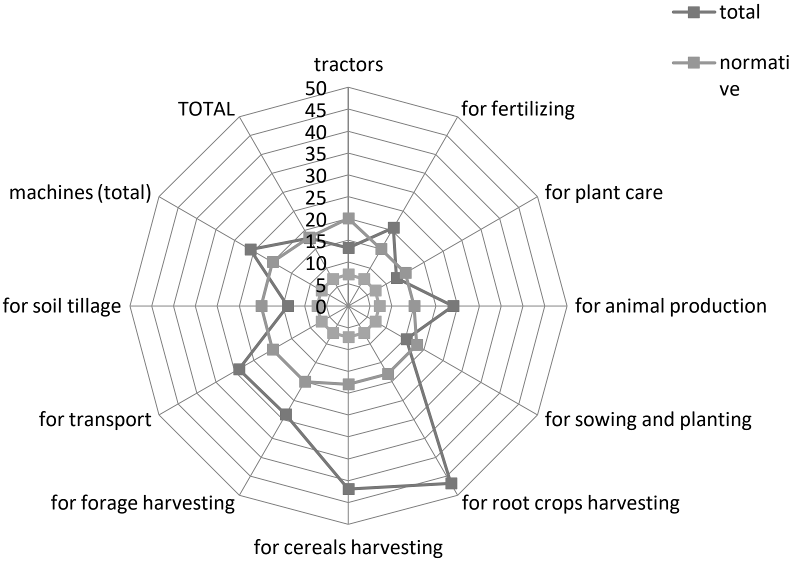


Fig. 2. Estimated period of replacement referred to the norms [PLN thousand]

Figure 3 shows the amount of own assets which a farmer should use for the purchase of farm machines to maintain the owned machinery park (column graph). The graph also shows participation of a subsidy in an annual amortisation (scatter diagram). The annual amount of amortisation was calculated based on the normative amortisation period.

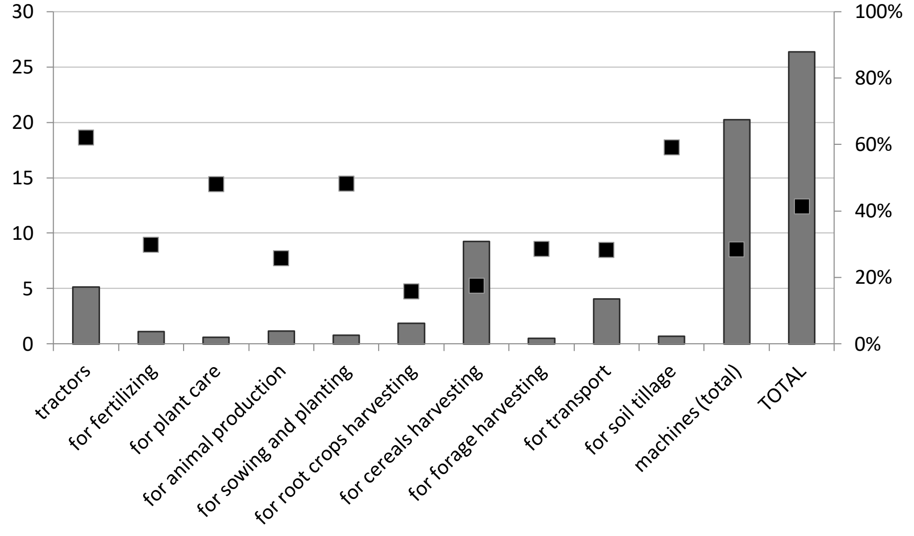


Fig.3. Annual amount of fixed assets which should be used for replacement of the machinery park [PLN thousand] and participation of subsidies in the annual amortisation [%]

The studies show that farms must replace the machinery park with the use of own funds although they use a subsidy. A subsidy was necessary for each group of machines and it was PLN 26.3 thousand annually per a farm. Simultaneously, participation of external funds referred to the annual amortization was 41% and was the highest in the group of machines and soil cultivation machines.

## CONCLUSIONS

The analyses proved that the farms are not able to replace the machinery park in the period determined by a standard, by purchasing only, for which they obtained funding. Such replacement is possible only for tractors and selected groups of machines. It should be stated that the analysed purchase was not performed entirely from the outside funds and the amount of the subsidy constituted only a part of the price of a machine. The obtained funds do not replace the costs incurred by a farmer and only supplement it. It should be mentioned here that the studies covered only farmers who used the aid as a part of the Program for Development of Rural Areas. Many farmers from Małopolska did not use such an aid, inter alia, due to too small area of farms or the owned farm was in the stage of closing of production.

The subsidy funds, although they considerably improve the condition of the machinery park, do not allow for complete replacement of this condition. It is mainly related to machines for crop harvesting. For replacement of the machinery park in the period defined with standards, in case of each group of machines, it is necessary to use own funds of a farm. The studies were carried out in Małopolskie Voivodeship. However, it may be assumed that the results may be extended also to farms with a similar area from the area of the entire country.

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# 5.5. BELCAM - A COLLABORATIVE AND INNOVATIVE WEBPLATFORM SERVING FARMERS NEEDS

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**Keywords:** smart farming, farmsourcing, satellite data, Sentinel, nitrogen management, crop growth monitoring

## ABSTRACT

The BELCAM webplatform (www.belcam.info) provides to Belgian farmers a set of innovative products and services, mainly derived from the ESA Copernicus programme, allowing to improve daily management of parcels and subsequently the durability of agricultural practices.

The products and the services freely available on the BELCAM webplatform have been selected based on continuous interactions with farmers and extension services. They are focused on the monitoring of crops growth and on the optimal management of nitrogen inputs. The BELCAM webplatform also provides meteorological observations and weather forecasts as well as yield estimations. Three crops are currently concerned: winter wheat, maize and potato.

By allowing to exchange in near real-time information and feedbacks between farmers and scientists ('farmsourcing'), the collaborative BELCAM webplatform is continuously improved. Farmers become not only users but also actors of the research conducted for them.

## INTRODUCTION

The management strategies of agroecosystems have evolved during the last 50 years in Belgium with, for instance, an intensification of the use of agrochemicals and agricultural machinery, an expansion of the irrigated areas and the use of new crop varieties. A major drawback of this evolution is the progressive degradation of the environment. Producers in Belgium and neighbouring countries are now under increasing pressure to maintain profitability within environmental constraints and the increases in fertilisers' prices that should encourage more rational and environmentally responsible management of inputs.

The advent of a new generation of high spatial and temporal resolution satellite sensors opens the doors to develop new prototype applications much more connected to the so called end-users. The high spatial and temporal resolution provided by these sensors (mainly Sentinel-1 and -2) is paving the way for new local applications on a smaller scale than in agricultural regions or in very large fields. This has motivated the development of the collaborative 'farmsourcing' webplatform BELCAM. The BELCAM webplatform is a Decision Support System aiming at the optimisation of management at parcel level based on the joint use of satellite (Copernicus) data, field observations and crop growth models. Building on the most recent remote sensing and Information and Communication Technology (ICT) penetration, the research challenge is to completely change the interactions between information users and producers and to markedly speed up the critical learning process for the remote sensing providers thanks to input and near real time feedbacks from the users.

Current available products are mainly focused on the Nitrogen management at parcel level primarily though information on the intra-field variability are also provided. Nitrogen (N) is indeed a major element of chlorophyll and enzymes implied in photosynthesis, a shortage results in lower yields whilst an excess has negative environmental consequences (e.g. groundwater pollution). Optimized fertilization practices (providing the right doses in the right places and at the right time) are therefore in line with the evolution of cropping systems toward a sustainable agriculture.

## THE BELCAM COLLABORATIVE PLATFORM CONCEPT

The BELCAM platform redefines the interactions between farmers (or extension services) and scientists in a more and more digital world.

Its originality relies in its collaborative / farmsourcing approach. The BELCAM platform allows the sharing of information in near-real time but also of feedbacks on the developed products between farmers (or extension services) and scientists. Products are therefore constantly improved based on these continuous interactions favoured by the digital nature of the platform.

Farmers do not only provide field data (e.g. parcels delineation, information on fields' management) but they also share their experience (on the developed products) as well as their expectations on possible products that could be developed. With the BELCAM farmsourcing platform, farmers are not only users but become actors/partners of the research.
The platform is available at www.belcam.info.

## THE BELCAM PRODUCTS

A first set of products are currently freely available on the BELCAM platform. The main products are described below. They have been developed for 3 Belgian major crops (namely winter wheat, potato and maize) based on satellite (Sentinel-2) data but also involve, for some of them, the use of meteorological data and (crop growth) models.

### 1. ***Provisional Nitrogen Balance sheet (Requaferti)***

A model, called REQUAFERTI (Cugnon *et al.*, 2013), has been implemented in the BELCAM webplatform. This model provides a total nitrogen recommendation at the start of the growing season for the different considered crops.

### 2. ***Meteorological observation and forecast***

Meteorological information currently available on the BELCAM platform on a daily basis are the total rainfall and the minimum, maximum and average temperatures. Both observations and forecast (up to 7 days) are provided. Meteorological observations for each parcel come from the nearest weather station of the PAMESEB network (www.pameseb.be). Forecasted weather data come from Dark Sky company (https://darksky.net/).

### 3. ***Sentinel-2 images***

Sentinel-2 images available on the BELCAM webplatform are pre-processed in near-real time by the Sen2Agri (http://www.esa-sen2agri.org) automated processing chains (Udroiu *et al.*, 2018). These processing chains produce in near real time the surface reflectance and the biophysical variables (such as e.g. the Leaf Area Index, see next section) displayed on the BELCAM platform. Users can choose to display either the RGB or the infrared false color images.

### 4. ***Leaf Area Index (LAI)***

As mentioned in the previous section, leaf area index (LAI) are provided in near real-time by the Sen2Agri processing chains. LAI can be linked to the biomass evolution. LAI is close to zero when no or very sparse vegetation is present and when the crop is in decline. On the opposite, LAI reaches its maximum when the field vegetation is at its maximum extent.

For each parcel and for each sentinel-2 acquisition date, the LAI values are displayed (figure 1, left). The LAI maps can be also used to monitor the intra-field heterogeneity. A smoothed LAI profile is also provided (in addition to the LAI observations). The parcel LAI profile can be compared to the mean regional profile considering all the parcels of the considered crop within a 3 km radius around the parcel (figure 1).

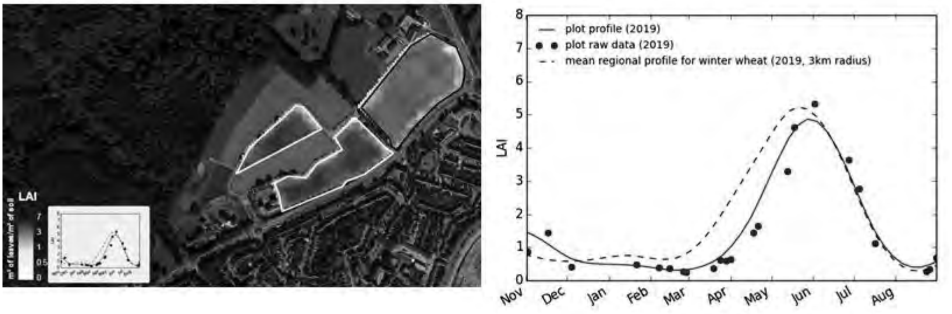


Fig. 1. (*On the left*) LAI map for 3 winter wheat parcels observed on the 13rd of May 2019 as displayed in the BELCAM webplatform ; *(on the righ*t) smoothed Leaf Area Index (LAI) profile for the winter wheat parcel delineated in blue and smoothed regional profile considering all the winter wheat parcels with a 3 km radius around this parcel.

### *5. Aerial Biomass*

Aerial biomass is estimated based on a linear relationship using the remotely-sensed LAI described above as explanatory variable. This product is provided at 20 m resolution. Aerial biomass is an important biophysical variables contributing to the assessment of the Nitrogen Nutrition Index (NNI) (see next section).

### *6. Absorbed Nitrogen and the Nitrogen Nutrition Index (NNI)*

Except for maize for which the nitrogen fertilisation is realised at once at sowing, in Belgium, nitrogen supply is usually split in order to better fit the crops nitrogen requirement which is variable all along the growing season. Dividing total nitrogen application into two or more treatments enhances nutrient efficiency, optimises the yields and mitigates the loss of nutrients. In cereals, it also limits the lodging and the disease development.

In winter wheat, nitrogen is usually applied in 2 or (most frequently) 3 applications at key phenological stages (tillering, stem elongation and flag leaf). For potato, nitrogen fertilisation can be, as for maize, applied at once at planting but considering that the major part of the N absorption occurs only after emergence (i.e. more than 1 month after planting). The split application is therefore recommended to minimize the N fertilizer losses by immobilization, denitrification or leaching as well as to meet crop N needs and supplies (Denuit *et al*., 2002).

Assessing the crop nitrogen uptake all along the growing season allows to adjust the nitrogen applications based on the real crop needs.

The ‘absorbed Nitrogen’ (Crop nitrogen content, CNC) product available on the BELCAM webplatform (currently only for winter wheat, figure 2) is based on a linear relationship using the canopy chlorophyll content retrieved from Sentinel-2 at 20m spatial resolution with an Artificial Neural Network.


Fig. 2. N absorbed map for 3 winter wheat parcels observed on the 13rd of May 2019 as displayed in the BELCAM webplatform.

The BELCAM platform also provides, based on this estimation of the crop nitrogen content, the nitrogen nutrition index (NNI, figure 3). The NNI is a reliable plant-based method for diagnosing the crop nitrogen status. The NNI is based on the concept of critical nitrogen (Nc) dilution curve describing the Nc concentration in the whole plant as a function of the total crop biomass. The critical nitrogen concentration of a plant can be defined as the minimum nitrogen concentration required for maximum growth rate at any time. In the BELCAM webplatform, we use the dilution curve developed by Justes *et al.* (1994).

The NNI is the ratio between the CNC and the critical nitrogen content. A NNI < 1 is synonym of Nitrogen deficiency while a NNI > 1 is synonym of overfertilisation. More details are available in Delloye *et al*. (2018).

NNI is available for different acquisition dates during key periods. As for some other products, a benchmarking with parcels in a 3 km radius is provided.

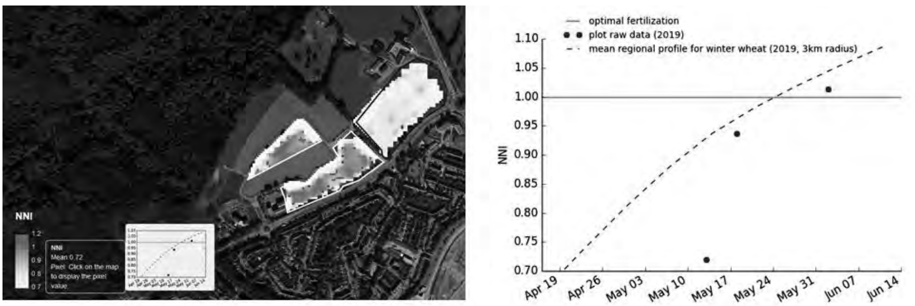


Fig. 3. (*On the left*) NNI map for 3 winter wheat parcels observed on the 13rd of May 2019 as displayed in the BELCAM webplatform ; *(on the right)* NNI values at different sentinel-2 acquisition dates for the winter wheat parcel delineated in blue and mean regional NNI profile considering all the winter wheat parcels with a 3 km radius around this parcel.

### *7. Yield estimation*

Yield estimation are provided by a joint use of a crop growth model, namely the Aquacrop model developed by FAO (Steduto *et al.*, 2009) and remotely-sensed data. Time series of the fraction of green vegetation cover (*f*Cover) retrieved from Sentinel-2 are used to estimate the maximum canopy cover and emergence date which are assimilated in the crop growth model (Sallah *et al.*, 2017).

Yield estimation is provided at parcel level. As for LAI, estimated value for a given parcel is benchmarked with all the parcels of the considered crop located in a 3 km radius (figure 4).

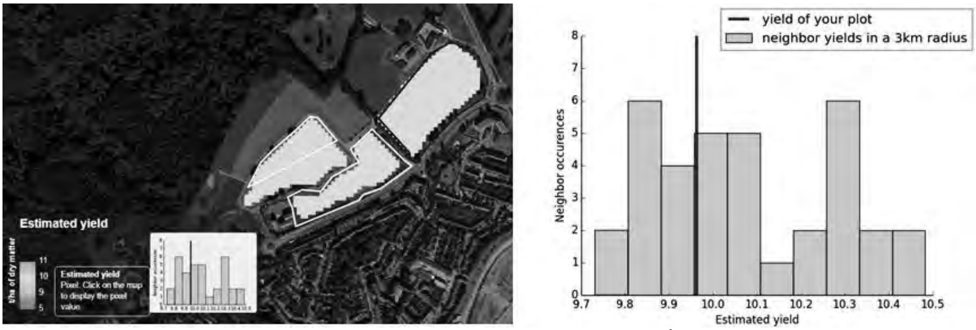


Fig. 4. (*On the left*) Yield map for 3 winter wheat parcels observed on the 15th of July 2019 as displayed in the BELCAM webplatform ; (*on the right*) Yields for the selected parcel (delineated in blue) and for the parcels located in a 3 km radius around this parcel.

## FORTHCOMING ACTIVITIES

The products available on the BELCAM webplatform, officially launched in July 2019, represent a first set. These products will be continuously improved thanks to the permanent interactions with the end-users. New functionalities and new products (still based on sentinel-2) are currently in development such as the assessment of the winter cover crops biomass (with a view to feed the REQUAFERTI model) or the nitrogen status all along the growing season for potato crop.

The constant interactions with end-users will also enhance the development of new user-oriented products and services.

## CONCLUSIONS

The BELCAM webplatform is a collaborative and freely available smart farming platform providing EO-based products and services to regional authorities, farmers and also agricultural extension services. Products and services currently available concern nitrogen recommendations, crop status and yield estimations. They are constantly improved and new products are developed based on constant interactions with end-users

The BELCAM web solution is a non-profit webplatform meeting a public service role. This objective is made possible notably by the free and open data policy of the Copernicus program (www.copernicus.eu).

By supporting decisions in agricultural practice management, the BELCAM webplatform helps for instance Belgian farmers to meet societal expectations in terms of good agricultural practices and product quality or public authorities to meet European regulations (e.g. Nitrates directive).

The BELCAM webplatform is also in line with the Commission's legislative proposal for the Common Agricultural Policy (CAP) of 1st June 2018 aiming at the setting up of a Farm Sustainability Tool for Nutrients (CAP FaST proposal).

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# 5.6. CONSUMER ATTITUDES AND BEHAVIOUR ON THE MARKET OF REGIONAL AND TRADITIONAL FOOD PRODUCTS

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**Keywords:** consumer behaviour, traditional products market, food, ecology, sustainable development, environment

## ABSTRACT

Research concerning consumers on the traditional and regional food market is a part of the area of consumer behaviour research, which in recent years has become increasingly important, because learning the motives of the decision-making process and product perception is an element of building relationships with consumers, building their competences by both producers and traders. The aim of the article is to identify consumer behaviour towards traditional and regional food products, as they fit into new consumer trends of a global nature, i.e. care for health and physical condition while respecting the natural environment. The quantitative survey conducted by the research company ARC Rynek i Opinion in April 2017 for Leclerc Polska shows that many Poles can distinguish traditional from regional products, but usually buy them occasionally because they consider them expensive. Traditional food is most often bought in small stores, specialty stores, at fairs; regional food - in places of their origin, while ready meals in chain stores or local stores (Dąbrowska, 2018). Interest in traditional food is a manifestation of new trends in consumer behaviour on the food market implied by the desire to preserve and display the values resulting from cultural heritage. Towards the growing demand for traditional food in Europe, it seems important to recognize the way Polish consumers perceive traditional food and determine the attributes attributed to this type of food. The literature on the subject and the analysis of own data shows that the vast majority of Polish consumers declare the purchase of traditional food, and the most important motive for purchasing this food is the belief in its unique sensory qualities. Traditional food consumers are dominated by older people who care about their health and are more involved in planning and preparing meals.

## INTRODUCTION

Tradition, understood as passed down from generation to generation behaviours, customs, beliefs and rituals recognized by a given community as important for its present and future, refers to both the production of food and its consumption (Gawęcki 2008). According to the definition adopted by the European Commission, the term 'traditional' refers to food that has been on the Community market for at least the duration of the transmission from generation to generation, which is defined as at least 25 years (Council Regulation (EC) No 509/2006 of 20 March 2006 on agricultural products and foodstuffs as traditional specialities guaranteed 31.3.2006). Over the past decade, demand for food has increased significantly, especially in developed countries, and this situation is particularly true for traditional and regional food. Ensuring greater consumption of this type of food per capita through an appropriate marketing approach is possible thanks to understanding consumer behaviour on the market, as well as faster development of the domestic market (Vehapi, Dolićanin 2016). However, as the demand for traditional and regional food is growing at a faster pace, this has led to global sales of organic food and drinks reaching USD 80 billion in 2014 (Doorn, Verhoef 2015).

The results of research conducted both in Poland and in the world indicate a very positive approach to traditional and regional products and the fact that the intention to buy this type of food was often associated with health and environmental awareness, as well as with safety and quality issues. It is believed that organic substances are healthier, tastier, more natural and environmentally friendly, although on the other hand - they are often less attractive and more expensive than conventional food (Hughner 2007; Hoppe *et al.*, 2013).

## MATERIAL AND METHODS

In order to assess the attitudes and behaviour of consumers on the market of regional and traditional food products and their impact on decisions made by consumers, a self-study survey was conducted with the participation of 405 people. The random sampling method was used - simple random selection (without returning). The research was carried out in 2018. The research tool was a structured proprietary survey questionnaire, consisting of 13 questions and 5 metric questions. It contained closed-ended questions, clearly designed so as not to require supplementary comments. In order to perform the demographic and social characteristics of the surveyed population, a metric, containing questions about gender, age and other variables, was attached at the end of the questionnaire The study involved 144 men (representing 36% of all respondents) and 261 women (64%). Other characteristics of respondents, who took part in the study, are shown in Table 1. The target population consisted of the population of the Lublin region, which may find itself as buyers or potential buyers of traditional and regional food. Due to financial and logistical obstacles, this study could not focus on all objects of the target population.

## RESEARCH RESULTS AND DISCUSSION

To achieve the goal set in the study, the obtained results, based on questionnaires, were analysed and presented in descriptive and graphic form. The majority of respondents were women, young people (18-25 years old), mainly living in the countryside or in a medium-sized city (30-300 thousand inhabitants). The detailed socio-demographic characteristics of the respondents are presented in Table 1.

Table 1. Socio-demographic profile of the population surveyed

| Socio-demographic profile | Number of respondents | Percentage share |
|---|---|---|
| Total: | 405 | 100.0 |
| Gender: | | |
| female | 261 | 64.4 |
| male | 144 | 35.6 |
| Age: | | |
| 18 – 25 years | 216 | 53.3 |
| 26-35 years old | 84 | 20.7 |
| 36-50 years old | 84 | 20.7 |
| 51 years and more | 21 | 5.2 |
| Place of residence: | | |
| rural area | 192 | 47.4 |
| city to 30.000 residents | 33 | 8.1 |
| 30 000 - 300 000 residents | 120 | 29.6 |
| city with more than 300.000 residents | 60 | 14.8 |

Source: the authors' own studies

Among respondents declaring food purchases in the form of regional and traditional products, there were similar numbers of people in two groups, considered according to gender. Although the number of respondents differed, as there were almost twice as many women (which may be due to the fact that they make purchases more often in the household), there were about 69.0% of women who declare purchases of this type of food, while men 68 8% (Fig. 1).

However, in the case of the frequency of purchases, the age groups of respondents were taken into account (Fig. 2 a, b). As it turned out, women in the age group of 18-25, 36-50 and over 50 declared purchasing regional and traditional food several times a month (63.8%, 30.6% and 25.0% respectively), in turn, women aged 26-35 buy this type of product occasionally (43.2%).

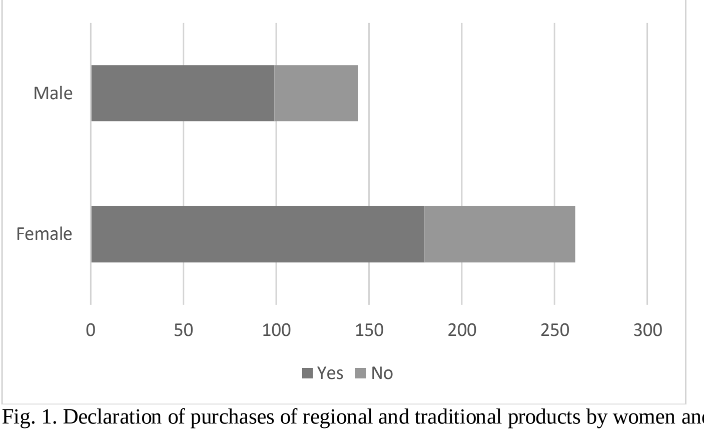


Fig. 1. Declaration of purchases of regional and traditional products by women and men
Source: the authors' own studies

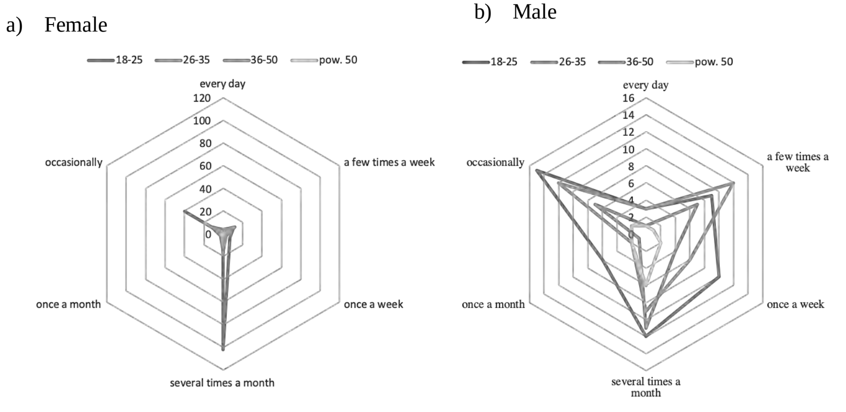


Fig. 2. a) The frequency of purchases made in different age groups among women, b) The frequency of purchases made in different age groups among men
Source: the authors' own studies

In the case of men in the age group 18-25, 26-35 years, purchases of regional and traditional food are occasional (27.3% and 27.3%, respectively), although the 26-35 age group also declared the same number of responses for purchases made several times a week (also 27.3% of responses among respondents). In contrast, among men in the age group 36-50 and over 50 years of age this type of shopping is carried out only several times a month (35.5% and 42.9%, respectively).

The results obtained in the author's own research are partly consistent with the results obtained by other authors regarding the consumer profile of traditional and regional food, which shows that the consumers of this type of food are mainly women and the elderly people (Roitner-Schobesberger *et al.*, 2008; Dimitri, Dettmann 2012; Grubor, Djokić 2016). In addition, as regards the frequency of purchases, it was found that a definite number of respondents purchase regional and traditional food occasionally, and regular buyers of these products account for only a small percentage of consumers (Vlahović *et al.*, 2011, Mesías Díaz *et al.*, 2012; Padilla Bravo *et al.*, 2013).

Later in the study, respondents were asked to answer the question whether they purchase regional and traditional products; if they expressed their approval, they were asked why they did it (Table 2). In the event of a negative opinion, they were also asked to indicate the main reasons for this fact (Table 3).

Table 2. The most important factors determining shopping choices in the opinion of consumers

| | 18-25 years old | Percentage share | 26-35 years old | Percentage share | 36-50 years old | Percentage share | 50 years and more | Percentage share |
|---|---|---|---|---|---|---|---|---|
| **Female** | - high quality<br>- health benefits<br>- supporting the development of the region<br>- better taste | 42.9<br>28.6<br>25.0<br>3.6 | - high quality<br>- health benefits<br>- supporting the development of the region | 69.2<br>15.4<br>15.4 | - high quality<br>- better taste<br>- health benefits | 76.9<br>15.4<br>7.7 | - high quality | 100.0 |
| **Male** | - high quality<br>- supporting the development of the region<br>- health benefits | 60.0<br>33.3<br>6.7 | - high quality<br>- supporting the development of the region<br>- better taste | 50.0<br>25.0<br>25.0 | - health benefits<br>- supporting the development of the region<br>- better taste | 40.0<br>40.0<br>20.0 | - high quality<br>- supporting the development of the region | 66.7<br>33.3 |

Source: the authors' own studies

**Table 3.** The most important factors discouraging from shopping choices in the opinion of consumers

| | 18-25 years old | Percentage share | 26-35 years old | Percentage share | 36-50 years old | Percentage share | 50 years and more | Percentage share |
|---|---|---|---|---|---|---|---|---|
| **Female** | - I don't know where to get them<br>- I like the supermarket products better<br>- high prices<br>- no matter what products I buy<br>- difficult to access | 40.0<br>25.0<br>15.0<br>10.0<br>10.0 | - high prices<br>- no matter what products I buy | 50.0<br>50.0 | - I don't know where to get them<br>- high prices | 50.0<br>50.0 | - high prices | 100.0 |
| **Male** | - I don't know where to get them<br>- I like the supermarket products better<br>- high prices<br>- difficult to access | 40.0<br>20.0<br>20.0<br>20.0 | - - no matter what products I buy<br>- I don't know where to get them<br>- high prices | 50.0<br>25.0<br>25.0 | - - no matter what products I buy<br>- I don't know where to get them<br>- high prices | 50.0<br>25.0<br>25.0 | - I don't know where to get them<br>- I like the supermarke t products better | 66.7<br>33.3 |

Source: the authors' own studies

As it turned out, the vast majority of modern consumers among the main factors determining the choice of traditional and regional food regardless of age group, indicated high quality and health benefits (table 2). However, what clearly distinguished the analysed groups due to the variable "sex" was that men more often pointed out the need to support the development of the region from which this food comes.

However, among the main factors discouraging consumers from making purchases, as the main reason respondents of different age groups pointed to the issues of access, costs or alternative products (Table 3). Among women, it was also a fact that they often do not know where to buy such products (18-25 and 36-50) and high prices (26-35 and above 50). Men, on the other hand, also indicated the answer that they do not know where such products can be purchased (18-25 years old and over 50 years old) and the fact that they do not care what products they buy (26-35 years and 36-50 years).

## CONCLUSIONS

Based on literature and own research, it can be concluded that consumer awareness and knowledge of regional and traditional food are still low. Even among the more aware and interested people, only a small percentage of them regularly buy this type of food, which means that there is a difference between preferences and their actual shopping behaviour. This is in line with the results of other authors (e.g. Hoppe *et al.*, 2013) who indicate that there is a gap between attitudes and behaviour, which means that consumers are positive about traditional and regional products, but usually do not buy it. However, the individual approach to buying such food is based primarily on beliefs about the benefits of their consumption (because consumers declare that they are healthy, natural and environmentally friendly products).

Therefore, it seems that in order to increase knowledge and awareness about food and its benefits, consumer education should become the main task of producers. Given into account the fact, that socio-demographic variables have been proven to be an important determinant of the frequency of food purchases, the food industry can increase its sales by targeting certain segments of consumers.

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# 5.7. APPLICATION OF RADIO FREQUENCY IDENTIFICATION IN SUSTAINABLE AGRICULTURE

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**Keywords:** Radio Frequency Identification (RFID), food supply chain management, food sector, temperature-controlled supply chain

## ABSTRACT
Logistics management of the supply chain between agricultural producers and processing plants or chain stores is broadly supported by IT technologies. Sanitary safety, quality guarantee, and protection of product originality in domestic and international food trade is supported by the *Radio Frequency Identification* (RFID) technology, which enables automatic identification of an object using radio waves. Functional and application analysis of the EPC Gen 2 standard was performed. Areas of application and the scope of operation of radio-frequency automatic identification (RFID) systems in agriculture and production, transport and storage of food were also presented. Additionally, directions of research and restrictions in the use of RFID technology were pointed out.

## INTRODUCTION
Supply chain logistics management is the control of the flow of materials and information - from the acquisition of raw materials to the delivery of finished products to the consumer. Agriculture, which is both a source of raw materials for individual industries of the food industry and ready fresh products (e.g. fruit and vegetables) for shops, is a multi-stage and complicated process due to the fact that most agricultural raw materials require meeting and maintaining special conditions during storage and transport. Logistics management of the supply chain between agricultural producers and processing plants, food companies or chain stores is extensively supported by IT technologies. Acquisition, collection, development, and processing of data is an integral element of an efficient logistics management process. For this requirement to be met, technologies that allow recording individual parameters in real-time are needed (Mazur, Mazur, 2013; Xiaowei *et al.*, 2012, Ko *et al.*, 2014).
Sustainable agriculture is a form of an effective and, sanitary-wise, safe production of raw materials that enables the production of high-quality food in accordance with practices that do not harm the natural environment. The basis for such solutions is the implementation of modern and efficient technologies that support both the production and distribution of raw materials (Ruiz-Garcia, Lunadei, 2011). Obtaining high-quality products in the food industry requires the use of raw materials with the best parameters, and tracking to what extent these parameters are stable or subject to change over time. An additional requirement is to identify both domestic and imported products along the entire logistics chain. Over the past decades, these processes have been supported by the barcode system. However, the technology of the contemporary age in the field of identification is RFID (Grunow, Piramuthu, 2013).

## GOAL AND SUBJECT OF RESEARCH
Sanitary safety, guarantee of quality and protection of product originality in national and international food trade are defined by the standards, guidelines and codes of conduct of *Codex Alimentarius*. The published document "*Principles for Traceability/product tracing as a tool within a food inspection and certification system*" (CAC/GL 60-2006) defines the conditions of product traceability (http://www.fao.org/). Product traceability is a guarantee of simple control of its path along the entire length of the logistics chain from the farm or production plant to the final buyer. *Codex Alimentarius* defines that the

product path control tool should enable identification at every stage of the chain - from production to distribution, where the food product comes from (one step backward principle) and where the food product ends up (one step forward), all in accordance with the needs of the control system and food certification. RFID technology extensively enables implementation of the aforementioned recommendations (Aung, Chang 2014a; Bolic *et al.*, 2010; Keller *et al.*, 2015).
*Radio Frequency Identification* (RFID) technology allows automatic identification of an object using radio waves. These types of systems allow remote reading, writing, and transmission of acquired data in real-time for archiving purposes. (Allane *et al.*, 2016, Fan *et al.*, 2013). Therefore, the process of obtaining parameter data is expedited and sending it to the database is automated. The use of radio waves for data acquisition and transmission eliminates time-consuming processes, making the presence of an employee during parameter reading redundant. In addition, manual data entry poses a potential risk of errors being made by a human operator. In agriculture, this is particularly important due to the large share of human labour and the impact of the costs incurred on this account on the total profitability of the business.


Fig. 1. Logistic management of fresh tomato stocks in sorting and storage using RFID technology, enabling error-free application of the FEFO method
*Source: https://espanol.rfidjournal.com/casos-de-estudio/vision?11485*

Fig. 2. Registration and reporting of temperature for shipments of perishable fresh fruit by using an RFID tag (label)
*Source: https://www.mhlnews.com/technology-automation/auto-id-getting-comfortable-rfid*

RFID technology thanks to the application of radio waves has a number of advantages:

- the reader does not require visual contact with the object,
- a large number of codes are read simultaneously,
- the data recorded in the tags (labels) can be changed many times,
- the system is resistant to external factors,
- there are no generic restrictions for product labelling.

RFID tags have the ability to function within allocated operating radio frequency bands. The choice of system operating in one of the four frequency ranges depends on the field of application:

- low-frequency bands are LF (125-134 kHz) and HF (13.65 MHz),
- high frequency bands are UHF (433 or 860-960 MHz),
- microwaves (from 2.5 GHz)

At the end of the 20th century, thanks to the development of electronic systems, the size of tags was minimized and the production costs of components constituting the RFID system were significantly reduced, leading to an increase in its market expansion. In 1999, in order to further advance RFID, the Auto-ID Center *(Auto-ID Labs)* organization was created to develop communication protocols and the *Electronic Product Code (EPC)*. This led to the birth of a uniform and universal standard, which in 2003 was taken over by the non-profit organization EPCglobal. It disseminated and implemented the EPC Gen 2 standard, which resulted in the unification of the data exchange between the reader and RFID tag within the UHF frequency range, which eliminated the problem of compatibility (EPCglobal, Tag Data Standard 2014). It should be noted that the introduced Gen 2 standard offers:

- high speed of reading and writing data,
- algorithms that check for errors,
- encryption of acquired data,
- high capacity memory,
- password protection of acquired data,
- anti-collision protocols when reading data from a large number of tags.

The approval of EPC Gen 2 as a global standard by the International Organization for Standardization, ensuring the ability to read data from an RFID identifier in any country in the world, has resulted in an unlimited availability of RFID technology to be used in identifying agricultural raw materials and products on an international scale. Gen 2 has also gained global significance thanks to the support of the largest producers supplying readers, tags, and software to the market. An additional factor that contributed to a wide application of the EPC standard in the logistics chain was the linking of the RFID technology with the Internet (Badia-Melis *et al.*, 2015).

The RFID system is a combination of three categories of devices:

- passive or active transponders (tags),
- readers that control the emitted electromagnetic field through transceiver antennas and electronic modules,
- a controller with user software and database.

In logistics management, it is important that the *Electronic Product Code* is a globally unique number assigned to a particular product batch. This means that each product equipped with RFID tags can be identified without error and in real-time, at every stage of the supply chain. When a single product equipped with a radio ID passes through any point where an RFID reader is located, a signal is automatically generated. The recording of subsequent logins creates an individual profile of the route in real-time and space for a particular food product, which can be easily controlled using electronic applications (Amador *et al.,* 2009; Ampatzidis *et al.,* 2009; Charlebois *et al.,* 2014; Duroc *et al.,* 2013). The high intensity of global trade in foodstuffs and the implementation of sustainable agriculture led to the RFID technology gradually extending to specific sectors of agricultural production, as well as transport and storage of plant and animal produce (Table 1). The beginning of RFID technology application can found in the identification of farm animals (Awad, 2016). Miniaturization and price reduction of tags stimulated research on extending their application range. The market gradually filled with tags equipped with various types of sensors that allowed them to be used as recorders of changes in basic physical parameters (Badia-Melis *et al.,* 2016; Kang, 2012).

Table 1. Areas of application and the scope of operation of radio-frequency automatic identification (RFID) systems in agriculture and production, transport and storage of food

| No. | Area of application | Scope of operation |
|---|---|---|
| 1 | Identification of raw materials and agricultural products | Supporting warehouse logistics, raw materials supply chain management between farmer, producer, and consumer. |
| 2 | Control of quality parameters of agricultural raw materials and products | Systems for tracking and recording parameters relevant to quality (e.g. temperature) and supporting the FEFO (First Expired First Out) method of issuing as the first products with the shortest expiry date. |
| 3 | Livestock | Animal identification, body temperature measurement using sensors. |
| 4 | Field crops | Soil temperature measurement and humidity control sensors for irrigation systems. |
| 5 | Greenhouse crops | Remote sensing using sensors: environmental parameters in the greenhouse, control of pot plant. |
| 6 | Horticulture | Fruit harvest management, sanitary certification support. |
| 7 | Viticulture | Plant material certification and cultivation monitoring for vineyards |
| 8 | Agricultural machines | Automatic harvest identification, e.g. cotton. |
| 9 | Cold storage | Sensors for control and management of temperature. |
| 10 | Warehouses | Humidity, light and temperature sensors dedicated to rooms. |
| 11 | Transport | Real-time monitoring of selected parameters (e.g. temperature) for products in individual packaging. |
| 12 | Intermodal transport | Real-time monitoring of selected parameters (e.g. temperature, humidity) for products in containers. |

*Source: Own elaboration based on (Bahareh, 2019).*

The most important task in food storage and transport was temperature control (Amador, Emond, 2010; Aung, Chang, 2014b). Hence the wide range of tags that have replaced traditional recorders, requiring repeated inspection by warehouse staff. Tags measure temperature with greater accuracy and do not require eye contact. The next stage of development was readers with the function of collecting information in set time frames. The next area intensively developed due to market demand was monitoring temperature changes in the cold chain (Badia-Melis, 2018; Chen *et al.,* 2014). Market selection range is also broadened by solutions in which tags are equipped with sensors measuring: humidity, shock and vibration, light intensity, concentration of selected types of gases and biosensors for detecting bacterial contamination of food products (Bedia *et al.,* 2015; Bedia *et al.,* 2018; Ketzenberg *et al.,* 2015).

## CONCLUSIONS

Application of RFID application provides a wide range of economic benefits in food supply chain management. It directly reduces the cost of labour in agriculture, transport, and storage and helps in reducing stock levels. It also fuels an increase in sales by accelerating product rotation. It has a particularly positive effect on the functioning of the supply chain of perishable products by limiting losses and on returns and comprehensive temperature monitoring in the cold chain. The use of tags with various types of recorders is already economically justified. Although they are still many times more expensive than the basic models, they can be continuously used in agriculture and processing for at least several years. Implementation in various areas of automatic identification thanks to the RFID system is being worked on comprehensively and will be still extensively developed because:

- it enables the management of the risk related to food safety of plant-based produce and health problems of farmed animals,
- it guarantees the authenticity of the agricultural product along the entire logistics chain for both production and trade,
- it enables control and improvement of the quality level of raw materials for the food industry.

It should be emphasized that the progress in research into the development and possibilities of innovative RFID applications does not mean there are no limitations associated with this technology. The challenges are technical in nature - the application of tags for various frequencies as well as the scope and time of measurement in extremely harsh environments is currently being sought. IT challenges stem from the need to collect, process and manage huge amounts of data on a global scale. What is more, there are legal and political challenges that tackle the issues of security and privacy of users and customers (https://eur-lex.europa.eu/…).

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# 5.8. EFFICIENCY OF MATERIAL AND ENERGY EXPENDITURE AND THE DIRECTION OF FARMS PRODUCTION

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**Keywords:** production process, material expenditure, energy expenditure, farms

## ABSTRACT

The paper presents analysis the effectiveness of material and energy inputs relative to the direction of farms. Farms conduct their business according to certain rules. These rules are strongly dependent on which production direction the farm chose. Choosing the right direction of production affects the achievement of adequate efficiency. The production direction for 679 farms was determined on the basis of standard production (SO), dividing farms by general types (8 types of farms). It was found that horticultural farms most effectively manage material resources. It was found that energy expenditure most effectively uses farms oriented towards field crops or permanent crops or dairy cows or herbivores animals or mixed production and having at least 10 hectares of arable land.

## INTRODUCTION

In the agricultural production process, there are specific relationships between production expenditures and their efficiency. In the literature there are many definitions of efficiency relating to the market and its functioning or to enterprises. Trying to define the efficiency in relation to the enterprise it can be stated that it means the ratio of the obtained effects, which are the objectives of economic activity, to the used means of action. The criterion of management efficiency in agriculture is the relation between the quantity of manufactured products, i.e. effects, and factors of production used in the production process, i.e. expenditures (Zimny, 2003; Sawa *et al.*, 2004; Kuboń *et al.*, 2018; Sawa, 2006; Kocira and Kołtun, 2013). According to Sawa (2006), the level of material and energy expenditures incurred and the level of production effects obtained in the farms surveyed, arranged according to the area of owned arable land, may allow to determine the nature of sustainability of the agricultural production process carried out there, in terms of economic and social sustainability. The proportionally high material and energy expenditures in the smallest farms (up to 20 ha of AL) as well as in the larger ones (20-60 ha of AL) provide the possibility of social sustainability of the production process, which is expressed by a relatively low workload (working-hours per employee per year), if we take into account the fact that the stocking density in these farms usually exceeds 100 LSU per 100 ha of AL. In a farm, incurring higher expenditures determines higher production intensity, which may be expressed by the amount of material expenditures per area unit. Material expenditures concern mainly used production materials, both own and purchased, production services and general economic expenditures. The amount of incurred expenditures may prove the size of the farm and its economic strength. The level of expenditures from the purchase may indicate strong links with the environment (Cooper *et al.,* 2007; Mohammadi and Omid, 2010; Kocira *et al*., 2017).

Energy has a key share in production expenditures in agriculture. Changes in the level and technology of agricultural production, increase in prices of energy carriers and decrease in the number of entities qualified to the category of agricultural farms have a significant impact on its consumption. The development of agricultural production is connected with increasing the demand for energy, especially those used during the implementation of production procedures (Gorzelany, 2010; Gorzelany *et al*., 2011; Hosseinzadeh-Bandbafha *et al*., 2018). According to Sawa (2008), Kocira and Malaga-

Tobola (2012) the direction of production may determine the efficiency of the use of material and energy expenditures in agricultural farms. Therefore, the aim of the study is to answer the question: is the efficiency of material and energy expenditures in family farms dependent on the direction of production?

## MATERIAL AND TEST METHODS

The materials used in the paper are data obtained within the Polish FADN in 2013, 2014 and 2015 from 679 family farms located in the Lubelskie Voivodeship. All data are collected from farms of natural persons (KRR).

For each year of the survey family farms were divided according to the direction of production determined on the basis of standard production (SO). These farms were divided into groups according to general types TF8: field crops, horticultural crops, vineyards, permanent crops, dairy cows, grass-eating animals, grain-eating animals, mixed animals.

Efficiency of material and energy expenditures I ($E_{NmeI}$) - was calculated as a ratio of total production ($P_o$) to total material and energy expenditures ($N_{me}$).

$$E_{NmeI} = \frac{P_o}{N_{me}} \tag{1}$$

where: $P_o$ – total production (PLN),
$N_{me}$ – total material and energy expenditures (PLN).

The efficiency of material and energy expenditures II ($E_{NmeII}$) was calculated as the ratio of gross value added ($W_{Db}$) to total expenditures ($N_{me}$).

$$E_{NmeII} = \frac{W_{Db}}{N_{me}} \tag{2}$$

where: $W_{Db}$ – gross value added (PLN),
$N_{me}$ – total material and energy expenditures (PLN).

The efficiency of material and energy expenditures III ($E_{NmeIII}$) was calculated as the ratio of net value added ($W_{Dn}$) to total expenditures ($N_{me}$):

$$E_{NmeIII} = \frac{W_{Dn}}{N_{me}} \tag{3}$$

where: $W_{Dn}$ – net value added (PLN),
$N_{me}$ – total material and energy expenditures (PLN).

The efficiency of material and energy expenditures IV ($E_{NmeIV}$) was calculated as the ratio of net agricultural income ($D_{rn}$) to total material and energy expenditures ($N_{me}$):

$$E_{NmeIV} = \frac{D_{rn}}{N_{me}} \tag{4}$$

where: $D_{rn}$ – net agricultural income (PLN),
$N_{me}$ – total material and energy expenditures (PLN).

The efficiency of material and energy expenditures V ($E_{NmeV}$) was calculated as the ratio of agricultural family income ($D_{Rr}$) to total expenditures ($N_{me}$):

$$E_{NmeV} = \frac{D_{Rr}}{N_{me}} \tag{5}$$

where: $D_{Rr}$ – agricultural family income (PLN),
$N_{me}$ – total material and energy expenditures (PLN).

For each indicator of expenditures efficiency (average values of indicators from the years 2013-2015) the analysis of significance of differences between individual groups of farms was carried out at the level of $p < 0.05$.

## RESULTS

Groups of farms defined according to the production direction were characterised by high variability of material and energy expenditure efficiency indicators. All groups of farms in each of the analysed years achieved the efficiency of material and energy expenditures expressed by the ENmeI indicator exceeding one (Table 1). This proves that farms obtained higher revenues from material and energy expenditures.

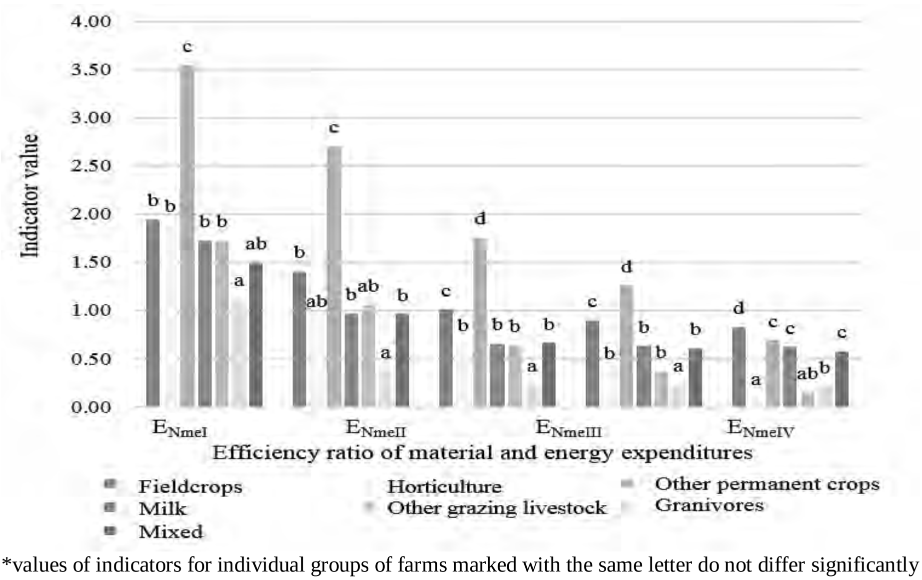
Similar conclusions were reached by Kurek and Wójcicki (2011) in their family studies, who reported higher income from incurred expenditures. This is a desirable situation and the higher the value of this indicator, the more advantageous it is for a farm. The highest value of the $E_{NmeI}$ indicator was obtained by farms from the group "Other permanent crops", which in the years 2013-2015 amounted to 3.78, 3.27 and 3.58 respectively and was 3 times higher than in farms with the direction of production "Granivores". Despite the efficiency of material and energy expenditures expressed by the $E_{NmeI}$ indicator at the level of 1.91-2.04, farms from the group "Fieldcrops " obtained the highest values of the $E_{NmeV}$ efficiency indicator at the level of 0.9-0.86. Farms with the direction of production "Other grazing livestock" despite the value of the $E_{NmeI}$ indicator at the level of 1.63-1.79, as a result of incurred production costs had one of the lowest values of the $E_{NmeV}$ efficiency indicator among the analysed groups, which was calculated as the ratio of the income of an agricultural family to the sum of material and energy expenditures.

The highest three-year average efficiency of material and energy expenditures expressed in the $E_{NmeI}$ indicator was achieved by farms with the production direction "Other permanent crops" (Fig. 1). Statistically significant differences were found between the group "Other permanent crops" and other groups of farms in the value of this indicator. The lowest value of all analyzed indicators was found in the group "Granivores". Similarly to the $E_{NmeI}$ indicator, the highest values of $E_{NmeII}$, $E_{NmeIII}$ and $E_{NmeIV}$ indicators were recorded in the group of farms "Permanent crops". However, the highest value of the indicator calculated as the ratio of income of an agricultural family to material and energy expenditures was found in the farms from the group "Fieldcrops". The value of this indicator in this group of farms differed significantly from the values in other groups.

Despite obtaining by farms targeted at horticultural crops the efficiency of material and energy expenditures expressed by the $E_{NmeI}$ indicator at a similar level as in the groups "Field crops", "Milk" and "Other grazing livestock", the value of the $E_{NmeV}$ indicator in this group of farms was the lowest. Such a decrease in the value of this indicator indicates high levels of horticultural labour input in farms targeted at horticultural production. Similar observations were made by Mikołajczyk (2014), who stated the highest demand for labour input in farms targeted at horticultural production.

Table 1. Values of efficiency indicators of material and energy expenditures and the production direction in particular years of the study

| Groups of farms according to the production direction TF8 | Year | $E_{NmeI}$ | $E_{NmeII}$ | $E_{NmeIII}$ | $E_{NmeIV}$ | $E_{NmeV}$ |
|---|---|---|---|---|---|---|
| Fieldcrops (1) | 2013 | 1.91 | 1.44 | 1.05 | 0.96 | 0.90 |
| | 2014 | 1.89 | 1.31 | 0.92 | 0.81 | 0.73 |
| | 2015 | 2.04 | 1.48 | 1.07 | 0.93 | 0.86 |
| Horticulture (2) | 2013 | 1.80 | 0.76 | 0.55 | 0.33 | 0.12 |
| | 2014 | 1.69 | 0.81 | 0.58 | 0.24 | -0.02 |
| | 2015 | 2.16 | 1.12 | 0.81 | 0.50 | 0.16 |
| Wine (3) | 2013 | - | - | - | - | - |
| | 2014 | - | - | - | - | - |
| | 2015 | - | - | - | - | - |
| Other permanent crops (4) | 2013 | 3.78 | 2.93 | 1.96 | 1.42 | 0.83 |
| | 2014 | 3.27 | 2.50 | 1.45 | 1.00 | 0.46 |
| | 2015 | 3.58 | 2.69 | 1.86 | 1.37 | 0.79 |
| Milk (5) | 2013 | 1.69 | 0.97 | 0.68 | 0.67 | 0.66 |
| | 2014 | 1.86 | 1.04 | 0.72 | 0.70 | 0.69 |
| | 2015 | 1.63 | 0.89 | 0.57 | 0.53 | 0.52 |
| Other grazing livestock (6) | 2013 | 1.63 | 0.90 | 0.54 | 0.26 | 0.23 |
| | 2014 | 1.76 | 1.10 | 0.62 | 0.28 | 0.11 |
| | 2015 | 1.79 | 1.18 | 0.75 | 0.56 | 0.12 |
| Granivores (7) | 2013 | 1.07 | 0.36 | 0.22 | 0.23 | 0.22 |
| | 2014 | 1.09 | 0.38 | 0.24 | 0.24 | 0.23 |
| | 2015 | 1.20 | 0.38 | 0.24 | 0.21 | 0.19 |
| Mixed (8) | 2013 | 1.49 | 0.99 | 0.69 | 0.64 | 0.62 |
| | 2014 | 1.45 | 0.92 | 0.63 | 0.58 | 0.54 |
| | 2015 | 1.54 | 0.98 | 0.67 | 0.60 | 0.57 |




*values of indicators for individual groups of farms marked with the same letter do not differ significantly statistically at $p < 0.05$.

Fig. 1. Average values of efficiency indicators of material and energy expenditures and the production direction in the analysed years 2013-2015.

## CONCLUSIONS

The analysis of the efficiency of material and energy expenditures in the studied family farms divided according to the direction of production allowed for the realization of the objective of the research. It was found that running a family farm according to a specific production direction affects the effectiveness of material and energy expenditures. It was observed that the efficiency of material and energy expenditures in farms focused on permanent crops and field crops differs significantly from the efficiency in other farms. The most effective material and energy expenditures were used for other permanent crops, field crops, milk or mixed production.

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# 5.9. SELECTED QUALITY IMPROVEMENT INSTRUMENTS USED IN THE AREA OF PRODUCTION SERVICES FOR AGRICULTURE

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**Keywords:** quality management methods, quality management techniques, continuous improvement, services for agriculture

## ABSTRACT
Modern enterprises operate in markets of very strong competition and must face the often unpredictable changes in the environment. Knowledge and use of appropriate instruments will allow not only to stay ahead of the competition by improving and introducing new products and services in accordance with the needs of customers, but also to efficiently manage the company by improving all processes. The paper presents tools and methods supporting quality management that can be used in the area of production services for agriculture. These instruments, based on collected quantitative or qualitative data, are possible to be used both directly at work stations in making operational decisions as well as in strategic decisions for the enterprise. Described in the article quality management instruments are illustrated by examples.

## INTRODUCTION
The use of effective production technologies is one of the factors determining the competitiveness of agriculture. Therefore, farms face the necessity of continuous modernization of agricultural techniques used. Modernization can take place, inter alia, by investing in process automation, which enables the growing market of technological systems. At the same time agricultural producers in order to improve their productive forces are looking for ways to rationalize the structure of production factors. The use of production services may be an element that allows for the elimination or reduction of the effects of a deficiency in factor which is in the minimum (Jabłonka *et al*., 2010; Supreme *et al*., 2013; Kołodziejczak, 2015; Kołodziejczak, 2016).
The socio-economic changes and the conditions in agricultural production also affect the increasing needs associated with the use of different types of services and change their importance and role. Increasing the degree of use of services has a positive effect on the efficiency of farm income growth, thanks to which activities aimed at developing and disseminating service activities in the agricultural sector are intensified (Kołodziejczak, 2015).
The market position between enterprises, including those operating in the area of production services for agriculture, depends largely on customer satisfaction. Considering the fact that consumers are becoming more and more demanding, the market leaders are companies that attract and retain customers by meeting their expectations and improving their products and services. A satisfied customer builds a positive and long-standing relationship with the company (Fotopoulos & Psomas, 2009; Fotopoulos & Psomas, 2010; Zendla &Wolniak, 2015; Wolniak & Sułkowski, 2018).
One way to improve the quality of offered products and services and build customer satisfaction is to use various types of methods, tools and techniques of quality management. It is therefore essential that people working in the company have knowledge about the possibilities and effectiveness of the use of certain instruments of quality management in a particular industry (Ahmad *et al*., 2016).
The aim of the work is to present some of the more important quality management instruments that can be used in the area of production services for agriculture. The

exemplification of practical applications is to convince potential users to more frequently use the presented quality management instruments.

## MANAGEMENT INSTRUMENTS IMPROVING QUALITY

### 6S

One of the instruments used by the companies focused on improving the quality is 6S method also called 5S + safety. The main aim of this method is to improve the quality of products and services by reducing production costs and increasing work efficiency while maintaining safety standards. As one of the easiest tools to implement, it is the basis for introducing and functioning of other elements of the Lean Management and is one of the effective control methods, thanks to which you can reduce losses and increase safety at the workplace (Gundlach, 2009; Ingle *et al*., 2014).


Fig. 1. Implementation steps of 6S method [author's work]

Quality improvement is achieved by following the five steps presented in Figure 1 (Falkowski & Kitowski, 2013; Osakue, 2014; Joshi, 2015):

1. selection – removing unnecessary items from the workplace and leaving only what is needed,
2. set in order – ordering items and assigning them a storage location according to the frequency of use, taking into account ease of access and ergonomics, placing items in designated places in the right amount,
3. shine – cleaning the workplace, machines, devices, instruments and tools,
4. standardize – creating of procedures that will ensure that the existing condition will be maintained and the introduced rules will be respected,
5. self-discipline/sustain – self-improvement in maintaining and developing the implemented method, raising standards,
6. safety – implementation and compliance with previously introduced rules contributes to improving workplace safety.

During the implementation process of the 6S method, you can encounter many barriers and threats that result primarily from the attitude of people involved in the implementation process and their internal motivation. However, according to Osakue (2014), Agrahari *et al*. (2015) and Joshi (2015) many companies in which organizational culture is based on the principles of the 6S method, it is observed that many problems can be solved using this method, e.g. product quality problems, production costs, machine failures, etc.

### ISHIKAWA DIAGRAM

The Ishikawa diagram allows you to recognize the actual or potential causes of failures in the undertaken projects which cause certain effects. Therefore, this graph is also called the cause - effect or fishbone diagram (a distinctive appearance resembling a fish skeleton). This diagram, thanks to a simple graphical form, allows to easily visualize and present relationships between seemingly unrelated elements (Kunadharaju *et al*., 2011; Zendla & Wolniak, 2015). Although this technique is one of the traditional organizing methods commonly used to solve quality problems in industry, it is also used to study the causes of problems with different levels of detail found in many other areas. Figure 2 presents an example of using the Ishikawa diagram to determine the causes of fuel pump assembly errors during repair presented by Luca (2011).

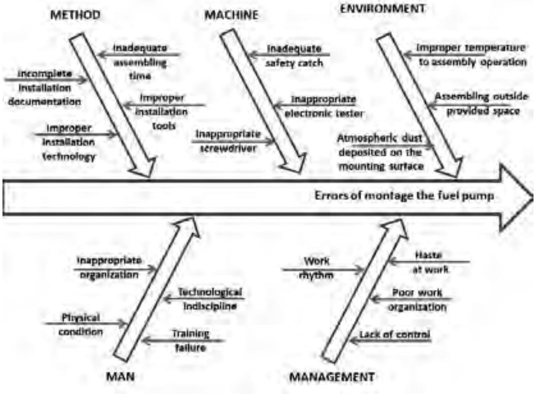


Fig. 2. Ishikawa diagram for errors of fitting the fuel pump at the service repair [Luca, 2011]

The advantages of using the Ishikawa diagram include: no need to develop documentation, orderly information transfer, comprehensive approach to the issue under consideration, data hierarchy, emphasis on the location and elimination of the causes of the problem.

**5WHY**

In problem situations that require corrective action, it is necessary to determine the in-depth causes of the problem. In the event of a problem being resolved, when the root cause of its occurrence has not been identified, over time, unfortunately, the situation can appears again. It is therefore important to correctly and quickly define the actual cause and eliminate it (Stanek *el al*., 2011).

One of the simpler tools for detecting the causes of failures and sources of problems is 5WHY analysis. It allows to thoroughly investigate the problem even when other analyses have proved to be too superficial. This tool does not require specialized preparation, and the results of the analysis can be presented graphically in the form of a tree-diagram (Mazur & Gołaś, 2010).

Performing an analysis and identifying the root cause of the problem involves repeatedly asking the question "why?". As a result, two aspects are discussed. The first concerns the cause of the problem. It tells us why the problem arose. While the second is related to the detectability of the problem situation. Detects weaknesses in existing enterprise systems, methods of control or supervision which did not allow the detection of the situation. Conducting analysis using 5Why, like the Ishikawa diagram, requires employees' independence and analytical thinking skills, thanks to which they are able to develop short- and long-term corrective actions (Mazur & Gołaś, 2010; Wolniak & Skotnicka-Zasadzień, 2011).

An example of using the 5WHY method to solve the problem of product return is shown in Figure 3.


Fig. 3. 5WHY diagram analysing the cause of the problem related to the return of goods by the customer [author's work]

**5W2H**

The 5W2H tool is another technique that is used to precisely describe the occurring irregularities and problem situations that worsen the quality of products and services. t is most often used before other tools to identify and collect accurate information about an event. As a result, it is possible to quickly define the main cause of the problem (Nagyova et al., 2015).

Analysis using this technique is based on the following specific questions: *What?, Why?, Where?, When? Who?, How?, How often?* (Table 1). Asking these questions makes the problem becomes more pronounced, so you can efficiently implement corrective and preventive action. The universality of this technique means that it is used to solve problems not only in the production area (Curt *et al*., 2004).

Table 1. A case study of using the 5W2H method (Nagyova *et al*., 2015)

| | 5W2H | Characteristic | Example |
|---|---|---|---|
| 5W | ***What?*** | What is the problem? Describe the problem in one sentence so that others can easily understand it | The problem is wet cardboard and moisture discovered in individual packs |
| | ***Why?*** | Why is it a problem? | It poses a problem because the deteriorated product is no longer tradable. Items with no visible damage are not tradable either, until the cause of the moisture is revealed |
| | ***Where?*** | Where do we encounter the problem? Specifies whether the problem occurs in a specific location in the organization (workplace, organizational unit or area of | The problem was discovered on 25th August 2013 |

| | 5W2H | Characteristic | Example |
|---|---|---|---|
| | | the organization, the whole area of the plant) | |
| | ***Who?*** | Who is impacted? | The problem was revealed in the company's own warehouse |
| | ***When?*** | When did we first encounter the problem? | The problem was discovered by a warehouse worker on 25th August 2013 |
| **2H** | ***How*** | How did we know there was a problem? What are the stages of its appearance? | The problem was detected visually during product preparation before delivery to the customer |
| | ***How often?*** | How often do we encounter this problem? Are there factors favouring the occurrence of the problem? | Initially about 34 wet cardboard packs were detected |

## CONCLUSIONS

In order to improve the quality of products and processes, enterprises operating in the area of production services for agriculture have the opportunity to use a number of methods and techniques supporting quality management. However, it should be noted, that the effectiveness of using the presented methods and techniques largely depends on the attitude of employees and the willingness to be fully involved in defining the causes of problems and improving the entire organization.

The instruments presented in the paper do not exhaust the whole set of usable methods and techniques of quality management. They are just an example of the possibilities of combining and using a number of tools to analyse problem situations and the subsequent implementation of corrective and remedial actions. The versatility of the presented instruments allows them to be used when analysing existing irregularities and problems related to quality also in agriculture.

However, as practice shows, not every tool is suitable for solving every problem. The effective analysis often requires the use of several instruments. Therefore, it is important to acquire practical skills in using production improvement tools, regardless of their type.

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# 5.10. PRECISION AGRICULTURE EFFECT ON FARMERS'INFORMATION NEEDS

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**Keywords:** information needs, digitalization, precision agriculture, farm management

**ABSTRACT**
The paper presents the information needs of the farmers related to digitization processes in precision agriculture. The collection of data was done for a group of 120 farmers using Computer-Assisted Web Interviewing (CAWI). The analysis of the results indicates that the main issue in the process is restricted by the use of old machinery. The lack of knowledge related to electronic equipment and some psychological issues created additional limitations. However, that applies mainly to older farmers, whereas young generation of farmers are comfortable with new technologies. It is expected that they will lead changes in order to improve production effectiveness in sustainable agriculture

## INTRODUCTION

The fundamental aspect of the precision agriculture is collection and proper interpretation of data, which is used to optimize farm management and control of technological processes. That allows for more precise and effective use of available means, which leads to better returns on inputs while preserving resources. The improvements in precision agriculture technologies increases farmers' knowledge and awareness of attributes and disadvantages of those technologies, and requirements regarding appropriate data. The improvement in knowledge and more experience in precision agriculture lead also to more advanced opinions regarding expectations (BMEL, 2017). That creates the need to learn attitudes, views and demands of the direct users regarding new technologies.

## MATERIALS AND METHODS

The aim of the investigations was to find the opinion of the farmers regarding data necessary for proper application of the precision agriculture in their farms. The additional goal was to investigate the opinion of the farmers on applied technologies. The analysis was done based on the literature review and, mainly, based on the survey of a selected population of farmers.

The survey was done in 2018 using Computer-Assisted Web Interviewing (CAWI) (Bojanek, 2018). It is one of the methods applied in quantitative analysis of consumers market and public opinion. It requests the responded to fill the questionnaire in an electronic form (Sondaż, 2019). The main advantage of this method is its low cost, quick access to the data and the possibility of direct application of digital tools since the data is collected in the electronic format. Despite low cost, the method is considered to be an effective and providing broad access to the respondents (Mider, 2013).

The method used in collecting the data (CAWI) determined the respondents' population, making it mainly of young farmers, actively using precision agriculture technologies, with internet and computer access. However, that is not really a limitation since that group of farmers is the actual one interested in the introduction of precision agriculture principles and actively uses those technologies. The potential respondents were approached by posting the invitation to participate in the survey on industry relevant portals and fora, and also approached by e-mails. That approach resulted in 85 responses. Another 36 responses were collected from participants of short courses and surveys by

Agrocom Poland. A total of 121 survey responses were collected, although after verification only 120 results were considered.

The survey was done using a web tool in the form of Google Forms. It consisted of 33 questions clustered in 3 groups: general characteristics of the farm and its production (12 questions), application of precision agriculture technologies (18 questions) and respondents' profile (3 questions). There were closed end (7) and open-ended questions (12), multiple choice questions, with also 5-point Likert scale questions (5), plus questions giving the possibility to choose more than one answer with an option to add a specific comment (9). The survey was prompted by German research Cieniawska and Rühle (Cieniawska and Rühle, 2018).

## CHARACTERISTICS OF THE SURVEY POPULATION

A great majority the respondents (75%) were below 40 years and could be considered as young farmers; with the average of 26 years, 69% - below 25 years and only 6% above 45. That age distribution shows clearly a huge interest of young generation of farms in the precision agriculture technologies. The interest among young farmers was also documented by the fact that 42% of the respondents were students and school attendants, 27% held a degree, 25% a secondary technical education and 6% vocational education.

The participants in the survey were from all regions of Poland, although the most were from the following voivodships: Wielkopolskie (24%), Łódzkie (18%) and Lubelskie (13%). Farming was the main income for 73% of the respondents; among the remaining 27%, one third owned farms below 10 ha and almost half were still schooling (either at tertiary or secondary level) but had direct connection with agriculture as members of the families.

The plant production was the sole income for 80% of the farmers, whereas husbandry was declared as either main or additional source of income for 32%.

Table 1 Farm sizes of the survey participants

| Size | < 10 | 10-19 | 20-49 | 50-99 | 100-199 | 200-299 | 300-500 | > 500 |
|---|---|---|---|---|---|---|---|---|
| No of farms | 15 | 19 | 28 | 28 | 12 | 6 | 3 | 9 |
| Percentage | 12.5% | 15.8% | 23.3% | 23.3% | 10.0% | 5.0% | 2.5% | 7.5% |

The majority of respondents' (or their families) farms were of the size between 20 and 49 ha and between 50 and 99 ha - Table 1. The average size of the farm was 184. The biggest declared farm was 5,600 ha and the smallest – 2 ha, with median 35 ha. The average size of cattle herd was 88 and that of pigs – 243. The characteristics data of the farms indicates that the survey covered all sizes of the farms, from small, through medium to large and very large.

More than 72% of the farms declared the plans to increase production, with 10.8% planning to keep the production at the same level and 7.5% considering changing the farm specialization. Although, none of the respondents planned to reduce or limit the production, there were 7.5% were not sure about further farm activities and 1.7% actually planned to close entirely the production.

The data indicating the majority of farms had the intention to increase the production implies investment towards both the machinery and know-hows, which has bearing on the needs in terms of precision agriculture technologies.

## PRECISION AGRICULTURE TECHNOLOGIES USED BY FARMERS

Great majority of the farmers who participated in the survey already used precision agriculture technologies (100 out of 120); those applications were mainly for fertilizing (75%) and plant protection (63%). Those were chiefly used in processes related to cultivation and sowing (50%), such technologies were not used very frequently for grain harvesting (28%) or animal feeding (17%). Only 11% of the participants used digital technologies for stock management with only four farmers were in possession of a milking robot.

The mostly used applications were section control and switching off of seeder sections, and also change in the fertilizer dosages and application maps. Although not considered to be one of the precision agriculture technology, ISOBUS (a standardised communication between the machinery and implements) is well known and popular, used by 30% of farmers.

Yield mapping was used in 29% of the reported cases. Auto tracking systems were even less popular at 20%. Nitrogen sensor was used by 12.5% farms and only one farmer declared usage of the satellite crop photos.

The survey results (Fig. 1) indicate that the respondents were generally either ‘satisfied’ or ‘very satisfied’ with application of the precision agriculture technologies.

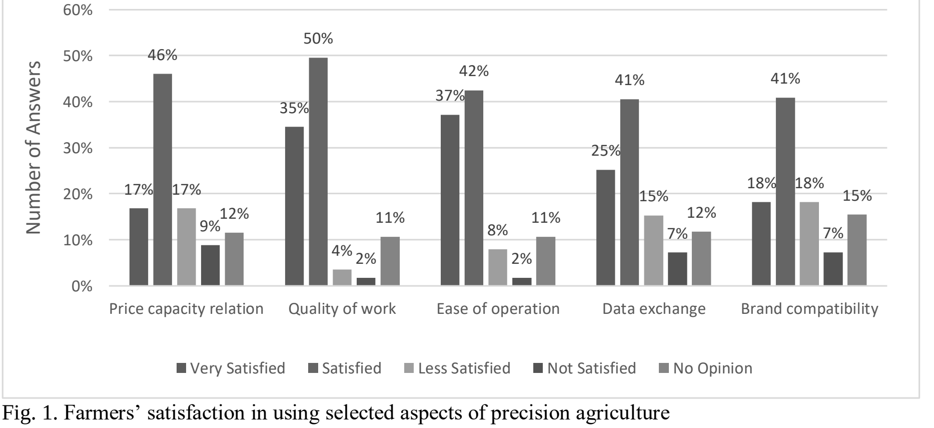


Fig. 1. Farmers’ satisfaction in using selected aspects of precision agriculture

Farmers were mainly dissatisfied with compatibility between different brands and also with price capacity relation. The quality of work and ease of operation, were the most applauded quality.

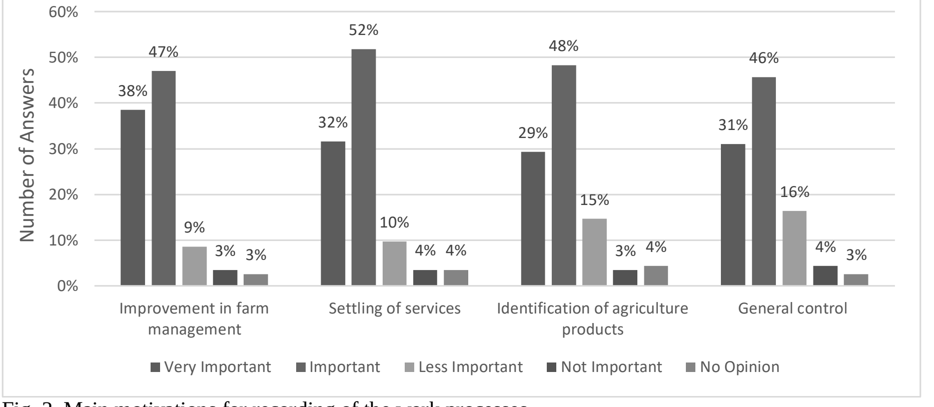

Fig. 2. Main motivations for recording of the work processes.

In the modern agriculture the proper documentation and records regarding production and farm activities play a very important role. The survey respondents considered their labour input in that aspect mostly as 'medium' (41%), although an equal number (41%) judged it to be either 'high' (27%) or 'very high' (14%). According to the replies, the average time spent on clerical work was 7.4 hrs (with a mode value of 2 hrs/week). On average, 39% of the above time, was used to record work processes, although some declared that it took up to 90% of office time. The work processes mainly documented were soil cultivation – 76% answers, field cards – 59%, machine repair and maintenance – 49%, cost calculations, leasing, insurance – 41%, transportation – 19%, service settling and animal production, - each 1%. Main rationales for the necessity to document work processes were listed as improvement in farm management, settling of services, identification of agriculture products and general control (Fig. 2).

Farmers argued that recording of the work processes enhances farm management, which allows for improvement in effectiveness and leads to cost reduction. It is also useful for financial analysis, guides profit and cost analysis, and ultimately facilitates plans for cost reduction.

The most popular software used for office applications was Excel spreadsheet (42), used in other sectors. The most common specialized software was '365FarmNet' with 27 respondents already using it, 18 who plan to use it and 27 declaring the awareness of that software. Only one third the above number confirmed the use of 'AgroPomiarGPS' (9 already using and 3 planning to use). It is also a software which is less known as only 17 farmers heard about that product, with 35 declining any knowledge of it. Another dedicated software, 'Sat Agro' was used by only 7, with 4 planning to use it and 15 stating some recognition of the product, and 33 denying any knowledge. Out of 86% software suggested in the survey, the most common answer was 'do not know', which may indicate lack of interest in dedicated software.

The survey included a question regarding the software potential for electronic recording of data; the majority of the farmers in a positive way assessed the potential, however, there were a lot of those who were uncertain. In detail, the potential was assessed in a scale from 5 – high, to 1 – low potential, 21.1% assessed potential at 5, 29.4% - 4, 37.6% - 3, with 1 and 2 at 11.9% of the respondents.

Smartphone and tablet were the most popular technology to keep an electronic records; declared by 53% with 41% using webpages, although also accessed by either smartphone or tablet (Fig. 3). Transmission by the machine terminal was applied by 15% but 46% still entered data manually. ‘Cloud’ applications were used by 15% of the farmers.

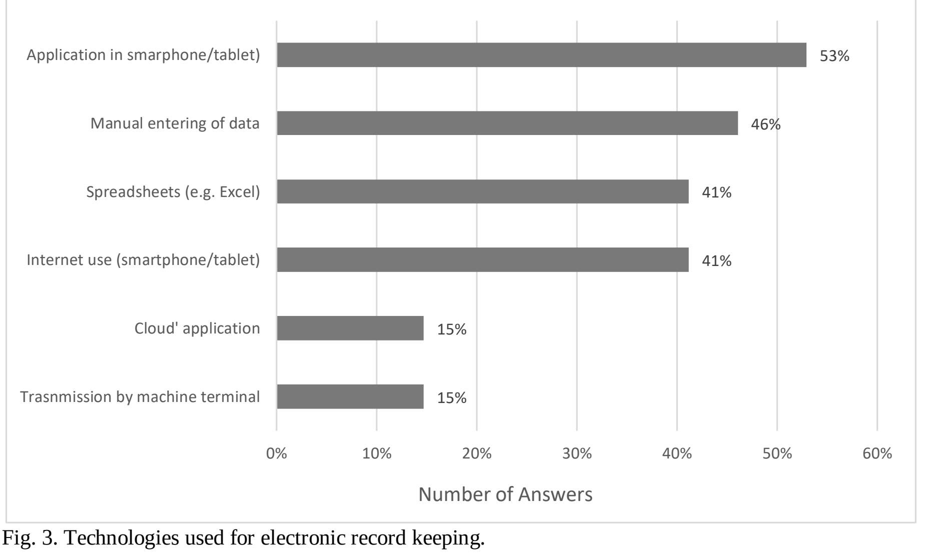


Fig. 3. Technologies used for electronic record keeping.

The farmers who declared manual entering of the data (39%) were asked for the motives for such action. The two main reasons were lack of knowledge of electronic recording (34%) and safety issues (22.5%). Lack of interface software was listed as another reason (18.3%), although there were also voices indicating high cost of investment. That high cost was quoted by 24.7% of all respondents, although lack of technical support was of the same importance level at 23.3%. Some farmers (21.7%) were of the opinion that their farms were too small for application of the recording systems whereas 19.2% did not trust the systems. Another group of reasons for not using electronic recording systems was related to lack of information about such systems (17.5%), lack of compatibility between those and systems used so far (6.7%) and finally, the opinion that such systems are disappointing not offering enough for practical applications (3.3%).

In terms of reasons for the use of recording software, the majority of farmers listed time saving (67.9%) and keeping the records in one source (47.2%). Additional advantages included better management of the records (42.5%) and the amount of data available for analysis (32.1%). However, the time saving, was the main reason, as it is the major factor in the farm management process.

## CONCLUSIONS

Recent years proved dynamic process of agriculture digitization, with precision agriculture constituting its main component. However, the main issue is the use of the old machinery in that process. An additional restriction is related lack of knowledge among farmers and also a mental blockage related to electronic equipment; that is on top of still existing shortage of electronic paraphernalia. The bottleneck related to knowledge and psychological issues are mainly associated to older farmers, who, to great extent, do not use computers or other electronic devices. Consequently, their farms loose contact with the leading edge and stay behind in the development. Younger generation of farmers educated already in the ‘digital society’, are comfortable with new technologies, and will lead changes in order to improve production effectiveness in sustainable agriculture.

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# 5.11. THE ROLE OF PRODUCTION GROUPS IN UPGRADING THE MACHINE PARK IN FARMS

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**Keywords**: agricultural machinery, decision system, agricultural producers

## ABSTRACT
In terms of agriculture, Poland is competitive as compared to the countries of the “old” EU, due to the use of new production technologies. Maintaining this trend requires continuous modernization of agricultural technology means on farms, with appropriate attention paid also to the appropriate adjustment of technical parameters of the purchased means. Failure to match the existing machine park, the farm's area or its branch of production can lead to a decreased financial result of the farm. The above mentioned threats are particularly important for small farms, which are characterized by low investment capacity, and at the same time have a limited amount of farming land, which results in less intensive use of the purchased machines. The study included a group of 20 individual farmers, making individual purchases, and 2 producer groups of 10 farmers each, who make purchasing decisions collectively. The majority of individual respondents came from the Małopolskie province, from the Gorlicki district, and were aged 21-30. The research of purchases of agricultural production equipment by individual and associated farmers shows that, in general, the machine park of farms is improving. As can be presumed, the surveyed farmers associated in producer groups probably leverage the knowledge and experience shared by group participants as the foundation for decision making. Observing the work of users of specific brands of devices, and conclusions about their usefulness in specific applications, were significant for their own purchasing decisions.

## INTRODUCTION
According to the Act of September 15, 2000 on groups of agricultural producers and their associations, as amended, these groups are created to adapt agricultural production to market conditions, to improve management efficiency, to plan production with particular attention to its quantity and quality, and to concentrate supply and organize sales agricultural products (Suchoń, 2015). As part of the amendment to the Act of 11 September 2015, amending the Act on Agricultural Producer Groups and Their Associations and other acts, and the Act on Supporting Rural Development with the Participation of the European Agricultural Fund for Rural Development under the Rural Development Program Rural for 2014-2020, the objectives of agricultural producer groups are changing in comparison to the Act of September 15, 2000.
Pursuant to the amendment, the purpose of agricultural producer groups is: sale of products produced through a given group, selection of appropriate agricultural production to match market conditions, regulation of supply, improvement of farming efficiency, reduction of costs to increase farmers' income, preparation of large, homogeneous, high quality batches of products and environmental protection.
Associating into groups of agricultural producers has their advantages and disadvantages for the farmers. The advantages are: reduction in the number of intermediaries in the sale of agricultural products, joint purchase of tractors and agricultural machinery and means of production, e.g. fertilizers, plant protection products or transport, etc., as well as producing more homogeneous yield, and thus easier sale, thanks to continuous supply, more contacts with the purchasers, the possibility of using farm buildings communally, e.g. for storage, garaging of vehicles, drying or labeling of products, much improved access to information and market

dominance, joint promotion (conducting training and marketing activities), the opportunity to share experiences between group members, and, in the case of problems, sharing the risk among all group members and solving them together. The main disadvantage of creating producer groups is the human factor (Niemiec *et al.* 2017). Even strict, constantly changing rules that work to the detriment of producer groups, e.g. The need to changing the company status, in order to adapt it to the founding act, which groups must submit to the Agricultural Market Agency (ARR) to confirm compliance with the recognition conditions, has not been indicated as the greatest disadvantage. It is the individual shareholders who can ruin things for the group, intentionally or unintentionally. Among the disadvantages, attention should be paid to the requirements for individual group shareholders, i.e. reaching a certain level of sales. Some farmers have a problem with this and resign from the group, or are excluded, which is the most severe penalty for a shareholder (Gródek-Szostak *et al.* 2019; Kocira *et al.* 2017; Sikora *et al.* 2017). The reason can be the failure to meet the obligations towards the group, i.e. not achieving the required level of sales or insubordination, i.e. sale of products outside the producer group. Such penalties are clearly specified by law and must be strictly observed by group members, which can also be seen as a disadvantage of the group model. A business plan is a serious challenge for this type of business activity as it requires groups to provide a lot of data, e.g. production level, farming plot numbers or livestock population (Gródek-Szostak *et al.* 2017; Niemiec *et al.* 2019; Kapusta-Duch *et al.* 2019). This is the basic document illustrating in which production branch the group will operate (Szeląg-Sikora *et al.* 2016; Szeląg-Sikora *et al.* 2017).

The purpose of the article is to determine the role of the brand, as part of marketing resources, in the decision-making process of purchasing tractors and agricultural machinery by members of agricultural producer groups.

## METHODOLOGY

The research was carried out in the form of a survey conducted in 2 producer groups, and among individual farmers. The research was based on a pre-prepared, proprietory questionnaire. The research was carried out two-fold:

1. During agricultural fairs in Kielce and online, on agricultural forums (agrofoto.pl and farmer.pl). This part of research included individual farms.
2. The research of two groups of agricultural producers was carried out in Złoty Sad Sp. z o. o., based in Samborec and SPWiO, based in Sielec. The research was conducted in the form of a survey.

The study included a group of 20 individual farmers, making individual purchases, and 2 producer groups of 10 farmers each, who make purchasing decisions collectively.. The majority of individual respondents came from the Małopolskie province, from the Gorlicki district, and were aged 21-30.

In order to prepare the survey results, the data was entered into Microsoft Excel 2007 in numerical form and presented in the form of drawings and tables.

## LEVEL OF TECHNICAL EQUIPMENT IN POLISH AGRICULTURAL FARMS

In early 2004, when Poland entered the EU, its farms experienced large investments, thanks to EU financial support systems and various programs introduced by the EU (Lorencowicz, 2008). The level of technical equipment in Polish farms depends mainly on their profitability. Polish agriculture is not developed enough to generate income sufficient to cover the costs of purchasing or modernizing agricultural machinery individually (Cupiał *et al.* 2015). By increasing the utilized agricultural area, modernizing the machinery park, creating new buildings and structures, or developing animal production, farmers can obtain higher income from their activities (Wójcicki, 2003). Polish agriculture, however, is still outdated. Farmers still use tractors of low and medium power with an obsolete design, often deprived of the necessary safeguards (Pasyniuk, 2003).

Farms operate on a free market, which makes them different from other sectors and subjects them to more regulations and norms. This is also related to the resource advantage over other sectors, which should often affect technical equipment, however, due to the level and direction of production, farms are unable to use it properly. Production volume, imports and exports depend on demand. They are important for the supply of agricultural tools and machines to the domestic market. The nature of production, constantly changing prices of agricultural products and means of production cause frequent fluctuations in the volume of production, as well as import and export of tractors and agricultural machinery. The rate of development of the machine park and the means of agricultural technology depends on the needs and at the same time, on the opportunities of their implementation. Only a few farms are able to bear the costs associated with the modernization of machinery. Financing new tractors or agricultural machinery should be considered in the light of the opportunities offered by available EU funds. The RDP (Rural Development Program) includes investment-related activities; the RDP 2007-2013 offered e.g. facilitating the start of young farmers, modernization of farms or groups of agricultural producers. On the other hand, those starting independent farming can apply for funding for young farmers, which can be implemented no later than 18 months after the commencement of agricultural activity. The criteria to be met by people applying for funding from the program include:

- being of legal age, but under 40, on the day of submitting the application,
- professional qualifications, i.e. education or experience in agriculture,
- farming in accordance with the previously submitted business plan,
- using at least 70% of the subsidy amount for purposes related to farm modernization,
- insurance in the Agricultural Social Insurance Fund (KRUS) for a period of at least 3 years, starting from the date of payment of funds,
- running the farm for 5 years, starting from the date of payment of funds,

Rules detailing the take-over of the farm specify that:

- the size of the arable land must be larger than the national average, but not exceeding 300 ha,
- the farm is, or will be the property, or subject of lease, of the applicant,
- the applicant meets the requirements for environmental protection, hygiene and animal welfare, or adapts to these conditions within 3 years of starting agricultural activity (Szeląg-Sikora, 2013).

## COLLECTIVE PURCHASE OF MACHINES AND PRODUCTS

In terms of agriculture, Poland is competitive as compared to the countries of the “old” Union due to the use of new production technologies. Maintaining this trend requires continuous modernization of agricultural technology means on farms, with appropriate attention paid also to the appropriate adjustment of technical parameters of the purchased means. Failure to match the existing machine park, the farm's area or its branch of production can lead to a decreased financial result of the farm. The above mentioned threats are particularly important for small farms, which are characterized by low investment capacity, and at the same time have a limited amount of farming land, which results in less intensive use of the purchased machines. Taking into account all these factors, proper management of the machine and tractor park plays a special role (Niemiec *et al.* 2017).

When it comes to machinery, the most important thing is the pull force, which has a huge impact on the use of accompanying machines. It is also related to timeliness, quality of production practices or the level of expenses, which ultimately translates into production efficiency (Tabor, 2006; Szeptycki, 2005). Machines working intensively during the year are not very durable (they depreciate). Such utilization means that they are often replaced with new generation machines, offering advanced agricultural production technologies. Unfortunately, only farms with a large acreage, or those that use tractors or agricultural machinery for service purposes are able to implement such a strategy. Obsolete machinery parks not only do disservice to the development of mechanization, but even prevent it as well (Szeląg-Sikora, 2013).

Most Polish farms' agricultural area is smaller than the national average, which causes a relatively smaller income, followed by investment plans of these farms. Land consolidation or intensification of production could be an effective solution to financial problems. Such opportunities are provided by establishing a group of agricultural producers. It should also be remembered that agriculture changes in terms of biology of production. The impact of changeable weather conditions, as well as the quality requirements increasing from year to year, changing eating habits or the search for new energy solutions, adversely affect agricultural production (Marczuk &Misztal, 2011). The area of modernization of the technical facilities in farms belonging to agricultural producer groups remains undiagnosed. Compared to the actions of other Western countries, the creation of agricultural producer groups has a positive effect on the economy of these countries. There is still no unambiguous and comprehensive research results to analyze the impact of external funding on the modernization of technical facilities in farms. The effectiveness of the use of EU funds for the modernization of machine parks in farms remains an area still unexplored in source literature. Resources mainly indicate formal and legal guidelines, goals, tasks or information on where to obtain a subsidy for farming activities (Szeląg-Sikora, 2013).

The introduction of progress is very costly and requires significant investment in the purchase and modernization of the farm's technical facilities or infrastructure.

Rational selection of the production branch, and the properly used machine park affect the efficiency of agricultural production. In this context, Szeląg-Sikora *et al.* (2017) adds that funding coming from the EU is important as it contributes immeasurably to the development of farms.

## RESULTS

The study included a group of 20 individual farmers, making individual purchases, and 2 producer groups of 10 farmers each, who make purchasing decisions collectively. The majority of individual respondents came from the Małopolskie province, from the Gorlicki district, and were aged 21-30. Most people had secondary education and owned their farm. The average utilized agricultural area declared by respondents was 25.85 ha. On the other hand, the respondents operating in formal producer groups came from the Świętokrzyskie province, districts of Sandomierz, Kazimierz and Pińczów.

They were mostly 31-40 years old and had mainly secondary education. 17 of them declared they were owners of the farm, and only 3 were members of the owner's family. Their average utilized agricultural area of the farms was 9.15 ha.

The average utilized agricultural area of all individual farms researched was 25.9 ha. The largest farms had an area of 50 ha and the smallest, 10 ha. The average area of land in agricultural producer groups was 9.2 ha. The largest farms had an area of 20 ha. The rest of the farms were relatively small, with a maximum area of 15 ha and a minimum area of 3 ha.

Most individual responders, i.e. 65%, obtained information about tractors and agricultural machinery from indirect sources, i.e. the internet, as well as direct, i.e. opinions of other users, while the least responders used another indirect source, i.e. television. Members of producer groups received information mainly from other users (95%). Similar to the group of individual producers, for members of agricultural producer groups, the worst source of information about tractors and agricultural machinery turned out to be television.

Respondents operating in agricultural producer groups with farms of 3 - 10 ha responded with the most "yes" and "rather yes" answers to the question of whether they buy tractors and agricultural machinery of brands they already own. This was the largest number of indications, both in terms of tractors and agricultural machinery, except that the answers for agricultural tractors were evenly divided equally among 25% of persons. In answers regarding agricultural machinery, 50% of respondents from producer groups indicated “rather yes” and only 10% answered definitely “yes”. Please note that in the largest individual farms the answers were equally positive when it comes to buying already owned brands of tractors and agricultural machines.

When asked if a well-known brand guarantees high quality, most respondents, 62.5%, answered "rather yes", with majority coming from producer groups owning 3-10 ha. Only 2.5% of respondents answered definitely negatively to this question, while 7.5% answered "rather not". Respondents from producer groups with the lowest acreage indicated that they would pay more for a specific brand than for other, i.e. 75% of all positive responses. In the largest individual farms, 20-50 ha, the respondents were not unanimous. 25% of respondents replied "yes" to the question whether they would be willing to pay more for a particular brand than for other, 20% indicated "rather yes" and 15% "rather no". The opinion with which most respondents in all ranges agreed was "despite the fact that I have my favorite brand, I am interested in other brands", which was 60% of the total answers.

## CONCLUSIONS

The research of purchases of agricultural production equipment by individual and associated farmers shows that, in general, the machine park of farms is improving. As can be presumed, the surveyed farmers associated in producer groups probably leverage the knowledge and experience shared by group participants as the foundation for decision making. Observing the work of users of specific brands of devices, and conclusions about their usefulness in specific applications, were significant for their own purchasing decisions.

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# 5.12. THE INFLUENCE OF ENERGETIC AND MATERIAL INPUTS ON THE SUSTAINABILITY OF AGRICULTURAL PRODUCTION

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**Keywords:** sustainable agricultural production, energetic and material inputs, intensity of agricultural production organization, balance of organic matter

**ABSTRACT**
The level of sustainability of agricultural production was analysed from the perspective of energetic and material inputs in 70 holdings in Biłgoraj county. The criteria used for the evaluation of sustainability: economic, social and ecological ones, were applied to energetic and material inputs, intensity of agricultural production and balance of organic matter. The study found that within the groups of the studied holdings the accepted criteria of sustainability were not universally satisfied. Larger holdings (over 30 ha UAA) introduced systems of agricultural production capable of sustaining the natural fertility of soil and thus they were able to satisfy the requirements of sustainable agricultural production.

## INTRODUCTION

The concept of sustainability with respect to agriculture is defined as an attempt to balance the following objectives: limiting threats to the environment, ensuring efficiency of agricultural production, satisfying qualitative and quantitative food requirements and comparable standards of living for their producers (Sawa, 2008). The development strategy for agricultural production relating to sustainable agriculture assumes that in the process of agricultural production the maximization of outputs and the minimization of inputs will be carried out from the perspective of environmental and social needs of people. With a correctly chosen crop rotation and a rational livestock density, holdings can balance the level of global organic matter on their arable land. (Golka and Wójcicki, 2006, Wójcicki, 2009). The effects of ecological sustainability are particularly difficult to evaluate (Wibberley, 1995, Morris and Winter, 1999, Leiva and Morris, 2001). Studies lasting many years are needed to obtain reliable information in this area because both the process of degradation and the renewal of organic matter in soil take from 5 to 30 years (Stelow, 2003). A negative balance of organic matter continuing for several years or longer can lead to a degradation of soil and a loss of its fertility and productivity. The decomposition of organic matter is usually accompanied by a release of a large quantity of minerals, particularly nitrogen, which can lead to the contamination of groundwater and surface waters.

## MATERIALS AND METHODS

The objective of the study is to try to evaluate the level of energetic and material inputs (current production inputs: seeds and seedlings, mineral fertilizers, crop protection products, fodder, purchase of animals, veterinary services) against ecological effects (Kaufmann and Cleveland, 1995, Czyż, 2000, Van Passel *et al*., 2007) obtained in 70 holdings from Biłgoraj county. The following indicators were used to evaluate the effects: balance of organic matter (Kuś and Krasowicz, 2001), annual workload and the level of commodity production. The holdings under study were divided into 5 territorial groups. The intensity of agricultural production was expressed by determining the rate of the intensity of production (Kopeć, 1987) and the level of labour and financial inputs into the current processes of agricultural production. The accepted indicators of the intensity of agricultural production reflected the character of the production process and defined the intensity of farming, which translates to the level of production (high or low) and its ecological character (friendly or dangerous to the environment). The balance of reproduction and degradation of organic matter was performed using the calculation method, using IUNG coefficients (Fotyma and Mercik, 1992). Based on this, we estimated how much organic matter accumulated or decomposed in soil in an area of 1 ha with a particular crop or how much of it has accumulated following the application of 1 ton of natural fertilizers or straw per 1 ha UAA. We assumed that during one year, one LSU produces 10 tons of manure, and 80% of the straw remains to be ploughed up in relation to the output from one ha UAA.

## RESULTS AND DISCUSSION

The level of agricultural production is connected with ensuring a high production potential of soil and the ability of a holding to use the potential. The production potential of soil is created and maintained by intentional agrotechnical procedures, which in intensive agriculture are connected with high costs of current production assets (Sawa *et al.*, 2006). In each of the studied groups of holdings, the nett commodity production (table 1) was directly proportional to the size and it definitely reached the highest values in the largest ones. Only holdings of an area of 50–70 ha UAA failed to maintain this relationship (47.3 $CU \cdot ha^{-1}$ UAA) and was lower than the one obtained in groups of 10–30 and 30–50 ha UAA (respectively: 57.6 and 84.2 $CU \cdot ha^{-1}$ UAA). This can be caused by low livestock density (31.2 $LSU \cdot 100\ ha^{-1}$ UAA) in those holdings, which also translates to other results of studies in this group of holdings. The level of energetic and material inputs and the level of production effects allows us to determine the character of economic and social sustainability. The lower labour inputs per each ha UAA (from 477 to 68 $lh \cdot ha^{-1}$ UAA) are connected with an increase in the energetic input of labour, which increased over fourfold for holdings with the largest area (from 12.3 to 51.5 $kWh \cdot lh^{-1}$). Whereas an increase in the area of holdings is consistently accompanied by a decrease in the costs of means of production (from 3197 to 999 $kWh \cdot ha^{-1}$ UAA), except for the ones over 70 ha UAA (1398 $kWh \cdot ha^{-1}$ UAA). The disproportionate costs of means of production in this group are connected with respectively higher livestock density (121.9 $LSU \cdot 100\ ha^{-1}$ UAA). An increase in energetic input of labour is connected with labour resources (5.9 $AWU \cdot 100\ ha^{-1}$ UAA) and guarantees higher productivity. It was found that an increase in the area of holdings was accompanied by an increase in current production assets inputs (except 50–70 ha UAA). At the same time, there was an increase in both nett commodity production (from 41 to 96 $CU \cdot ha^{-1}$ UAA) and the organization of production (from 299 to 510 points).

Table 1. Energetic and material inputs and production effects of holdings studied in 2011

| Description | Units | Holding groups according to the area of ha UAA | | | | | Total/ average |
|---|---|---|---|---|---|---|---|
| | | <10 | 10–30 | 30–50 | 50–70 | >70 | |
| Number of studied holdings | quantity | 11 | 41 | 6 | 3 | 9 | 70 |
| Holding area | ha UAA | 7.1 | 16.1 | 42.8 | 65.0 | 89.5 | 44.1 |
| Livestock density | $LSU \cdot 100\ ha^{-1}$ UAA | 42.0 | 55.3 | 116.2 | 31.2 | 121.9 | 73.3 |
| Labour input | $lh \cdot ha^{-1}$ UR | 477 | 207 | 95 | 77 | 68 | 184.8 |
| Workload | $lh \cdot AWU^{-1}$ | 2000 | 1967 | 1611 | 1444 | 1444 | 1693.2 |
| Labour resources – persons in full employment | $AWU \cdot 100\ ha^{-1}$ UAA | 15.1 | 6.9 | 3.1 | 2.3 | 2.1 | 5.9 |
| Energetic inputs kWh | $kWh \cdot ha^{-1}$ UAA | 3197 | 2033 | 1151 | 999 | 1398 | 1755.6 |

| Description | Units | Holding groups according to the area of ha UAA | | | | | Total/ average |
|---|---|---|---|---|---|---|---|
| | | <10 | 10–30 | 30–50 | 50–70 | >70 | |
| | $kWh \cdot lh^{-1}$ | 12.3 | 18 | 25.7 | 32.8 | 51.5 | 28.1 |
| Current production inputs | $PLN \cdot ha^{-1}$ UAA | 1108 | 1248 | 1821 | 999 | 2049 | 1445 |
| Nett commodity production | $CE \cdot ha^{-1}$ UAA | 41.0 | 57.6 | 84.2 | 47.3 | 96.0 | 65.22 |
| Intensity of production organization | points | 299 | 257 | 392 | 327 | 510 | 357 |
| Balance of organic matter | $ton \cdot ha^{-1}$ UAA | -0.35 | 0.02 | 0.26 | 0.64 | 2.12 | 0.54 |

AWU – Annual work unit, lh – labour hours

Large holdings, with the lowest employment rate (2.1 $AWU \cdot 100\ ha^{-1}$ UAA) achieved the highest productivity, which was 1444 $lh \cdot AWU^{-1}$, against 2000 $lh \cdot AWU^{-1}$ in the smallest holdings. It was found that the level of sustainability of organic matter was the most favourable in the territorially largest holdings (over 0.2 ton per ha UAA). They had animal farms and the waste material was used as organic fertilizer. Whereas small holdings, with lower animal output, did not produce enough organic matter and the rate of sustainability was unfavourable (beneath 0.02 ton per ha UAA). An effectively high rate of sustainability of organic matter is evidence of the holding's care for maintaining soil fertility. The results of the study show that large holdings are becoming more ecological and more environmentally friendly.

## CONCLUSIONS

In the studied holdings, an increase in the area of ha UAA results in a decrease in energy inputs ($kWh \cdot ha^{-1}$ UAA), but an increase in the energetic input of labour ($kWh \cdot lh^{-1}$) and net commodity production ($CU \cdot ha^{-1}$ UAA). At the same time, the rate of intensity of production increases as well as the level of reproduction of organic matter. This allows us to conclude that territorially larger holdings (over 30 ha UAA) introduced a system of agricultural production capable of sustaining natural fertility of soil and thus able to satisfy the requirements of sustainable agricultural production. We can assume that the aim of the production process in the studied holdings is the effective application of energetic and material inputs in a way which takes into consideration the scale of production in each of the holdings. The studies confirm that over the last few years there has been a structural change in the shape of the organization of holdings, expressed by an increase in its intensity and level of sustainability in larger holdings.

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# 6. ENVIRONMENT AND ERGONOMICS

# 6.1. IMPACT OF AGRO-ECOLOGICAL SERVICE CROPS AND THEIR TERMINATION STRATEGIES ON SOIL MINERAL NITROGEN AVAILABILITY, SOIL HUMIDITY, WEEDS DEVELOPMENT AND CABBAGE HARVEST

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**Keywords**: Agro-ecological Service Crops, soil, termination mode, water, nitrogen, weed control

## ABSTRACT

The use of Agro-ecological Service Crops (ASC) can be beneficial during its growth, but what is the effect on the following crop (cash crop, e.g. cabbage)? The effect of three ASCs, made of a mix of barley and pea in different proportions (0, 30 and 50%), were tested. They were crossed with three ASC termination strategies: Chopped and Incorporated (GM), Chopped and No-Incorporated (CNI) and flattened with a Roller-Crimping (RC). These strategies were compared with a tilled Bare Soil (BS). The soil water and mineral nitrogen availability were lower at planting when a winter ASC was grown. The soil mineral nitrogen content before planting was 6 times higher in BS than RC (35 vs. 6 kg N $ha^{-1}$). CNI and RC maintained a mulch under the cash crop reducing weed development. But the barley could, when mature enough, reseed itself, becoming a competitor for the cash crop. The termination strategy and date had a significant effect on the cash crop biomass production from 25 to 75% of reduction.

## INTRODUCTION

Two big challenges in organic cropping systems are the management of the soil fertility and the weed control. To face this challenge, Agroecological Service Crops (ASC) are an alternative. SoilVeg project was an European research consortium in eight countries (Italy, Slovenia, Denmark, Estonia, Spain, France, Latvia and Belgium) which had studied the ASC effect on the next vegetable crop. In the temperate climate of Western Europe, winter fallow could last 9 months, for example between a winter wheat and a cabbage crop. On bare soil, the risks of erosion and nitrogen leaching are high. The introduction of agro-ecological service crops could deliver several benefits to the environment and the agricultural system: soil protection, winter weed control, soil quality increase, carbon sequestration, pest management and water quality protection (Dabney, S. M., J. A. Delgado, 2001).

The species and varieties, the sowing density, the sowing date, the fertilisation and soil sowing preparation of ASC are essential parameters to guarantee its development and the production of enough aboveground biomass to set-up the tested management schemes (ASC terminated by chopping and incorporated into the soil as green manure (GM), not incorporated (CNI) or flattened by roller crimping (RC)). The ASCs selected must be non-sensitive to frost, cover the soil before winter and have no regrowth after destruction. The ASC composition has to include a minimum of cellulose rich species like cereals to obtain an important thickness and a lasting effect of the mulch cover.

This article is going to present the results obtain in Belgium (Wallonia) during the 2016-2017 season on a spring vegetable crop. Three ASCs and three ASC termination strategies have been tested before the planting of red cabbage.

## MATERIALS AND METHODS

The study was located in Wallonia, Belgium (50°60'98.53''N and 4°95'47.5'' E), on a silt loam soil managed according to European organic farming regulation since 1995. The 2016-2017 season had a rainfall deficit (480 mm from September 2016 to October 2017, instead of an expected average value of 870 mm).

The used ASC was cereal alone or a mixture of cereal and legume. The choice of the cereal species was driven by its precocity. Indeed, in order to avoid any regrowth problem, the cereal has to reach its full flowering stage before destruction without postponing cash crop plantation date. For that reason, winter barley has been used. The legume proportion in de ASC was expected to influence the fertility delivered by ASC residue mineralisation but to reduce the mulch longevity. Only winter pea or winter vetch could be adapted. Aside the pure barley cover (C), two proportions of pea and barley were therefore tested: a mix of 70% barley and 30% pea (C7/P3) and a mix of 50% barley and 50% pea (C5/P5). The 50% by weight of legume in the cover mixture being the maximal limit in Wallonia. Before ASC sowing, cow manure was applied on the 25$^{th}$ August 2016: 20 t ha$^{-1}$ corresponding to 82 kg total N ha$^{-1}$. The ASCs were sowed on September 15$^{th}$ 2016 (the latest date allowed by the Walloon legislation for the implantation of winter cover crop). In parallel, a bare soil (BS) modality was maintained as a control. The weed control, on these control plots, during the ASC growing period, was done 4 times (31/03, 05/04, 05/05, 31/05/2017), making use of rotary harrow.

Fig. 1. RC roller-crimping material

Each ASC was destroyed following three termination modes: (1) chopped and incorporated like green manure (GM), (2) chopped and no-incorporated (CNI) and (3) flattened by roller-crimping (RC). The GM destruction is the traditional termination mode for cover crops: the ASC is incorporated as green manure into the soil by tillage. This favours the residue mineralisation and makes cash crop planting easier. The GM termination mode may induce a nitrogen immobilisation due to the microbial activity just after incorporation (Recous, 1995). To reduce this effect on cash crop, the GM destruction was planned three weeks before cabbage planting. The RC termination mode was the more innovative and constraining technic. The RC destruction consists in flattening the ASC without cutting plants, just by hurting them. The technic reduces tillage and establishes a mulch where the straws are organized in the same direction. Another new technic tested was CNI that can also produce a mulch. To be as close to farmer's practices as possible, the termination dates differed between treatments: GM on May 5$^{th}$, CNI on May 23$^{nd}$ and RC on May 31$^{st}$ 2017. Therefore the 'termination mode' effect included also the impact of the corresponding 'termination date'.

The cash crop planted after the ASC termination was red cabbage (*Brassica oleracea* var. *rubra*; variety: Klimaro (F1)). A challenge for RC and CNI termination is the planting of cabbage while maintaining mulch on the surface. To solve this technical constraint, a strip-till (Kuhn Striger – 4 rows) was used on all trials before planting to limit soil tillage in the planting row. The strip-till was 15 cm wide and 10-12 cm deep. The planter (3 rows) was equipped with discs in front of each share to cut the plant residues avoiding any jam. Planting was performed on 31st May 2017, with an inter-row distance of 0.60 m and 0.40 m of distance between the cabbage plants within the row.

The cabbages were fertilized when planted, with 60 kg ha$^{-1}$ of nitrogen and 33 kg ha$^{-1}$ of phosphorous (commercial organic fertilizer). The fertilization rate was based on the residual soil N content in BS plots and the cabbage needs. Planting was performed on 31st May 2017, with a row spacing of 0.60 m and a plant spacing of 0.40 m. The strip-till was 15 cm wide and 10-12 cm deep. Just after the planting, the experimental platform was covered with a protective net against insects.

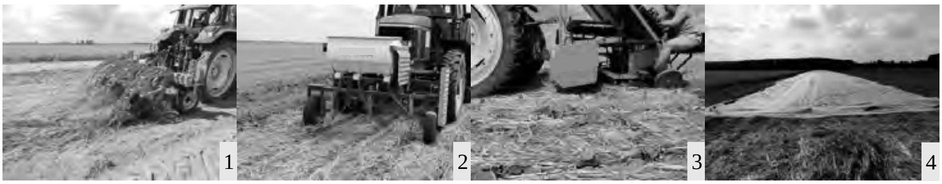

Fig. 2. The succeeding operations at the planting date. 1 = strip-till soil tillage, 2 = row fertiliser and 3 = cabbage planter, 4 = protective net.

Post-planting, the weed control was conducted manually the 14th July 2017 only on GM and control plots. In CNI and RC plots, the mulches were sufficient to maintain an acceptable weed control.

Soil was sampled to evaluate soil mineral nitrogen (SMN) and water content to 30 cm depth before planting and each month till the harvest of the main crop. Each date, six samples were collected per plot area and mixed into one composite sample. The mineral nitrogen analyses were done with KCl 0.5 N extraction following by a colorimetric determination and the soil moisture content was determined. The ASC biomass was measured on a surface of 2 m$^2$ per plot. For each plot, 21 cabbages were sampled in the three centrelines and weighed. Finally, the cabbages were harvested on October 25$^{th}$ and 26$^{th}$.

The experimental design was a split-plot with four replications. The ASC factor (3 levels) is the main plot while the ASC termination factor (3 levels) is the sub-plots. An additional treatment was included in each block as a control with a bare soil (BS) during ASC season. To analyse data with the control, it was necessary to combine ASC termination date and ASC type. The analyses of variance (ANOVA) were done with 1 variable which contain 10 treatments replicated in 4 blocks. We performed post-hoc tests with all pair-wise comparisons and with p-value correction (default "single-step" method in the `multcomp` R package). Statistical analyses were performed using R software.

## RESULTS

### ASC biomass and N accumulation

Termination modality, performed at different dates (GM: 5/05 ; CNI: 23/05 ; RC: 31/05/2017), led to significantly different ASC biomass accumulation before its destruction (figure 3). Barley biomass increased significantly for each date while maximum pea biomass was reached on 22/05. The ASC treatments have no significant impact on final biomass. There is not interaction between ASC factor and termination modality-date.

### Soil mineral nitrogen availability

ASCs reduced soil mineral nitrogen (SMN) availability for succeeding cabbage compared with BS. From the beginning of spring to June 2017, the SMN in BS were significantly higher than in GM, CNI and RC modalities (figure 4).

On June 12th 2017, the SMN did not vary significantly regarding the legume proportion in the ASC ($F(2,4) = 1.38$ ; $p = 0.32$). However, we can note that SMN presented a small increase of 11 kg N $ha^{-1}$ only for ASC C5/P5 under GM modality.

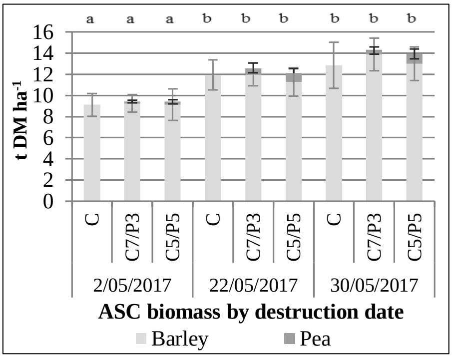


Fig. 3. ASC dry biomass (t DM $ha^{-1}$) at the different destruction dates. C = pure barley, C7/P3 = mix of 70% barley and 30% pea, C5/P5 = mix of 50% barley and pea. Bars indicate standard deviation. Different upper-case letters indicate significant differences at $P < 0.05$.

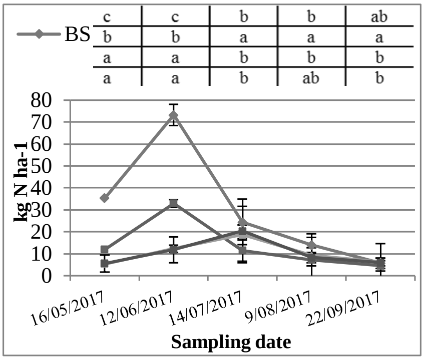


Fig. 4. Soil mineral nitrogen content (kg N $ha^{-1}$) in 30 cm depth after destruction modalities. GM = green manure, CNI = chopped and no-incorporated, RC = roller-crimping, BS = bare soil. Bars indicate standard deviation. Different lower-case letters indicate significant differences at $P < 0.05$ by date.

As observed on June 12th, ASC mineralisation under GM mode had begun earlier than under CNI and RC modes due to early destruction date and to residue incorporation into the soil. On July 14th, the SMN of CNI and RC was significantly higher than GM and could highlight a postponed mineralisation under these treatments. The SMN under CNI and RC modalities was not different during cabbage season.

### Soil water availability

At the end of winter, soil water availability in BS was higher than in plots with ASC. When the ASCs were destroyed the soil water stock could rebuild. That was observed on 15/06 and 12/06 (figure 4). With a low initial soil water stock and mulch, soil humidity recovery was slower under CNI and RC modalities as water needed to penetrate the mulch before reaching the soil. Nevertheless, once the soil water stock was rebuilt, the mulch reduced soil water evaporation and maintained a better soil water availability as observed on July 14th (figure 5).

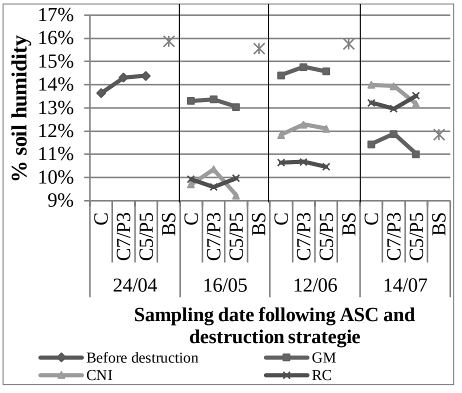


Fig. 4. Soil humidity in the first 30 cm soil layer under the different ASCs, following the different destruction dates and one month after cabbage plantation. GM = green manure, CNI = chopped and no-incorporated, RC = roller-crimping, C = pure barley, C7/P3 = mix of 70% barley and 30% pea, C5/P5 = mix of 50% barley and 50% pea, BS = bare soil.

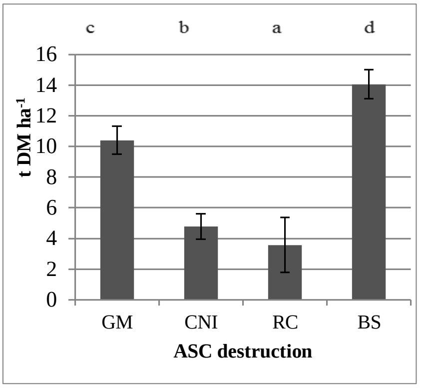


Fig. 5. Cabbage biomass at harvest time (t ha$^{-1}$). GM = green manure, CNI = chopped and no-incorporated, RC = roller-crimping, C = pure barley, BS = bare soil. Different lower-case letters indicate significant differences at $P < 0.05$. Bars indicate standard deviation.

## Weed control

The winter weed control was made by all ASC with success. During cash crop development, the occurrence of annual weed (mainly *Chenopodium album*) was observed on BS and GM plots while mulch limited its development under CNI and RC modalities. The barley regrowth were principally observed under GM and CNI modalities due to the cereal cut above tillering zone but in low number. In CNI and RC plots, the barley self-sowing, acting as a weed, was important because the ASC destruction was done after barley seed maturity, favored by hot and dry weather. At the end of the cash crop growth period, the cover and biomass of weeds were low in all treatments except for CNI and RC plots where barley self-sowing was not controlled.

## Cabbage harvest

The cabbage biomass at harvest time was significantly higher under GM and BS modalities compared to CNI and RC modalities (figure 6). Cabbage development was too limited by GM, CNI and RC modalities to be harvested. BS treatment led to a marketable yield of 7.73 t DM ha$^{-1}$.

## DISCUSSION

The use of ASC controlled weeds and reduced the tillage energy consumption during their growth comparatively at BS. The legume introduction in the ASC mix increased the nitrogen availability in the system but, whatever ASC termination mode, this nitrogen was not enough to fulfil cabbage needs until harvest. The ASC needed uptake of soil water and nitrogen to develop itself. The ASC biomass could produce an enough mulch to control weeds during cabbage crop. On the other hand, the seeds or the regrowth of ASC could be problematic if the mode and date of ASC destruction is not appropriate.

In a situation of limited nitrogen fertilisation, the cabbage biomass at harvest reflected the carry-over effects of ASC managements on the following cash crop in terms of water (1) and nitrogen (2) availability, on one hand, and competition due to barley self-sowing (3), on the other hand. (1) A lack of water availability due to the low water reserve following ASCs development and the low rainfall before and after cabbage planting induced a worse cabbage growth at planting. Moreover, RC and CNI treatments led to the occurrence of mulch, a buffer organic cover that could limit water percolation to the soil. (2) The soil nitrogen availability at cabbage planting was limited in ASC presence and was not compensated until harvest. The particularly dry weather observed in 2017 did not allow a good mineralisation of soil and mulch organic matter. The tillage absence in CNI and RC reduced even more the soil mineralisation. Now, the fertilisation of the cash crop at planting was determined based on the nitrogen availability in spring in the control BS modality, which was also the modality with the highest level of residual soil mineral nitrogen. This showed the clear effects of ASC termination strategies on nitrogen and crop yields. An alternative would have been to adjust the N fertilisation to the SMN observed before plantation under each management mode. (3) Competition due to barley self-sowing reduced cabbage growth.The destruction dates of CNI and RC should be earlier to avoid seed maturity and germination. Nitrogen uptake by barley seedlings may also have contributed to low N availability for the crop in CNI and RC modalities.

## CONCLUSIONS

Winter ASC can be profitable to reduce weed occurrence in spring crop. In our trial, under CNI and RC management strategies, the produced ASC biomass was sufficient to control weed development during cabbage season. Nevertheless, undesirable effects of ASC were observed in the cash crop growth period. Indeed, the choice of ASC's destruction and the timing of cash crop planting determine, in interaction with the weather conditions, the soil water and nitrogen availability for the cash crop. Key points to take into account are (1) the winter ASC biomass production enough, (2) the destruction of ASCs at the end of ASC vegetation stage but before the development of mature seeds, (3) the management between ASC destruction and cash crop planting to enable the recovering of soil water stock and (4) to adapt cash crop fertilisation to SMN availability before planting.

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# 6.2. ASSESSMENT OF DIFFERENT MEANS TO REDUCE THE POTENTIAL EXPOSURE TO PESTICIDES OF RESIDENTS LIVING IN THE VICINITY OF TREATED FIELDS

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**Keywords**: pesticides, resident exposure, drift reduction, fan nozzles, screen

## ABSTRACT
The use of pesticides is an undeniable reality in our countryside. However, there is an emergent collective commitment to improve and reduce their use, and to provide better guidance to pesticides users. Therefore a set of European Directives and Regulations (ex: Dir 2009/128/CE, Reg (CE) 1107/2009…) have been enforced and implemented in the Member States (MS). Recently the Walloon Government adopted a new Regional Decree (AGW 14 June 2018) that reinforces the protection of the residents to the pesticides, imposing 3 mandatory measures: use of 50% drift reduction nozzles, spray under wind of 20 km/h and spray at a minimum distance of 50 m from public spaces frequented by children (school, nurseries, recreation park…).
In 2018, a large study has been realised by three Walloon Research Institute (ISSEP, CRAW and ULg Agro-Bio Tech) to objectivise the exposure to pesticides of residents living near treated fields. This publication report the results of one part of the study concerning the efficacy of the mandatory measures and others that would be worth to support and implement. The use of anti-drift nozzles and the respect of a security distance from the non-target areas allow reducing significantly the potential exposure of the residents. The installation of a protective screen at the field border provide also a significant efficiency. Unfortunately, the data set of results were not sufficient to show a clear effect of the weather conditions on the potential exposure to pesticides of the residents.

## INTRODUCTION
When Plant Protection Products (PPPs) are sprayed, a part of the spraying solution may drift away from the target area. Following the weather conditions and the spray technics, 25 to 75%, even 90% of the sprayed pesticides is released in the air (van der Werf & Zimmer, 1998; Bedos *et al*., 2002; Ravier *et al.*, 2005; Jensen & Olesen, 2014). This spray drift that reaches areas outside the target field is either as droplets, dry particles or vapours. It leads to an undesirable exposure of the environment but also of the people living nearby, the by-standers, causing potentially a risk for their health (Siebers *et al.*, 2003; Houbraken *et al*, 2015; van den Zande *et al.*, 2018).
For that reason, different technics are developed to limit and decrease the spray drift. The study aimed at determining the efficiency of three means to mitigate de spray drift: the use of drift reducing nozzles, the use of a screen at the edge of the field and the weather conditions. This study was only a part of a larger research on the assessment of the exposure to pesticides of residents living near treated fields. This research was done in Wallonia by a consortium of the following research institutes: ISSEP, CRAW and ULg Agro-Bio Tech). For this part, only the sedimentary spray drift has been measured directly after the spraying by a horizontal hydraulic pressure sprayer.

## MATERIALS AND METHODS

### Description of the experimental site

The trials have been realised on a grassland of 2.40 ha. Therefore, the crop roughness to the wind may be considered as null. An artificial screen has been installed on half of the field to constitute two different zones: one protected from the prevailing winds and the other not. The screen was 2 m high and 50 m long. It consists into a double layer of net used usually in horticulture to protect the plant against insects (transparent HOWICOVER, 50 gr/m² from HOWITEC Netting). In this configuration, the screen has a porosity of 60% and reduces the wind speed by 21% on average.

### Description of the spray techniques

The sprayer used was a 24 m working width trailed boom sprayer (Tecnoma, Fortis) operated at 9 km $h^{-1}$ and applying 200 L $ha^{-1}$ at a boom height of 1 m. The spray drift measurements were performed making a comparison between three types of flat fan nozzles. Table 1 show the spraying parameters for the three nozzles types.

Table 1. Characteristics of the three nozzles types and spraying parameters

| Nozzle | Brand | Type | Size | Drift reduction (%) | Applied volume (L $ha^{-1}$) | Forward speed (km $h^{-1}$) | Spraying Pressure (bars) |
|---|---|---|---|---|---|---|---|
| 1 | Nozal | Conventional flat fan | 110 04 | 0 % | 200 | 9 | 2.7 |
| 2 | Nozal | Air induction flat fan | 120 04 | 50 % | 200 | 9 | 2.7 |
| 3 | Albuz | Air induction flat fan | 110 04 | 75 % | 200 | 9 | 2.7 |

The spray liquid was tap water with added fluorescent dye (Tartrazine, DOUCY®, 15 gr $L^{-1}$) and non-ionic surfactant (Trend 90; 0.1 %) in accordance with the methodology developed by van de Zande *et al*. (2018). The dye was chosen for its non-toxicity and the possibility to extract and analyse easily the deposit by colorimetry (Gil *et al.*, 2015).

### Spray drift collector layout

Two collectors (Miracloth, CALBIOCHEM®) of 0.15 m × 0.40 m were positioned side by side on a rigid support to obtain a collecting surface of 1200 cm². Following the standard ISO 22866 (2005), the collector should reach at least a surface of 1000 cm².
A triple line of collectors was laid out at 2 m spacing between the lines and positioned at a distance of 0.5 m, 2.5 m, 7.5 m, 10 m, 15 m, 25 m, 35 m and 50 m from the field border that correspond to the screen axis. Two such collecting devices were placed downstream of the prevailing winds; the first being protected by the screen and the second not.
The sprayer applied the liquid in the upper zone from the collecting devices; the last nozzle being at 1 m from the field border. The sprayer makes two passages on a distance of 100 m, spraying consecutively the collecting devices protected or not by the screen.
The weather conditions (wind: speed and direction, air: temperature and relative humidity) were measured and registered during the whole trials by a mobile station.

### Spray drift deposition analysis

After spraying, the collectors were removed, put separately in plastic bags, coded and collected for further analysis of the spray drift deposition. Moreover, samples of the spray liquid were taken from a spraying nozzle, to determine the actual concentration of the dye for each spraying.

Extract were analysed by colorimetry (NANOCOLOR ®500D, wavelength: excitation 436 nm). For determination of the background dye signal, series of blank collectors were analysed following the same protocol. The detection limit was defined as 3 times the STD of the average response of the blank collectors.

The measured dye concentration in the extract was used to calculate the amount of spray volume per unit area. The percentage of spray drift was calculated by expressing the spray drift deposition per unit area as percentage of the applied spray volume in the field per unit area.

Three modalities were tested: screen (presence or not), nozzles types (drift reduction potential of 0%, 50% and 75%), weather conditions (spraying early morning and later in the afternoon. A total of six sprayings were performed (three in the morning and three in the afternoon) and 648 samples were analysed.

## RESULTS AND DISCUSSION

### Efficiency of the drift reduction nozzles

Table 2 and Figure 1 show the global results of the spray drift following the three tested nozzles types (0 %, 50 % and 75 % drift reduction). Each value is the average of 24 data including the modalities: screen and weather conditions. This globalisation affects the variability of the results. This confirms the works of Nuyttens (2007) who demonstrated that the drift may variate by ten regarding the weather conditions during the spraying.

Table 2. Average drift (%) and STD regarding the distance (m) and following the tested nozzles types

| Distance (m) | Average drift (%) ± STD | | |
|---|---|---|---|
| | Nozzle 1 (0%) | Nozzle 2 (50%) | Nozzle 3 (75%) |
| 0.5 | 4.42 ± 3.01 | 2.54 ± 2.67 | 1.05 ± 0.97 |
| 2.5 | 1.56 ± 1.03 | 0.71 ± 0.64 | 0.45 ± 0.33 |
| 5 | 0.76 ± *0.55* | 0.36 ± 0.33 | 0.35 ± 0.24 |
| 7.5 | 0.58 ± 0.46 | 0.30 ± 0.21 | 0.27 ± 0.24 |
| 10 | 0.45 ± 0.33 | 0.22 ± 0.17 | 0.25 ± 0.27 |
| 15 | 0.30 ± 0.20 | 0.12 ± 0.12 | 0.20 ± 0.15 |
| 25 | 0.22 ± 0.18 | 0.10 ± 0.11 | 0.26 ± 0.51 |
| 35 | 0.19 ± 0.11 | 0.10 ± 0.11 | 0.14 ± 0.15 |
| 50 | 0.18 ± 0.11 | 0.14 ± 0.08 | 0.10 ± 0.08 |

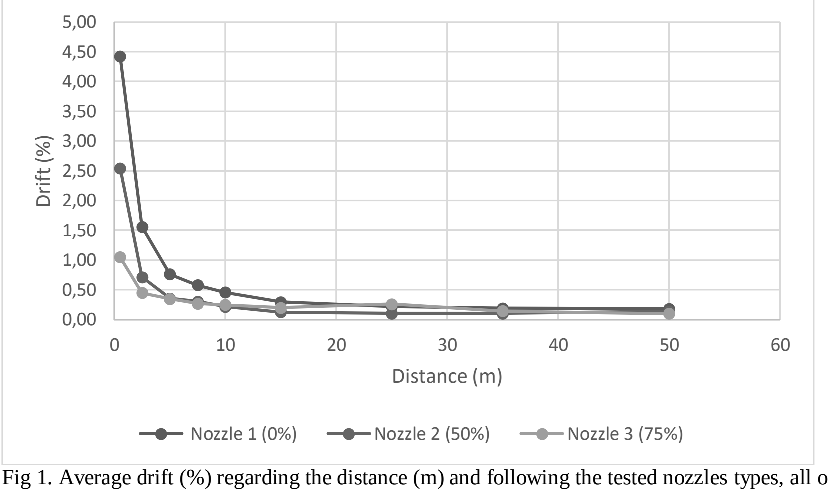

Fig 1. Average drift (%) regarding the distance (m) and following the tested nozzles types, all other modalities being globalised

The use of anti-drift nozzles reduces significantly the direct spray drift deposition and mainly within the first 10 m next to the sprayed area. After, the drift remains always under 0.5 %. Till the distance of 10 m, the analysis of the variance shows that the average results of the anti-drift nozzles (50% and 75 % drift reduction) are significantly different from the ones of conventional nozzles (0% drift reduction). On average, the results show that the 50% drift reduction nozzle reduce by two the drift and the 75% nozzles reduce it by three.

**Efficiency of the screen**

Table 3 and Figure 2 show the global results of the spray drift regarding the presence of a screen or not. Each value is the average of 36 data including the modalities: nozzles types and weather conditions.

Table 3. Average drift (%) and STD regarding the distance (m) and following the presence of a screen or not

| Distance (m) | Average drift (%) ± STD | |
|---|---|---|
| | With screen | Without screen |
| 0.5 | 2.40 ± 2.26 | 2.95 ± 3.14 |
| 2.5 | 0.74 ± 0.70 | 1.07 ± 0.98 |
| 5 | 0.39 ± 0.32 | 0.59 ± 0.51 |
| 7.5 | 0.28 ± 0.30 | 0.48 ± 0.37 |
| 10 | 0.25 ± 0.25 | 0.36 ± 0.30 |
| 15 | 0.17 ± 0.14 | 0.25 ± 0.19 |
| 25 | 0.16 ± 0.17 | 0.23 ± 0.43 |
| 35 | 0.13 ± 0.11 | 0.16 ± 0.14 |
| 50 | 0.16 ± 0.10 | 0.12 ± 0.10 |

Although low, the studied screen has an impact on the spray drift deposition. The effect is clearly significant up to 10 m. After, even on a statistical point of view, the modalities with or without screen are significantly different, this effect is not more perceptible in practice.

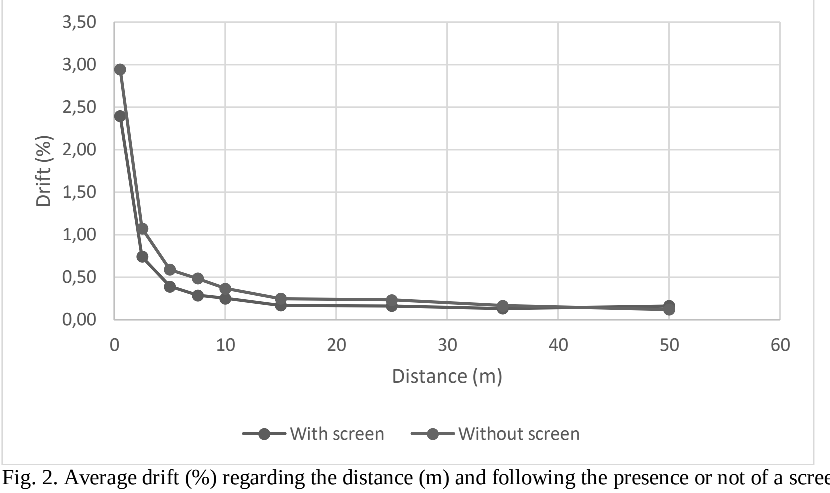

Fig. 2. Average drift (%) regarding the distance (m) and following the presence or not of a screen, all other modalities being globalised

Table 4 shows the cumulative spray drift regarding the presence or not of a screen, for all trials, for trials realised in the morning and those realised in the afternoon. The average impact of the studied screen on the spray drift reaches ± 25 % (values into brackets).

Table 4. Cumulative spray drift regarding the presence or not of a screen, for all trials, for trials realised in the morning and those realised in the afternoon

| Cumulative spray drift (%) | With screen | Without screen |
|---|---|---|
| Morning and afternoon | 168.41 (25 %) | 223.51 |
| Morning | 136.42 (24 %) | 179.33 |
| afternoon | 31.99 (28 %) | 44.18 |

**Effect of the weather conditions**

Concerning the weather conditions, it was not possible to correlate and establish a clear relationship between the studied weather factors (wind speed, air temperature and humidity) and the spray drift. However, the spray drift depositions observed during the morning are clearly different from the afternoon. The observed drift was five times higher during the morning than the afternoon. It emphasis the crucial impact of the weather condition on the spray drift. Taking into account the versatile character of the weather, it is always difficult to advice to spray at a precise moment in the day. Nevertheless, Good Agricultural Practices agree to advise to spray early in the morning or in the evening, when weather conditions tend to calm down. This general practice is common sense.

## CONCLUSIONS

The study is focussed on the spray drift, part ground deposit, which is defined as the physical movement of droplets in the air, during the spray or directly after, from the sprayed zone to all other next zones that are not targeted. Therefore, the conclusions concern only this « direct » drift.

The field trials show the predominant influence on the spray drift of the weather conditions, the use of anti-drift nozzles and to a lesser extent the use of a screen.

The same trials have been repeated the morning and the afternoon in order to generate different weather conditions. The spray drift was 5 times lower the afternoon than the morning. This result contradicts the conventional good practices, but it is difficult to give explanations and conclusions based on so few trials. On the other hand, the weather conditions have a clear impact on the drift and the best spraying timing is crucial.

The use of anti-drift nozzles reduces significantly the spray drift and principally within the first 10 m next to the sprayed area. The 50% nozzles reduce by two the drift and the 75% nozzles by three.

The use of a screen reduces also the spray drift, but in a lesser extent. For the conditions of the trials and the studied screen, the average reduction of the drift was around 25 % under any other modalities (nozzles types and weather conditions). Complementary studies with other screens would be necessary to validate these positive results and to define practically the efficiency of natural and artificial screens.

Finally, the trials show the high variability of the spray drift regarding the different modalities and studied conditions. One may notice that the spray drift obtained for the most favourable conditions was 20 times lower than the one obtain for the less favourable conditions.

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## 6.3. THE SUSCEPTIBILITY OF SUGAR BEET VARIETIES TO THE PRESENCE OF SPIDER MITES (ACARI: TETRANYCHIDAE) IN RELATIONSHIP TO ENVIRONMENTAL CONDITIONS

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**Keywords:** sugar beet, spider mite, yield, acaricides, integrated control

## ABSTRACT
This paper presents the results of research on the presence of spider mites (*Tetranychus urticae* Koch) on four varieties of sugar beet: Janusz, Panorama, Silezja and Marynia. The study included the effect of mite feeding on yield, sugar content in roots and molasses. The aim of the study was to assess the suitability of selected acaricides used in fruit crops for the control of sugar beet spider mite. The largest yield of sugar beet (1026mg · $ha^{-1}$) was obtained for the Panorama variety. In the years 2015-2016 the earliest spider mite was found on the Janusz variety, and the latest on the Panorama variety. The lowest spider mite activity was monitored on the Silesja variety. No significant differences were between the control and the acaricides Envidor 240 SC and Vertimek 018 EC in 2016. In the applied formulations, 50 to 80% spider mite mortality was achieved. In the years 2017-2018 the earliest spider mite was seen in Panorama, and the latest in Marynia. Due to the low pressure of spider mites on monitored plots no chemicals were used.

## INTRODUCTION

Spider mites (Acari: Tetranychidae) are an important group of pests that until recently were associated with damage in greenhouses or on ground vegetables. However, for several years they have been observed with increasing frequency on sugar beet plantations (Fiedler *et al.* 2013, Jakubowska 2014, Jakubowska and Fiedler 2014). The spider mite (*Tetranychus urticae* Koch) is a poligraphic pest of various arable crops (Naher *et al.* 2006). Recently they have also been a problem for different field crops, especially sugar beets. They cause early yellowing and drying of the leaves which negatively affects the growth and yield of the plants. Photosynthesis is disrupted, followed by limited nutrients, stunted plant growth and development as well as lower sugar quality in the leaves and roots. In Poland's climate there may be four to six generations of spider mites during the growing season. With favourable temperatures (25–30°C), which often occur in late spring and summer, the time for one generation to develop is shortened to 10 or even 8 days (Jakubowska *et al.* 2017, 2018).

Damage done by spider mites is initially observed along the edges of fields. With time it spreads across the entire crop. The mites feed on both sides of the leaves. On the lower side delicate "cobwebs" with varying stages of spider mite development appear. On the leaves' upper side, as a result of intensive feeding, small, light spots appear, creating a so-called mosaic. Very often these symptoms are not considered to be serious and mistakenly are thought to be caused by viruses, nematodes or drought. Increased numbers of spider mites and further feeding deforms the leaves and spider webs cover the apical part of the plant. The drop in root yield due to the intensive feeding of the spider mites can range from 20 to 50% and the sugar content of the beet roots can be lowered by as much as 2% (Legrand *et al.* 2000, Fiedler & Jakubowska 2015, Ulatowska *et al.* 2015). Currently in Poland there is one registered acaricide to control spider mites in sugar beets (Ortus 05 SC – active substance phenpyroximate). It belongs to the phenoxypyran group and fights all mobile stages of spider mites. However, it does not entirely meet the expectations of producers in protecting sugar beets from spider mites. For several years the Institute of Plant Protection – PIB, together with Pfeifer & Langen Company have been researching the effectiveness of selected acaricides in controlling this pest in sugar beets.

The aim of this study was to determine the direct impact of spider mites on sugar beet yields and to assess the effectiveness of selected acaricides in controlling spider mites on plantations with four varieties of sugar beets.

## MATERIALS AND METHODS

Field experiments were carried out in 2015-2016 and 2017-2018 on sugar beet plantations of the COBORU experimental station in Słupia Wielka (52°13’02”N, 17°13’04”E) on four varieties: Janusz, Panorama, Silezja and Marynia. The mean monthly air temperature during the growing period from April to October (2015-2018) was 16.9℃, and total rain fall was 221.2 and 470.9 mm (Tab. 1).

Table 1. Monthly rainfall and average daily temperature sums in vegetation period during 2015-2018, Słupia Wielka

| Years | Months | | | | | | | Sum /Mean (IV-X) |
|---|---|---|---|---|---|---|---|---|
| | IV | V | VI | VII | VIII | IX | X | |
| Rainfall (mm) | | | | | | | | |
| 2015-2018 | 37,8 | 29,2 | 64,4 | 115,9 | 41,4 | 34,7 | 52,9 | 376,3 |
| 2010-2018 | 40,5 | 45,0 | 64,7 | 105,9 | 57,8 | 45,9 | 50,9 | 410,7 |
| Monthly average temperature (ºC) | | | | | | | | |
| 2010-2018 | 10,1 | 15,2 | 18,3 | 20,1 | 20,1 | 14,6 | 8,0 | 15,2 |

The study was carried out on humus-type soil formed on light loamy sand. Rapeseed was a forecrop in 2014 and winter wheat in 2015. Soil characteristics were as follows: in 2016 P – 22.4 kg $ha^{-1}$, Mg – 3.8 kg $\cdot ha^{-1}$, K – 21.7 kg $\cdot ha^{-1}$, pH 6.3 (in KCl $mol \cdot dm^{-3}$); in 2015 P – 38.8 $kg \cdot ha^{-1}$, Mg – 5.1 $kg \cdot ha^{-1}$, K – 18.8 $kg \cdot ha^{-1}$, pH 6,4 (in KCl $mol \cdot dm^{-3}$). During the 4 year study only one fertilizer was used, namely: N – 121 kg $\cdot ha^{-1}$, P – 96 kg $\cdot ha^{-1}$, K – 208 kg $\cdot ha^{-1}$, Mg – 26 kg $ha^{-1}$ as well as organic fertilizer (compost) (2014 – 80 $dt \cdot ha^{-1}$; 2015 – 200 $dt \cdot ha^{-1}$). Four replications were carried out. Using long rows, plots for harvesting were 10.8 $m^2$. Throughout the entire growing seasons the sugar beets were systematically monitored for pests. The spider mites were counted immediately before spraying, and then 4-5 times following the treatment, at 1-2 week intervals. The spider mites were counted on 25-30 randomly picked leaves of each variety. The number of spider mites was determined according to Henderson and McBurn (1943). The effectiveness of pest control agents in protecting sugar beets from being consumed by spider mites was carried out by determining the number of pests on protected and control (with no protective treatment) plants before treatment and 2, 6 and 14 days after each treatment. The following acaricides variants were applied:

- Magus 200 SC (fenazachin), at a dose of 0.9 l/h,
- Karate Zeon 050 CS (lambda-cyhalotryna), at a dose of 0.2-0.3 l/ha,
- Ortus 05 SC+ Nissorun 050 EC, at a dose of 0.5 l/ha and 0.75 l/ha,
- Vertimec 018 EC (abamektyna), at a dose of 0.05l/ha,
- Envidor 240 SC (spirodiklofen), at a dose of 0.4 l/ha,
- Control – no treatment.

The sugar and molasses contents were determined in the SHR Straszków laboratory on an automatic processing line. During harvest, the sugar beet root yield (Mg ha-1) was determined and the sugar content (%) was measured, as well as the molasses content in beet roots directly during harvest. The results were analysed statistically. One way analysis of variance (ANOVA) was done independently of the aim to verify the hypothesis that the individual years and the acaricide had no impact on the root mass, sugar content and potassium, sodium and nitrogen in the roots. For the years of the experiment and the preparations used the mean values and standard deviations of the coefficients of particular root yield values were estimated. The correlation between the values of molasses and sugar content in sugar beet roots and the mass of roots was assessed on the basis of appropriate correlation coefficients. All statistical analyses were performed using the Gen Stat 17 statistical package.

## RESULTS AND DISCUSSION

In 2015-2016 the spider mites were seen the earliest on the Janusz variety (15 June), and the latest on Panorama (13 July). The least number of spider mites in both 2015 and 2016 were seen on the Silezja variety. In 2017 the first spider mite eggs were found on the Marynia variety – 15 June. The spider mites on beet leaves were the most numerous from 20 July to 20 August. Since the weather in 2018 was not conducive to the development of spider mites, they were seen on the experimental plots at the beginning of September. Spider mites on individual varieties impacted the sugar beet crop. Since the pest was observed the latest on Panorama, this variety had the largest crop, greater than even the reference variety – 1020 $dt \cdot ha^{-1}$. On the Silezja variety, where the number of spider web mites during the vegetative season was not more than a mean of 20 for the separate developmental stages, the crop in every year was on the same level as the reference variety - 700 $dt \cdot ha^{-1}$ in 2015 and 900 $dt \cdot ha^{-1}$ in 2016 (Fig. 1).

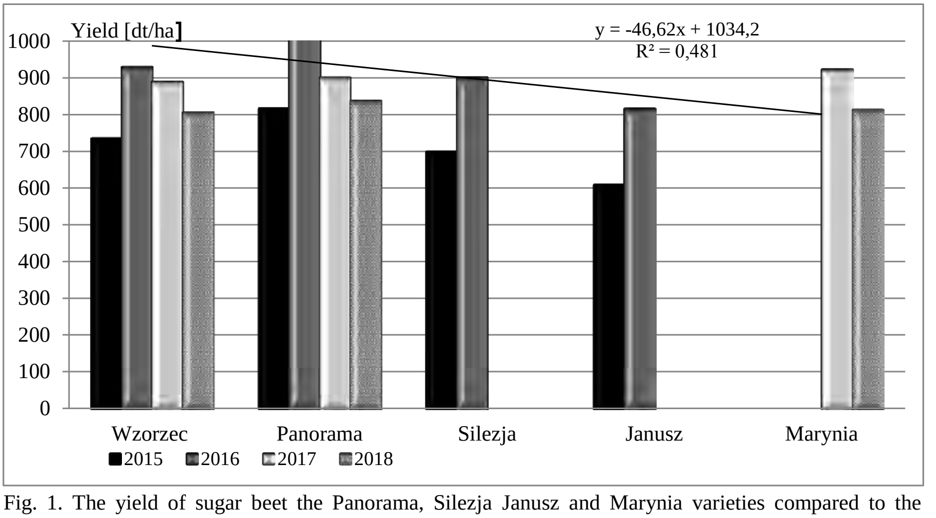


Fig. 1. The yield of sugar beet the Panorama, Silezja Janusz and Marynia varieties compared to the reference variety (Wzorzec) in the years 2015-2018, Słupia Wielka

The variety Janusz was the most susceptible to spider web mites. Each year of the research its yield was about 20% less than both the reference variety and the other varieties being studied. In relation to this, additional analyses on the sugar value in the roots and molasses were carried out. The relationship between some crop traits and root crop mass and the technological sugar yield of the Janusz variety, and in 2017-2018, in the Marynia variety were analysed. Root mass (root crop) correlated positively (r = 0.5762) with sodium (Tab. 2, Fig. 2). However, α-amino nitrogen correlated positively with sugar content (r = 0.6303) and potassium (r = 0.8232) (Tab. 2, Fig.2).

Table 2. Qualitative analysis - yield, polarization, molasses forming in roots of sugar beet varieties Janusz in Słupia Wielka in 2015-2016

| Source of variation | Degrees of freedom | Root weight [kg] | Polarization [%] | Potassium [K] | Sodium [Na] | Nitrogen [N] |
|---|---|---|---|---|---|---|
| Year | 1 | 547,43*** | 119,10*** | 9424,81*** | 25,37521*** | 1065,03*** |
| Formulations | 5 | 22,19 | 0,1475 | 15,7 | 0,01171 | 3,5 |
| Year x Formulations | 5 | 19,84 | 0,1595 | 16,57 | 0,01471 | 18,05 |
| Error | 36 | 15,06 | 0,1546 | 16,48 | 0,07715 | 22,13 |
| *** p<0,001 | | | | | | |

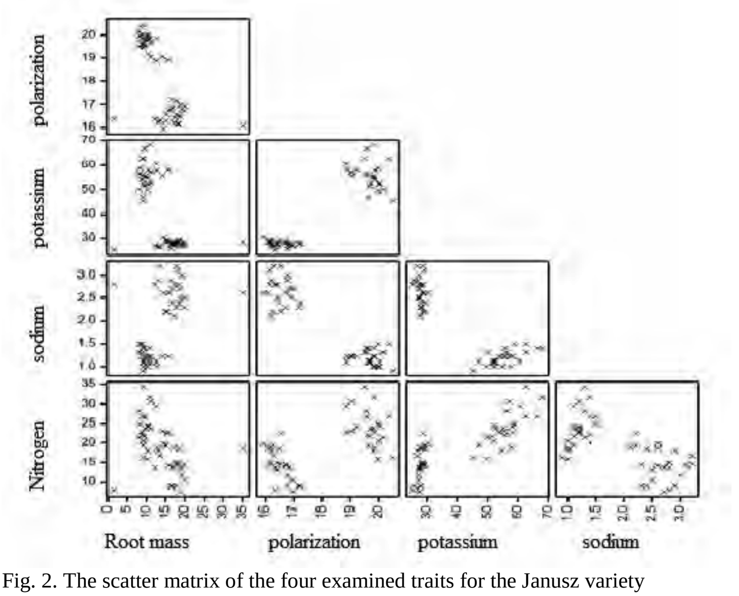


Fig. 2. The scatter matrix of the four examined traits for the Janusz variety

For the Marynia variety, it was observed that the root mass was significantly positive (r = 0.2333) correlated with the percentage of sugar (polarization) (Table 3, Fig. 3). In contrast, α-amino nitrogen was significantly positively correlated with: sodium (r = 0.966) and potassium (r = 0.962), and sodium was significantly positively correlated with potassium (r = 0.933) (Table 3, Fig. 3). Palmer and Casburn (1985) also found a similar positive correlation between sugar content and α-amino nitrogen. A statistically significant negative interdependence was observed between root mass and sugar content, root mass and potassium, root mass and nitrogen, sugar content and sodium, potassium and sodium (Tab. 2, Fig. 2). It is worth noting that for some pairs of traits there is a dual distribution of interdependence (Fig. 3).

Table 3. Qualitative analysis - yield, polarization, molasses forming in roots of sugar beet varieties Marynia in Słupia Wielka in 2017-2018

| Source of variation | Degrees of freedom | Root weight [kg] | Polarization [%] | Potassium [K] | Sodium [Na] | Nitrogen [N] |
|---|---|---|---|---|---|---|
| Year | 1 | 26,181 | 33.15*** | 3594.9*** | 329.2*** | 9146.6*** |
| Error | 46 | 7,441 | 0,122 | 8,517 | 0,1947 | 7,174 |
| *** P<0.001 | | | | | | |

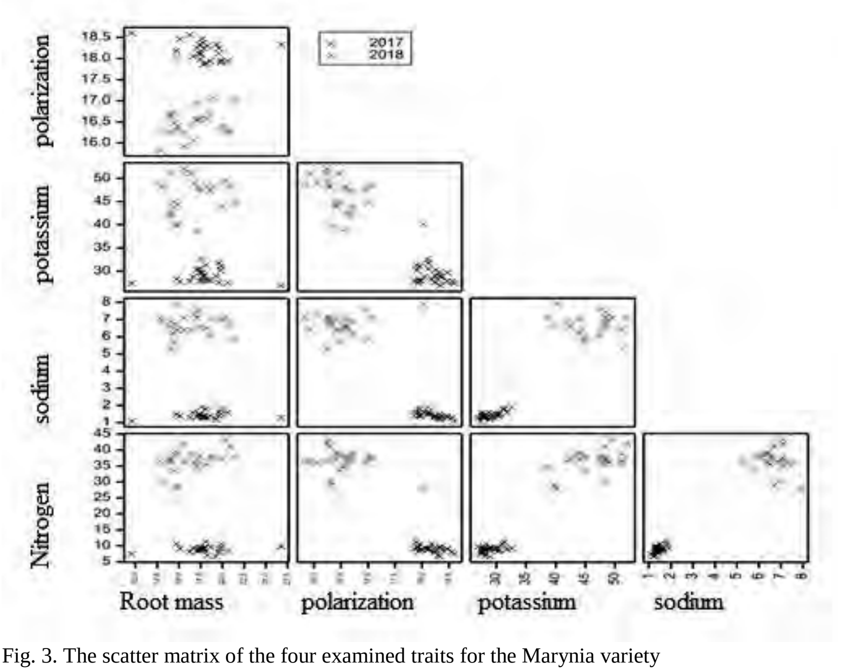


Fig. 3. The scatter matrix of the four examined traits for the Marynia variety

Beet production and its technological value are clearly affected by the weather and above all by the amount and frequency of rain. In terms of yield the least favourable conditions were in 2015 and the most favourable, in 2016. For sugar concentration and its energy requirements the most favourable vegetative conditions occurred in 2015. The long vegetative period and little rain in August and September contributed to a high accumulation of sugar in that year. Märländer (1991) is of the opinion that the location and climatic conditions have a greater affect than agrotechnical factors. Weather conditions (very high temperatures and no rainfall) which dominated in 2015 were very conducive for spider mite development.

## CONCLUSIONS

Research confirms that the use of tolerant varieties that are less susceptible to a given pest is very important. Such varieties have a defence mechanism against pests which guarantees undisturbed growth and high yields even when there is high pest pressure. Many examples can be found that show how important the choice of variety is for the occurrence of pests and the damage they incur (Ismail 2002, El-Rawy et al. 2011). Tolerant varieties are the easiest way to combat potential losses due to diseases and pests which are difficult to fight with traditional methods. In the case of spider mites the greatest problem currently is the lack of available chemical products to fight them on sugar beet plantations. Therefore, the use of sugar beets which are less susceptible to the presence and feeding of spider mites would be a good alternative especially in regions where this pest may pose a serious threat.

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# 6.4. HAZARDS AND PREVENTION METHODS IN JUICE PRODUCTION ON SMALL FARMS

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**Keywords:** hazards, juice production, small farms, sustainable agriculture

## ABSTRACT
This paper discusses the hazards during the production of fruit juices on small farms. They were identified in three categories: physical, chemical and biological. In addition, methods for reducing or eliminating these hazards at individual stages of juice production are provided. Small farms, due to obtaining raw material from their own crops, can effectively eliminate most of the hazards and ensure that a final product of high quality and low risk of contamination is obtained.

## INTRODUCTION

Product safety should be one of the most important criteria when placing food on the market, therefore raw materials and food products must not pose a danger to those who eat them. This is particularly important in plant production where more and more fertilizers, protective agents and other chemicals are used.

One of the ways to improve food safety is to apply the principles of sustainable agriculture. Agri-environment-climate measures taken as part of sustainable agriculture are aimed at obtaining healthy and high-quality food while ensuring environmental protection.

The protection and promotion of regional and traditional products is one of the most important factors supporting the sustainable development of rural areas because it increases the income of agricultural producers, prevents depopulation and increases the attractiveness of rural areas (Wilczyński *et al.*, 2019).

Production of natural juices (NFC - not from concentrate) with a low degree of processing can be one of the ways to increase profitability in small farms (Kobus *et al.,* 2018). Such juices are characterized by a high content of pro-health compounds such as polyphenols, flavonoids, vitamins and dietary fibre.

The process of fruit juices production should be characterized by a high efficiency, and result in the final product with a high content of soluble solids, low acidity and a high content of health promoting components. To meet these requirements, new methods of raw material pre-treatment, such as freezing and thawing of the pulp, or new types of presses, including screw presses are used (Nadulski *et al.,* 2015, Nadulski *et al.,* 2016, Kobus *et al.,* 2018).

Nowadays, juice producers, especially those operating on a small scale (orchardists, local entrepreneurs), in addition to stationary sets, can use mobile fruit juice production lines. In both cases the juice processing, like any kind of food production, requires meeting specific hygiene and health safety requirements.

Hence, the purpose of the work is to discuss the threats and methods of hazard prevention during the production of fruit juices.

## HAZARDS IN JUICE PRODUCTION

Hazards in juice production are identified in three categories: physical, chemical and biological.

**Physical hazards**

Physical hazards include any potentially harmful extraneous matter not normally found in food. Sources of physical hazards include:

- parts of equipment and installation,
- personnel: jewellery items, hair, nails,
- raw materials: sand, stones, skins, pips,
- packaging processing aids: plastic, glass, pieces of wood, metal.

**Chemical hazard**

Chemical hazards are any chemical contaminants or naturally occurring substances in food that can cause harm to human health. Chemical hazards are divided into following groups (Gasik *et al.*, 2012):

- naturally occurring in food: amygdalin seeds and fruit stones,
- environmental - introduced into food during cultivation (pesticides, fungicides, insecticides), toxic metals,
- technological - added to products in the technological process, e.g. sorbic acid (E200), sodium sorbate (E201), dyes, sweeteners,
- technical - chemical substances from machines and devices (e.g. lubricants, fuels, washing and disinfecting agents, paints, solvents).

Pesticides are among the most dangerous compounds that pose chemical hazards. Pesticides are widely applied during agrotechnical treatments to control weeds, insects, and diseases. As a consequence, residues of these substances can be found in food, thus constituting a potential risk for human health, considering their toxicity and the exposure to these compounds. The pesticide residues tend to deposit on the fruit peels and transfer from peels into pulps and juices in long-term processes and pose some risk to human health (Bates *et al.*, 2001).

In 2009, 21 different pesticides were found in 655 samples of orange juice from different countries in the EU. The most frequent pesticides were carbendazim and benomyl, followed by imazalil and thiabendazole. No maximum residue level (MRL) exceedances were reported (EFSA 2011, Marin and Ramos 2014).

Preservatives are practically not used in the production of natural cloudy juices. The only exception is ascorbic acid, which is used to prevent enzymatic browning of the juice.

**Microbiological hazard**

According to the definition of the International Commission on Microbiological Specifications for Foods (ICMSF), microbial hazard is the presence of microorganisms in food that could cause its deterioration or the production and persistence of toxins, enzymes, biogenic amines or their metabolism products. Contamination of raw materials or finished products with pathogenic microorganisms is difficult to detect because it is invisible and does not cause organoleptic changes. Thus, it is hard to recognize by the consumer. Microbiological hazards include the following: viruses, bacterial pathogens, parasites and microbial toxins.

Among the microorganisms that contaminate plant materials, we can find, above all the family bacteria Enterobacteriaceae (Salmonella enterica and S. bongori), Bacillus, Clostridium Listeria (Marin & Ramos 2014).

Orange juice, apple juice, and apple cider were usually involved, while the infectious agents were Salmonella, Escherichia coli and Cryptosporidium (Bates et al., 2001). In most cases the outbreaks were caused by the consumption of unpasteurized juices (Vojdani *et al.,* 2008).

Fruits can be contaminated with Escherichia coli when grown in fields, during harvesting, or during processing. Most cases of Salmonella and Escherichia coli contamination are caused by the consumption of fresh unpasteurized juices. Acidic pH below 4.6 protects against reproduction of Escherichia coli (Presser *et al.,* 1997).

Among the most common parasites are: human whipworm and human roundworm. Cryptosporidium parvum is a highly infectious protozoan parasite that causes persistent diarrhea (Keller & Miller 2006). The reason for this threat is the producers' failure to comply with the prohibition on using fertilizers and sewage.

Mycotoxins are metabolites which are metabolic products of mold, especially of the genera Aspergillus, Penicillium and Fusarium. In Polish climatic conditions, the presence of ochratoxin A and patulin is of particular importance.

Patulin is a mycotoxin produced by molds Penicillium (claviforme, expansum, patulum), Aspergillus (clavatus, terreus), Byssochlamys (fulva, Nice) and Paecilomyces variotii. Patulin is a major threat to fruit juices and especially apple juice. From 7820 apple juice samples collected in the EU, 60% contained detectable amounts of patulin, with a mean level of 15.6 μg/kg, while in 551 samples of other fruit juices, 26% of samples were found to be positive, with a mean level of 11.3 μg/kg (Marin & Ramos 2014).

## WAYS TO PREVENT HAZARDS

*At the raw material stage*

Raw materials are the main source of physical, chemical and biological hazards in the final juice product. Particular attention should be paid to the use of manure as a fertilizer; the use of fruit contaminated by insects, birds and other animals. Checking for exclusion of damaged, wormy or rotten fruit is required. This step will reduce the initial microbial load. The raw material should be inspected for stones, glass, metal and wood contamination. Physical hazards will be reduced at this stage.

The most difficult issue is to eliminate chemical hazards. In the production of fruit and vegetables, the main source of chemical hazards are agrotechnical treatments related to plant care (spraying) and fertilization. An additional danger arises from the accumulation of heavy metals from the soil.

Some hazards can be eliminated by following good agricultural and hygienic practice (Sałata 2014). Monitoring of their residues is used to reduce the risk associated with the application of fertilizers and pesticides.

The obligation to use integrated plant protection from 1 January 2014 has a very significant impact on the reduction of residues in plant products. The obligation include (DPER 2009):

- monitoring harmful organisms,
- preferring non-chemical methods to chemical methods,
- limiting the use of pesticides to the necessary minimum,
- using strategies that counteract the development of organism resistance to a given preparation.

In summary, all raw materials prior to processing should be clearly identified and checked for risks to consumer safety. If there are any doubts, laboratory tests should be carried out.

*Cleaning and washing fruit*
Fruit cleaning and washing is the next stage at which some physical and biological hazards can be removed. Washing the raw material in chlorinated water or the use of other disinfectants is crucial to reduce the microbial load (Bates *et al.*, 2001). Seymour and Appleton (2001) recommended chlorination to inactivate Norwalk viruses (10 mg / L) and hepatitis A (5 mg/L), and concluded that ozone is an effective antiviral agent. Chlorine and other disinfectants reduce populations of bacterial cells exposed to the product surface by up to 2 or 3 log10 units.

*Juicing*
Presses, tanks and pipelines can become a source of secondary juice contamination. To reduce the risk of juice contamination during the pressing process, the following actions should be taken:

– use equipment made of corrosion-resistant materials (stainless steels),
– the design of the presses should enable them to be kept in good technical condition and to efficiently wash and disinfect,
– cleaning and disinfection have to take place at the appropriate frequency and ensure that the equipment is completely emptied and flushed,
– presses should be installed in places where dust and dirt do not accumulate and arranged in a way that allows maintaining cleanliness around them and the surrounding area,
– lubricants for processing equipment must be food grade.

*Inactivation processes of microorganisms*
Raw juice deteriorates quickly due to enzymes and microorganisms. Over the years, preserving fruit juices has mainly consisted of pasteurization, maintaining low pH levels, cooling and adding preservatives. Often, two or three of these methods were required to ensure the stability of finished fruit juices (Tribst *et al.,* 2009). It should be remembered that the pasteurization process inactivates not only microbes but also affects biologically active substances and rheological properties of juices (Kobus *et al.,* 2015).

To avoid or minimize the negative effect of pasteurization and prevent the use of preservatives, scientists turned their research to finding preserving techniques that are able to ensure the safety of the juice. To eliminate severe degradation of the nutritional and sensory aspects of the juices, several non-thermal methods have been tested, such as ultrasound (Nadulski *et al.*, 2019), high pressure processing (HHP), ultraviolet light (UV), pulsed electric fields (PEF), electron beam irradiation and processing at using high carbon dioxide (Marin & Ramos 2014).

Still, due to its effectiveness and low operating costs, pasteurization remains the basic way of preserving fruit juices. During juice preservation, the pasteurization time and temperature should be strictly observed. Regularly check the technical condition of the temperature sensors. In addition, hygiene requirements for cleaning and washing the pasteurizer must be strictly observed.

*Packaging*

One of the most commonly used methods of filling is aseptic processing. This method of filling gives the highest quality product. It should be prevented sterilized packaging from contamination. Cross-contamination can occur through direct or indirect contact with raw materials, ingredients, primary packaging, equipment, environment and personnel.

## CONCLUSIONS

During the production of fruit juice in small farms, there are typical types of threats like in the case of industrial production. They were identified in three categories, physical, chemical and biological hazards. The most important physical hazards include: parts of equipment and installation, sand, stones, skins, pips, plastic, glass, pieces of wood and metal. Chemical hazards can be divided into following groups: naturally occurring in food (e.g., amygdalin), environmental (e.g. pesticides, fungicides, insecticides, toxic metals), technological - added to products in the technological process (e.g. sorbic acid, sodium sorbate, dyes, sweeteners) and technical (e.g. lubricants, fuels, washing and disinfecting agents, paints, solvents). Microbiological hazards involve the following: viruses, bacterial pathogens, parasites and microbial toxins.

The process of threats elimination begins at the raw material stage. Small farms have a greater chance than large juice producers to significantly reduce chemical hazards due to obtaining fruit from their own production. Adherence to the principles of good manufacturing practice allows to reduce or completely eliminate hazards also at the stage of washing, pressing, pasteurizing and bottling juices.

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# 6.5. EVALUATION OF HYGIENE CONDITIONS DURING MILKING AND MILK PROCESSING AT THE FARM LEVEL

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**Keywords**: farm, milk production, hygienic conditions, quality

## ABSTRACT
The research was carried out on a low-input farm located in the Bieszczady Mountains. Simmental cows were kept on the farm in a tie-stall barn with litter. Hygiene conditions during milking and traditional processing of milk into rennet cheese were visually assessed. Microbiological assessment of the facilities and equipment used to store the raw milk and for cheese production was carried out as well, specifying the total bacterial count, number of yeasts and moulds, and the quality of the water used on the farm. The hygiene conditions on the farm were shown to be unsatisfactory, which was confirmed by the results of the microbiological tests. The bacteria and the moulds and yeasts on the surfaces of equipment used for milk collection and cheese making were too numerous to count, which indicated a lack of hygiene on the farm. It is important to note that the water quality satisfied legal requirements.

## INTRODUCTION

Appropriate product quality and health safety are fundamental to a company's activity in the food sector. The primary producer, as the first link determining the safety of food entering the market, is an important player throughout the food chain. Food hazards and factors that negatively affect food quality arise at the stages of production, processing and distribution (Król *et al.*, 2017). The main food hazards are biological factors, in particular pathogenic microbes, chemical factors, and physical factors (Kołożyn-Krajewska & Sikora, 2010). Health hazards in food may thus be the result of contamination of the raw material, improper implementation of the technological process, the surrounding environment (unsatisfactory condition of machines, production halls, or surfaces in contact with food), poor water and air quality, or lack of proper hygiene (Król *et al*. 2016). It is therefore crucial to begin supervision with the production of agricultural raw materials. During food production, the farm owner is required to meet certain conditions and take the necessary measures to ensure food safety and hygiene. This goal can only be met by implementing a structured procedure based on good practices. These practices guarantee that food is produced according to specific rules, requirements, standards and conditions. In agriculture, these are Good Agricultural Practices (GAP), which are the basis of primary production (Król *et al.*, 2017). At the processing stage, Good Hygiene Practices (GHP) and Good Manufacturing Practice (GMP) apply (Litwińczuk *et al.*, 2016). Compliance is particularly important for production of perishable food, including foods of animal origin, such as milk and dairy products. According to Krzysztofik (2009), high quality of raw milk is a key criterion for its suitability for processing, as it ensures that dairy products have an adequate shelf life and quality. The European Union imposes requirements on producers which oblige them to comply with sanitary and hygiene regulations during milk acquisition (Regulation No 1662/2006). It is also important to properly equip the livestock building. According to the *Codex Alimentarius*, livestock housing should be designed, located and maintained in a way that minimizes the introduction of hazards to the raw material. Improper maintenance of livestock facilities can contribute to contamination of milk. The raw milk should be obtained from healthy animals to ensure the safety and quality of the final product. Milk and dairy products made from raw milk obtained from sick cows are not completely safe and are not suitable for human consumption. Maintaining healthy animals reduces the likelihood of pathogens entering the milk via the udder or faeces. Moreover, in addition to compliance with hygiene requirements, in the places where milk is obtained and stored it is important to properly manage sewage and waste, provide a cold chain, and ensure drinkable water. Bogucki *et al.*, (2010) have pointed out the importance of cow hygiene. The dirtier the udder, lower limbs or lower abdomen, the more the milk quality deteriorates.

The aim of the study was therefore to assess hygiene conditions during the acquisition and processing of milk into cheese at the level of the farm.

## MATERIALS AND METHODS

The research was carried out on a low-input farm located in the Bieszczady Mountains. Cows of the Simmental breed were kept on the farm in a tie-stall barn with litter. From spring to autumn the animals grazed in a pasture. The cows were milked in a direct-to-can system. Hygiene conditions during milk production and traditional processing into unripen rennet cheeses were visually assessed (according to the criteria in Table 1). A microbiological assessment of the buildings and of the equipment for storing the raw milk and for cheese production was carried out as well. For this purpose, the total bacterial count (using PCA LAB-AGAR) and the number of yeasts and moulds (SABOURAUD DEXTROSE IRR) were determined, as well as the quality of the water used on the farm (HYGICULT TPC).

Table 1. Criteria for visual assessment of personnel and rooms used for storing and processing milk

| Scale | Milk acquisition and storage | Milk processing into cheese |
|---|---|---|
| Level satisfying requirements | 1. The room is clean, tidy and in good technological and sanitary condition.<br>2. Equipment and utensils are clean, with no signs of soiling with milk, feed residue, soil, etc.<br>3. Equipment for washing and disinfection (sink and trough) is clean, without dirt or stains.<br>4. Absence of pests (birds, rodents, insects, etc. or their faeces).<br>5. Personnel meet requirements, have gloves, aprons, caps, no jewellery; individuals are clean and well-groomed. | 1. The room meets requirements, is clean and in good technological and sanitary condition.<br>2. Utensils (strainer and board) are kept clean and dry, with no cheese residue.<br>3. Equipment for washing and disinfection of utensils (sink) is kept clean, with no dirt or cheese residue.<br>4. Personnel meet requirements, have gloves, aprons, caps, no jewellery; individuals are clean and well-groomed. |
| Level satisfying requirements with certain aberrations | 1. Slightly soiled room, unwashed floor, flaking paint, dirty walls, etc.<br>2. Equipment and utensils are not completely clean, slight traces of soiling with milk or stains, faintly visible feed residue or soil.<br>3. Lightly soiled or stained equipment for washing and disinfection (sink and trough).<br>4. Faint traces of the presence of pests.<br>5. Personnel do not have all required protective clothing (e.g. a cap). | 1. Slightly soiled room, unwashed floor, dirty walls, stains on the worktop.<br>2. Utensils (strainer and board) are not completely clean, slight traces of cheese residue, stains.<br>3. Equipment for washing and disinfection (sink) is slightly dirty, with cheese residue.<br>Personnel do not have all required protective clothing (e.g. a cap). |
| Level failing to satisfy requirements | 1. Room with visible dirt on the walls and floor, spilt and dried milk residue, flaking paint in many places, chipped tiles. | 1. Room with visible dirt on the walls and floor, spilt and dried milk and cheese residue. |

| Scale | Milk acquisition and storage | Milk processing into cheese |
|---|---|---|
| | 2. Equipment and utensils have substantial traces of milk and stains, visible feed and soil residue on the tools.<br>3. Equipment for washing and disinfection (sink and trough) is substantially soiled, with greasy stains and dried milk.<br>4. Numerous signs of pests or their faeces.<br>5. Personnel have no protective clothing, dirty clothing. | 2. Utensils (strainer and board) have substantial traces of cheese and stains.<br>3. Equipment for washing and disinfection (sink) is substantially soiled, with greasy stains, dried milk stains, and cheese residue. Personnel have no protective clothing, dirty clothing. |

**RESULTS**

The visual assessment showed that according to the scale presented in Table 1, the degree of cleanliness in the milk storage room did not meet the requirements. Numerous traces of dirt, including fragments of excrement, were observed on the walls and floors. In general, the condition of the room indicated a prolonged lack of regular cleaning. Utensils and equipment intended for contact with milk had numerous stains, straw residue, etc. The trough and sink used for washing and disinfection were also not washed regularly. A great number of live and dead insects were seen in the window frame, as well as traces of their droppings. The farmers that milked the cows did not have protective clothing, and their clothes were not suitable or sufficiently clean. The observations were confirmed by the results of microbiological analyses, as shown in Table 2. In all cases, TBC was too high to determine, while the number of yeasts and moulds ranged from $6.40 \cdot 10^1$ CFU/cm$^2$ in the case of the trough for washing milking equipment to too numerous to count for the milking cluster, milk tank lid, cloth for wiping the sink, and the floor in the milk storage room. The presence of moulds and yeasts, as well as bacteria, at the stage of milk acquisition may due to unsanitary milking and improper maintenance of the facilities, equipment and utensils used to obtain and store the raw milk (Nowicka et al. 2014).

Table 2. Total bacterial count (TBC) and number of yeasts and moulds in the material at the milk acquisition stage

| Sample | Sample collection site | TBC (CFU/cm$^2$) | Number of yeasts and moulds (CFU/cm$^2$) |
|---|---|---|---|
| 1 | Milking cluster | TNTC | TNTC |
| 2 | Milk pail | TNTC | $1.63 \cdot 10^2$ |
| 3 | Milk tank lid | TNTC | TNTC |
| 4 | Strainer in milk tank | TNTC | $2.40 \cdot 10^3$ |
| 5 | Milk tank (interior) | TNTC | $1.52 \cdot 10^2$ |
| 6 | Milk churn washing liquid (exterior of container) | TNTC | $7.30 \cdot 10^1$ |
| 7 | Trough for washing milking equipment | TNTC | $6.40 \cdot 10^1$ |
| 8 | Cloth for wiping sink | TNTC | TNTC |
| 9 | Wall tiles above sink | TNTC | $2.47 \cdot 10^2$ |
| 10 | Floor in milk storage room | TNTC | TNTC |

TNTC – too numerous to count

Many shortcomings were also observed in the processing room. The visual assessment showed that according to the scale presented in Table 1, the level of contamination in the room where milk was processed into cheese did not meet the requirements. There was visible dirt on the walls and floor, and the sink, worktop, and utensils had not been adequately cleaned in numerous places. The individual making the cheese had no protective clothing. The assessment of TBC and the number of yeasts and moulds confirms these observations (Table 3). Irrespective of the sampling site, the bacteria were too numerous to count. The number of yeasts and moulds ranged from $1.30 \cdot 10^1$ CFU/cm$^2$ for the cheese warming and coagulation vessel to too numerous to count for the worktop.

Table 3. Total bacterial count (TBC) and number of yeasts and moulds in the material at the milk processing stage

| Sample | Sampling site | TBC (CFU/cm$^2$) | Number of yeasts and moulds (CFU/cm$^2$) |
|---|---|---|---|
| 1 | Kitchen worktop | TNTC | TNTC |
| 2 | Strainer for cheese drying | TNTC | $3.18 \cdot 10^2$ |
| 3 | Vessel for cheese heating and coagulation | TNTC | $1.30 \cdot 10^1$ |
| 4 | Ladle | TNTC | $6.10 \cdot 10^1$ |

TNTC – too numerous to count

The presence of bacteria, fungi and yeasts at the processing stage may result from noncompliance with Good Hygiene Practices and the sanitary requirements for rooms used for cheese production. According to Król (2012), measures can be taken to ensure an adequate, minimum standard. These include following GHP principles, which is fundamental to processing in suitable hygienic conditions. Disinfection at the dairy plant is a very important process. When production activities are finished, the surfaces that come into contact with food should be washed. After washing, the cheesemaker should disinfect all machines and devices, as well as the workspace (Baranowska *et al*., 2014). The sanitary condition of the devices and the hygiene of milk processing largely determine the quality of the finished product, especially in the case of products that are not subject to heat treatment, which significantly increases the risk of pathogens. Nowicka et al. (2014) indicate hazards occurring in minimally processed foods, including bacteria of the genera *Salmonella*, *Clostridium*, *Staphylococcus*, *Escherichia*, *Pseudomonas*, *Listeria*, *Yersinia* and *Campylobacter*. Rola and Osek (2015) report that a common cause of food poisoning is cheese made from non-heat-treated milk contaminated with *Salmonella*, *Campylobacter, Staphylococcus aureus* or *Escherichia coli*. The dangerous *E. coli* strain O175:H7 is found in a variety of cheese types. Usually these are cheeses produced by traditional methods, in small industrial plants and on farms producing raw milk. The most common cause is the use of unpasteurized milk and inadequate hygiene conditions for cheese preparation (Garbowska & Berthold-Pluta, 2013). Nowicka *et al*., (2014) have found that in minimally processed products, milk is very often contaminated with yeasts and moulds that cause unfavourable changes. Berthold and Stachura (2009) have reported numbers of moulds and yeasts in curd cheese ranging from $5.0 \cdot 10^2$ to $9.6 \cdot 10^5$ CFU/cm$^2$.

The results of the microbiological quality assessment of cold water taken from the tap in the milk storage room indicated minimal contamination, at a level meeting the requirements. The total plate count in the water used on the farm was $10^3$ CFU per ml.

## CONCLUSION

The state of hygiene on the farm was shown to be unsatisfactory, which was confirmed by the results of microbiological tests. Significant numbers of bacteria, as well as moulds and yeasts, were found on items used during both milk acquisition and cheese production, which indicates a lack of hygiene on the farm. The results demonstrate the need for continued research, especially regarding the finished product, i.e. cheese. Importantly, the water quality was found to be good, meeting the requirements.

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# 6.6. EXPOSURE TO DUST DURING WORK ON A SUSTAINABLE FARM

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**Keywords:** dust, exposure, rapeseed harvest, farmers

## ABSTRACT

The aim of the study was to determine the exposure of farm workers to dust during various work activities. The research was carried out in the summer. The following activities were taken into account: mowing cereals with a combine harvester, baling straw, and manually handling cereals during feed production. The dust concentration in the air was assessed by the gravimetric method. According to data from the National Research Institute, dust particles with a diameter not exceeding 7 μm are the most hazardous to human health. The highest dust concentration was noted during manual handling of grain, when the concentration of inhalable dust was 1.56 mg/m³. It is crucial to assess the working conditions of farm employees and to implement technical and organizational preventive measures to reduce their exposure to dust.

## INTRODUCTION

Organic dust poses a significant threat in the farmer's work environment. In addition to particles of inanimate matter, dust also contains bacteria and fungi, as well as harmful metabolic products of microorganisms, i.e. toxins and allergens, which constitute bioaerosols. Microbes inhaled with dust enter the respiratory system, which may cause local inflammation and allergic reactions or even lead to the development of occupational or para-occupational diseases (Mołocznik, 1999; Mołocznik, 2002; Szewczyk, 2012; Pawlak & Nowakowicz-Dębek, 2015; Gilbey *et al.*, 2018). The degree of penetration in the respiratory tract depends mainly on the size of the particles, their concentration in the air, the activities performed, and the length of time during which the worker is exposed. Field work intensifies in summer, and atmospheric conditions cause an increase in dust concentrations. The preventive measures used at that time are of great importance (Dutkiewicz, 2006; Nowakowicz-Dębek *et al.,* 2014; Szewczyk, 2012). Therefore, a study was carried out to determine the exposure of farmers to dust during work on a farm in a sustainable agriculture system.

## MATERIAL AND METHODS

The research was carried out in summer on selected farms in southern Poland, operating in a sustainable agriculture system. Dust concentrations were measured during typical harvest work, such as harvesting cereals with a combine, baling straw, and manual handling of grain in the feed room and warehouse. The dust level during these activities was assessed by the gravimetric method. The inhalable and respirable fractions of dust were measured using Whatman Glass microfiber filters and a previously calibrated personal air sampling pump. The filters were conditioned in a desiccator before the measurements were taken and the field research was begun. Dust measurements were carried out according to Nowakowicz-Dębek *et al.* (2014). Microclimatic parameters were measured at the same time. Statistical analysis of the results was performed using Statistica v. 8.0 software and presented graphically.

## RESULTS AND DISCUSSION

Figures 1 and 2 present the results of the dust concentration measurements on the farms. The concentration of inhaled dust was 4.31 mg/m³ on average and ranged from 1.9 to 6.64 mg/m³. The highest dust level was recorded during manual handling of grain in the feed room or warehouses, where the concentration of inhaled dust was 6.64 mg/m³ (Fig. 1).

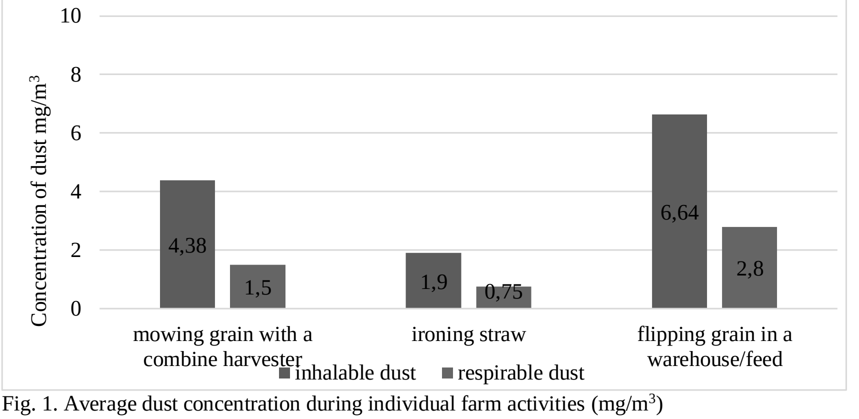


Fig. 1. Average dust concentration during individual farm activities (mg/m$^3$)

The dust level for the respirable fraction ranged from 0.75 to 2.80 mg/m³, with an average value of 1.68 mg/m³. The difference between the average concentrations of inhalable and respirable dust was 2.62 mg/m³. The greatest differences were noted for activities associated with grain handling in storage and feed rooms. When the occupational exposure was calculated per day of work, the weighted average concentration for the inhalable fraction slightly exceeded the MAC (maximum allowable concentration, 4 mg/m³). However, the weighted average concentration for the respirable fraction did not exceed the MAC (2 mg/m³). People working long-term at this position may certainly be at risk of respiratory disease, and therefore the use of personal protective equipment is recommended. Research by Yashiro, Savova-Bianchi, & Niculita-Hirzel (2019) indicates the complexity of worker/farmer exposure during this time.

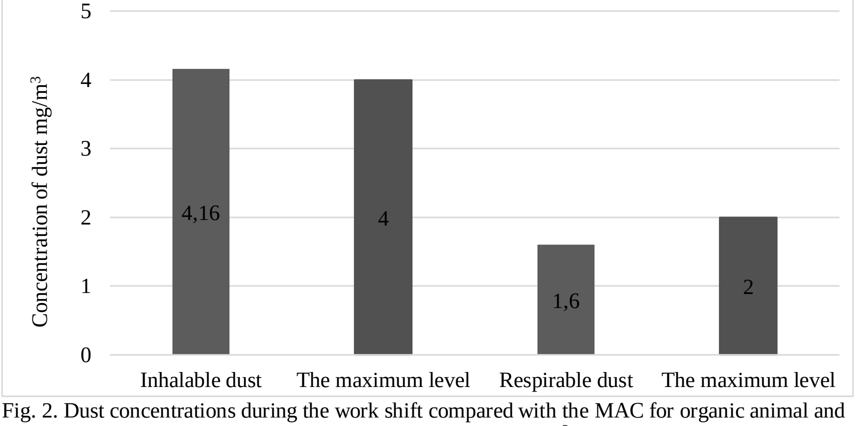


Fig. 2. Dust concentrations during the work shift compared with the MAC for organic animal and vegetable dust, with the exception of wood dust and flour (mg/m$^3$)

Numerous studies indicate that dust concentrations are highest during work associated with harvesting of cereal crops and compacting the earth with a roller. Therefore, to protect the farmer from the harmful effects of organic dust, occupational advisors should recommend protective measures such as masks, half-masks or filtering equipment with a forced air flow. Preventive measures to protect the health of the farmer, aimed at reducing exposure to dust while they work, involve the implementation of numerous technical and technological solutions, such as the use of machines with climate-controlled dustproof cabins during work in the fields, modernization of currently used systems, e.g. by using granulated feed and fertilizers, proper feed storage, and automation of production lines. Training is crucial to raising farmers' awareness of the effects of long-term occupational exposure to high dust levels in the work environment (Mołocznik, 2002; Gilbey *et al.*, 2018; Musiała, 2006; Pawlak & Nowakowicz-Dębek, 2015). The importance of this form of activation is underscored by the fact that negative health effects may be revealed even many years after the farmer has stopped working in these harmful conditions and the occupational exposure has ceased.

In Poland, there is no system monitoring the impact of the work environment on farmers' health, and hazards are not registered as in other occupational sectors. Polish legislation on protection of workers' health does not provide farmers with free preventive health care. For this reason, individual farmers should monitor the health and safety conditions of their own farms, taking into consideration themselves and the family members working with them (Mołocznik, 2002; Szewczyk, 2012; Dörre-Nowak 2010; Musiała, 2006; Gawda *et al.*, 2015).

The Institute of Rural Medicine has developed a concept of system solutions in prophylactic care for private farmers, aimed at both prevention and improvement of existing working conditions according to widely accepted health and safety principles. The importance of this programme is underscored by the persistent low level of occupational health and safety and the resulting high accident rates and incidence of occupational and para-occupational illnesses (Mołocznik, 2002; Szewczyk, 2012; Dörre-Nowak, 2010; Pawlak & Nowakowicz-Dębek, 2015; Donham *et al.*, 2019). The implementation of a preventive health care system for farmers should also be facilitated by case law on occupational diseases of farmers. There is a need for educational measures for farmers to reduce or eliminate the consequences of the presence of organic dust and other occupational hazards. Farmers should be encouraged to use personal protective equipment on a daily basis, and farms that invest in ventilation equipment and up-to-date dust protection technologies should be rewarded.

## CONCLUSIONS

During work, farmers are at risk of inhaling respirable organic dust at levels exceeding permissible MAC levels. Preventive measures should be implemented immediately to eliminate the consequences of the presence of dust in the air, as workers should not perform their professional duties at this level of exposure.

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# 6.7. SPRAYER INSPECTION IN LUXEMBOURG

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**Keywords**: history, horizontal boom sprayers, sprayers for bush and tree crop, test equipment, future prospects

**ABSTRACT**
Sprayer inspection was introduced in 1998 as a mandatory commitment for AECM-Schemes in Luxembourg. In 2014, the so-called SUD-directive was implemented, and PAE-checks became mandatory for all users with first checks to be performed before the end of 2016. In 2018, a legal decision was taken for measuring and adjusting air distribution of used sprayers for 3D Crops. Challenges for the future are the inspection of special PAE and new technologies like drones application.

## KEY FIGURES

Luxembourg as a co-founder state of the European Union is a small country with utilized agricultural area of 130,000 ha and around 2000 farm holdings plus 1300 ha of vineyards with around 300 wine growers. The country owned in 2017 around 1000 boom sprayers, 290 sprayers for bush and field crops and all kind of specific other PAE in small numbers.

## INTRODUCTION

Sprayer inspection has a long tradition in Luxemburg. It was introduced because of the so-called Mc Sharry-reform in 1992 and as a result of implementing agri-environment schemes in Luxembourg. Sprayer inspection (PAE) became mandatory for participating in AECM-schemes, which have a long tradition in Luxembourg. Largely implemented in the Luxemburgish CAP (common agriculture politics), they cover 95% of the total surface of agricultural land. Currently well-known problems with sprayers are their use without correct adjustment. They contribute to negative effects like drift and point-source pollutions. Experts in Europe consider plant protection product (PPP) pollutions responsible for over 50% of total amount of pollutions, mainly due to bad handling of PAE-equipment.


Fig.1. ASTA: official sticker after sprayer inspection

There are three main arguments for the periodical inspection (certified as indicated in Fig.1):

- improve the operator’s safety
- decrease the potential risk of environmental contamination by crop protection products
- good control of the pest with a minimum input of crop protection products.

By implementing the so-called SUD-directive (2009/128/EC) as a national law in 2014, sprayer control became mandatory for all users of PAE in Luxemburg. First control was to be done by end of 2016. This was not a big change for traditional farmers and winegrowers, but a new challenge for special PAE and other PAE-users outside agricultural sector.

## MANDATORY PERIODICAL INSPECTION OF APPLICATION EQUIPMENT IN USE

First inspections started in 1998 with test equipment from German supplier E. Herbst Pflanzenschutztechnik following the German standard. At that time, the decision was made to check the horizontal distribution for boom sprayers (Fig. 2) and the flow rate of the nozzles for 3D-sprayers (Fig.3).

Fig.2. ASTA: horizontal distribution measuring

Inspections take place at farm machinery suppliers in order to guarantee a direct service for repairing minor defects and enabling a successful inspection the same day. This is considered as a win-win situation for all parties.


Fig.3. ASTA: Single nozzle test bench

**2014: IMPLEMENTING THE SUD-DIRECTIVE IN LUXEMBURG**

A mandatory periodical inspection of application equipment in use was implemented in 2014 by national law and specific regulation. These national legislations implement the Directive for a sustainable use of pesticides (2009/128/EC) and assure the following demands:

a. All equipment should be inspected by the end of 2016

b. The frequency of the inspections are 3 years up to and after 2020

c. Equipment used on a low scale can have another inspection frequency based on a risk assessment.

d. Handheld equipment like backpack sprayers can be exempted from inspection following a risk assessment.

e. The inspections should be done on base of the requirements in this Directive and on base of harmonized standards (EN-ISO 16122 series)

f. The Member States should recognized the inspections done in other Member States (mutual recognition), which is particularly important for a small country like Luxembourg with short distances to the borders.

g. Each Member State should have a responsible body for the organization. In Luxembourg the inspection is organized by the administration.

## VERTICAL DISTRIBUTION IN 2018: SPRAYER TESTING AS A NATIONAL REQUEST BUT ALSO AS A SERVICE FOR USERS

Adjustment of working height and rectangular vertical air distribution to the needs of the buyer at an air distribution test bench are still voluntary and not generally offered by suppliers of brand new sprayers before purchase.

In order to provide the owner/operator with further information and to guarantee a correct application of PPP, the vertical spray distribution measurement by using a vertical patternator became mandatory in 2018 for all sprayers for bush and tree crops (Figs. 4 & 5). As the risk of drift is particularly high for 3D-sparyers the initial national decision in 1998 was not logical to check the horizontal distribution for boom sprayers and not to check the vertical distribution which represented far higher risks.


Fig. 4. ASTA: new patternator in 2018

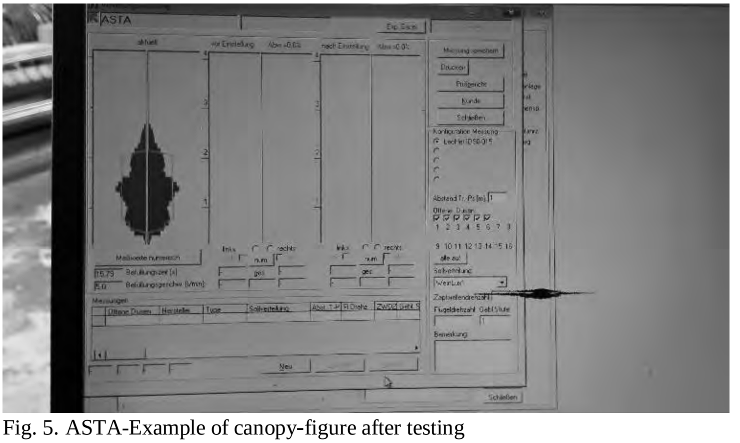

Fig. 5. ASTA-Example of canopy-figure after testing

**FUTURE PROSPECTS**

Testing facilities for 3D-sprayers was located in the national wine-growing administration since starting the checks with the new horizontal patternator in 2018 (Fig.6). However, those facilities were not satisfactory as they did not fit the full height of the testing equipment.

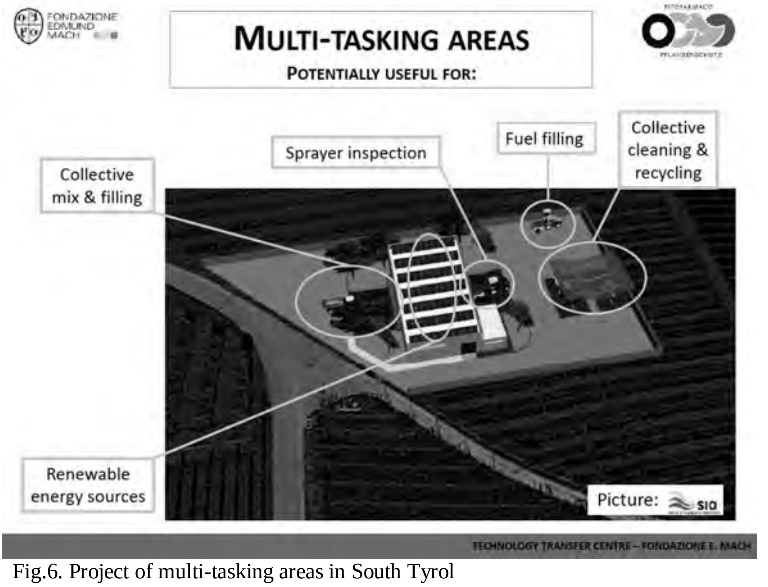


Fig.6. Project of multi-tasking areas in South Tyrol
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Fig.7. ASTA: test facilities 2019

Internal discussions lead to build a new building for testing, filling, washing and collecting waste waters for practical but also pedagogical reasons (Fig. 7). Mandatory testing facilities offer a good way to raise awareness and educate farmers and other PPP-users about correct handling of PPP in general.

Some initiatives took place in test facilities, as they offer a good way to train the actors individually.

## CONCLUSIONS

Thanks to right decisions 20 years ago, by linking the MAEC-schemes to PAE-testing and parallel grant invest subsidies for buying new equipment, the European obligations of the SUD-directive could be easily implemented in Luxembourg.
Mainly due to SPISE-initiatives, small countries like Luxembourg, without a specific research sector in this particular domain, are able to fulfil the requirements. Challenges for future results in assuming inspections for PAE with specific requirements will be possible. This will even be feasible for PAE which exist only in small numbers, which cannot be exempted from checks and have very specific checking requirements. Exchanges with surrounding member states and/or support from SPISE-community enable us to fulfil all our requirements. Spraying with drones is one of those practices that are increasing at the moment and where many open questions still remain. Another topic that has not been implemented is the periodical inspection of slug pellet applicators.

At a scientific level, a lot of knowledge exists on handling PP-Products, but the challenge for the future will be to bring this expertise at a farm level.

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# 6.8. ELECTROCUTION RISK EVALUATION INSIDE STABLES

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**Keywords:** Lightning Protection Systems, safety, agricultural-livestock sector

**ABSTRACT**
A continuous increasing of thunderstorms can be observed and the large spread of electric and electronic devices, sensitive to dangerous effects of electro magneticity, require attention on potentially dangerous effects of lightning. Employers must assess the risk raised by lightning and to ensure that everything used by workers (buildings, devices, etc.) is protected from possible dangerous the effects of lightning.
In case of faults, the electric circuit must be interrupted and, in particular in the agro-zootechnical structures, due to animals' sensitivity, it is necessary to keep the contact and step voltages to very low values, by designing extra-equipotential connections also with the electro-welded metal grids inside the concrete floor of the animal shelters. This work aims at analysing the standards related to lightning protection referring to the agricultural-livestock sector with particular attention to a lightning protection system for a medium-sized stable.

## INTRODUCTION

In Italy about 600 thousand lightning falls every year, with an average ground lightning density of about 2 strokes per km$^2$ which, obviously, also depends largely on the geographical conformation (Mona T., Horváth À., Ács F. (2016); Barthe, C., Deierling, W., Barth, M.C. (2010); Wapler, K., James, P., (2015)) The way in which a lightning is produced is largely described in literature (Meyer, V.K., Höller, H., Betz, H.D., (2013); Smith, S.B., LaDue, J.G., MacGorman, D.R., (2000); Carey, L.D., Buffalo, K.M., (2007); Csirmaz, K., Simon, A., Pistotnik, G., Polyánszky, Z., Neštiak, M., Nagykovácsi, Z., Sokol, A., (2013)) The obtained charge density can produce electric fields having strengths of several hundred kV/m, so lightning discharge mechanisms are triggered with all the potential damaging effects. (Pascuzzi S., Santoro F. (2015); Pascuzzi S., Santoro F. (2017); Deierling, W., Petersen,W.A., (2008); Sánchez, J.L., López, L., Garca-Ortega, E., Gil, B. (2013).

A lightning protection system (LPS) includes the lightning protection equipment itself, the protection for electrical and electronic equipment from the electromagnetic pulses (LEMP) and the possible subsequent overvoltage (SPM) and, all the side protection against fire and to safeguard technological structures and systems (Anderson R. B. and Eriksson A. J. (1980); Armstrong H. and Whitehead E. (1968); Berger K., Anderson R. B., Kroninger H. (1975)).

The possible damages caused by lighting can be useful to better understand the composition of an LPS and SPM. i) damage for electrocution in living beings; ii) damages for high-energy discharges in charge to material; iii) damage for electromagnetic pulse conducted and induced by the power lines or due to the radiated electromagnetic field connected to the lightning (LEMP) to electrical and electronic equipment and systems (Berger K., Garbagnati E. (1984); Borghetti A., Nucci C. A., Paolone M. (2004); Borghetti A., Nucci C. A., Paolone M. (2007); Borghetti A., Nucci C. A., Paolone M. (2009)).

The sources of damage are lightning strokes which impact: i) on the structure; ii) on the field near the structure; iii) on the power lines that feeds the structure; iv) on the field near the power lines that feeds the structure (Borghetti A., Napolitano F., Nucci C. A., Tossani

F. (2017); Borghetti A., Napolitano F., Nucci C. A., Tossani F. (2017); Dellera L., Garbagnati E. (1990)).

The effects can be: i) loss of human lives or permanent injuries; ii) loss of public service; iii) damages of cultural heritage; iv) economic losses.

According to Dellera L., Garbagnati E. (1990), the LPS is made up of:

1) the external LPS. It intercepts the lightning on the structure using a pick-up system and provides the lightning current to reach the ground by mean of a leakage system.

2) the internal LPS. It prevents dangerous shocks within the structure (equipotential connections between the metallic masses and SPD (surge protection device) insertion on the power lines). The aim of both these components is to protect against the very high voltages which, depending on the characteristics of the stroke and those of the protection system itself, cause potential differences between the protection system and the protected structure and metal objects close to the LPS that could affect electrical equipment (Blanco I., Sotirios Anifantis A., Pascuzzi S., Scarascia Mugnozza G. (2013); Manetto G., Cerruto E., Pascuzzi S., Santoro F. (2017); Pascuzzi S., Santoro F. (2017a); Pascuzzi S., Santoro F. (2017b)

The design of an LPS starts from the evaluation of the risk of fulmination (EN 62305-1; 2; 3; 4). If higher than acceptable, is necessary to organize protective measures, otherwise, the structure is self-protected, and nothing has to be done. The identification of risks can be divided into three possible losses; i) human lives; ii) public service; iii) cultural heritage.

In the agricultural and zootechnical structures, it is necessary to maintain the contact voltages to very low values, by designing extra-equipotential connections among all the potential interested masses. Considering the high sensitivity of animal to step voltages, particular care has to be taken in connecting electro-welded metal grids inside the concrete floor of the animal shelters, to the equipotential collector. This work aims at analysing the technical standard regarding the lightning protection with reference to the agricultural-livestock sector with particular reference to a suitable lightning protection system for a medium-sized stable in which should be hosted about 200 animals and 10 employees should work

## MATERIALS AND METHODS

### *The stable*

In a farm located near Tursi (Matera Disctrict, Southern Italy - 40.24739N 16.44855E), a new stable suitable to host about 200 beef cattle is going to be built. Inside the stable, during the day, will work about 10 workers to manage the animals. The stable will have a length L = 20 m and a width W = 50 m (Figure 1).

The stable is designed in order to ensure operational functionality for animals' management, workers safety and comfort (Pascuzzi S., Santoro F. (2015); Pascuzzi S., Santoro F. (2017)) and cost reduction

***The LPS***

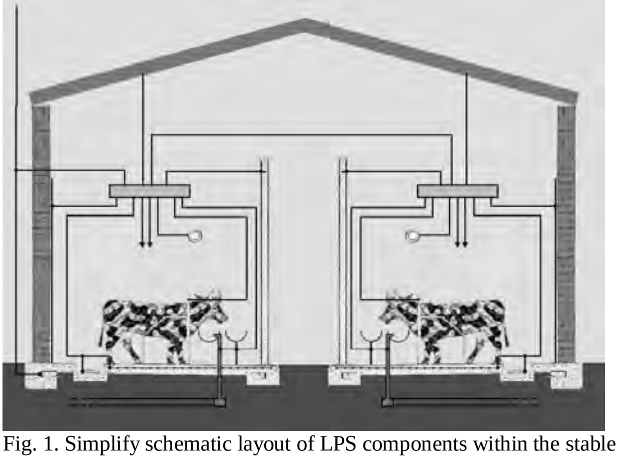

Fig. 1. Simplify schematic layout of LPS components within the stable

The Lightning Protection System will protect the stable from direct lightning and, also, from consequent possible fire. Will be respected the following regulations: i) general standard and technical requirements for the "lightning protection systems (LPS)" itself (EN 62305-1&2); ii) standard for risk assessment due to ground lightning (EN 62305-1&); iii) standard for design, installation, verification and maintenance of the LPS to limit material damages on structures and people risk (EN 62305-3); iv) standard for design the LPS design in order to protect electrical and electronic systems inside the structures (EN 62305-4). In Figure 1 is represented a simplified and schematic layout of the LPS components needed in the case of a stable.

## RESULTS AND DISCUSSION

The risk R that lightning damage occurs has to be considered the sum of all the $R_x$ risk relevant for the specific type of loss. In this case the possible losses taken into account are: 1) loss of human lives; 2) economic loss

Regarding the assessment of economic losses, as no data was available for this analysis, the representative value of acceptable risk has been used. (EN 62305-2&3&4) and only the risk of loss of human lives has been evaluated.

The R risk for losses of human lives is given by the following equation:

$$R = N \cdot P \cdot L \quad (1)$$

where:

N is the number of lightning strokes per year on the surface to be evaluated;
P is the probability of damage;
L is the loss, or the quantitative assessment of damages

In order evaluate the potential risk, the first step is the determination of the lightning density value on the ground $N_g$ which is the average number of lightning/ $km^2$ evaluated on a statistical basis. It is evaluated using the lightning stroke localization networks (LLS) covering Italian national territory (EN 62305-2)

$$N_g = 2.62 \frac{lighting}{km^2 \cdot year} \quad (2)$$

To evaluate the correct number N of dangerous events that could affect the stable the lightning density on the ground Ng must be related to the collection area equivalent to the stable (EN 62305-2). It is necessary to evaluate the lightning frequencies that may affect the stable, considering four different parameters: direct lightning stroke on the structure ($N_D$); lightning stroke that produce magnetic effects ($N_M$); direct lightning stroke on power lines ($N_L$); lightning near the power lines ($N_I$).

A single homogeneous area considering the characteristics of the stable (internal flooring, presence of people, layout of the internal installations, etc.) has been identified and for it were evaluated: a) the equivalent collection surface $S_D$ for direct lightning stroke; b) the $S_M$ collection surface for indirect lightning stroke c) the $S_L$ collection surface for direct lightning on power lines and d) the $S_I$ collection surface for indirect lightning on power lines (EN 62305-2) - Figure 2.

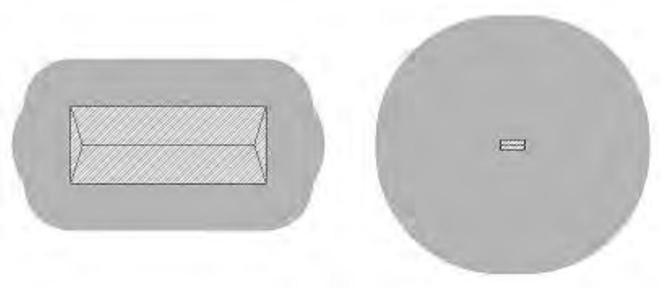

Fig. 2. Collection area for both direct ($A_D$) and indirect ($A_M$) lightning stroke

The following data have been taken into account:

$$S_D = 3.22 \cdot 10^{-3}\ km^2 \text{ - } S_M = 4.36 \cdot 10^{-1}\ km^2 \text{ - } S_L = 8.00 \cdot 10^{-3}\ km^2 \text{ - } S_I = 8.00 \cdot 10^{-1}\ km^2$$

and the corresponding numbers of dangerous events due to direct and indirect lightning stroke on the structure ($N_D$, $N_M$) and for direct and indirect lightning strokes on the power supply lines ($N_L$, $N_I$) were evaluated (EN 62305-2&3&4):

$$N_D = 0.016900/year \text{ - } N_M = 1.140000/year \text{ - } N_L = 0{,}010480/year \text{ - } N_I = 1{,}048000/year$$

finally, considering the probability of damage to living beings ($P_A$), to the structure ($P_B$), to the installations ($P_C$) and the probability of failure of the installations ($P_M$) all evaluated to be around 1% was possible to evaluate that the risk deriving from fulmination for the structure (R) which resulted to be lower than the acceptable risk ($R_T$) (EN 62305-2&3&4). In particular:

$$R = 3.38 \cdot 10^{-6} < R_T = 1.00 \cdot 10^{-5}$$

In this case the structure is self-protected and there is no need to install a lightning protection system.

Nevertheless it’s advisable to insert an electro-welded steel mesh in the concrete base, make equipotential connections between the reinforcement of the structure and connect all these metal masses to an efficient earth plate made of a bare copper rope buried along the entire external perimeter of the stable and 4 linear sinks driven into the ground, by drilling, placed at the vertices of the structure at a depth not less than 6 meters. This with the aim of reducing step voltages and avoiding contact voltages.

## CONCLUSIONS

Modern agriculture widely uses computer and electrical systems to increase profitability with the aim, to optimize and automate the most time-consuming processes. In agricultural in general and in livestock plants in particular, lightning can have particularly serious consequences for the structures also in consideration of their geographical location, their construction technique or their use. Remembering that nowadays are frequent agricultural buildings equipped with robotic milking systems and considering that, often, all the equipment need to achieve such task are controlled through data lines and that can they be controlled from remote locations, it appears clear why it is recommended to install protective measures against both lightning and overvoltages. Even if what has been considered in this study is the case of a simple and quite small stable, the methodology used could be considered to be a possible approach that, taking into account the technical standard which define the technical and design procedures in the field of protection from lightning with reference to the agricultural-livestock sector, could be used in the design of a medium and large-sized stable in which, for sure, the risks are more relevant.

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## 6.9. NOISE HAZARDS DURING WORK ON A PIG FARM

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**Keywords**: noise, exposure, farm, pigs, workers

### ABSTRACT
Noise is regarded as one of the nuisance factors in the work environment. People employed in agriculture are exposed to this factor as well. Therefore, a study was carried out to assess worker exposure to noise during work with pigs. Noise levels were measured during routine activities in the course of an 8-hour working day. The highest noise level was recorded during handling of piglets and nursing sows. With all activities taken into account, the worker's daily noise exposure level during handling of animals is 81.9 dB. This exceeds the noise threshold but does not exceed the maximum acceptable sound level in the work environment. According to the Polish Standard, the diagnosed exposure is almost half of the recommended level (82 dB). Therefore, employees should be provided with appropriately adapted preventive measures to reduce the sound level of the noisiest activities or to automate certain activities in the handling of animals.

### INTRODUCTION

Noise is one of the significant harmful environmental factors occurring in agriculture. It is generated during the operation of various machines, such as tractors working in conjunction with agricultural machines, self-propelled agricultural machines (e.g. combine harvesters, beet harvesters, chaff cutters or windrowers), stationary agricultural machines (grain mills, mixers, threshers, crushers, potato sorters, and milking machines) and machines used in feed preparation and handling of animals. According to Polish law (Journal of Laws, 2017), animal handling comprises activities related to the rearing, breeding and use of animals, performed daily or periodically, specifically work related to feeding, watering, milking, reproduction, litter replacement, assistance during veterinary procedures, grooming, transport, and manure removal (Adamczyk, 2005). According to research carried out in the United Kingdom, the risk of hearing problems may increase after just one year of work at increased noise levels. After five years of exposure to this factor, the risk of significant hearing loss is almost three times greater than for people who work at relatively low noise levels. In Poland, the problem of noise exposure for individual farmers is largely unacknowledged. This is due to the lack of appropriate legal provisions enabling supervision of working conditions, environmental testing, and preventive medical examinations (Indulski & Starzyński, 1997; Sułkowski, Kowalska & Guzek, 2000; Cieślikowski & Ślipek, 2007). Improper working conditions increase the number of accidents at work and the incidence of occupational and para-occupational diseases, causing temporary, long-term and even permanent inability to work (Kuta & Cież, 2013). One of the adverse factors in the work environment is noise, which often imperceptibly leads to a gradual loss of hearing. Therefore, a study was carried out to assess the noise exposure of workers employed in the handling of pigs.

### MATERIAL AND METHODS

The research was carried out on a farm in southern Poland with 500 breeding sows, i.e. 175 LSU. Prior to the measurements, a schedule of individual activities was drawn up. Measurements were performed three times at workstations during animal handling. The measurements were made with a Sonopan integrating sound level meter, meeting the requirements of standard PN-EN 61672-1:2014-03 (2014). The schedule of activities for an employee's typical working day on the farm was as follows:

1. handling piglets (duration – 1h)
2. handling boars (0.5h)
3. handling nursing sows (1h)
4. handling sows in late gestation kept on straw (2h)
5. handling sows kept on slatted floors in preparation for or after insemination (2h)
6. work involving cleaning (washing, cleaning, disinfection; duration – 1h)

Once the measurement results were obtained, the noise exposure level for an 8-hour working day (LEX, 8h) and the expanded uncertainty (U) were calculated, in accordance with PN-EN ISO 9612:2011 (2011).

**RESULTS AND DISCUSSION**

The research was carried out in the pig housing of a breeding farm, where employees performed typical activities during an 8-hour working day. Their main tasks were handling of piglets, boars, lactating sows, sows being prepared for insemination, inseminated sows, and sows in late gestation, as well as other work, including cleaning.

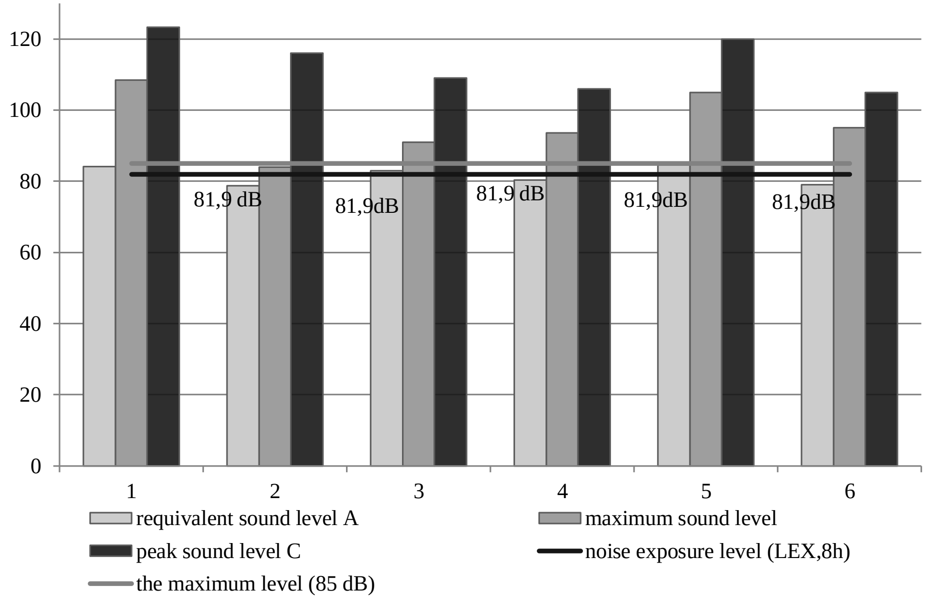


Fig. 1. Sound level during work activities in comparison with the maximum acceptable level; numbers 1–6 refer to the activities listed in 'Material and Methods'.

Analysis of the results indicates that the maximum acceptable sound level for exposure to noise during work was not exceeded. However, a slight increase of 0.1 dB would lead to exceedance of half of the maximum acceptable level. Therefore, it is very important to train pig farmers with regard to the risk associated with noise exposure and to specify its sources and means of eliminating them (Fig. 1).

During the noise measurements, the microclimatic conditions prevailing in the piggery were measured as well. The average temperature during this period was 27.4°C, and the relative humidity was 66.7%. These values were optimal for this type of building and in accordance with applicable standards (Table 1).

Table 1. Microclimatic parameters in the pig housing during the measurements

| Measurement point/ activity | Temperature (°C) | Relative humidity (%) |
|---|---|---|
| 1 | 29.7 | 71.2 |
| 2 | 22.3 | 59.6 |
| 3 | 28.9 | 55.8 |
| 4 | 26.1 | 73 |
| 5 | 28.7 | 60.7 |
| 6 | 26.9 | 76.5 |
| Mean (M) | 27.10 | 66.13 |

Noise is a continual work safety problem in many environments, including agriculture. Despite numerous studies, it remains a significant threat to people employed in this production sector, which is confirmed by our research. Mead-Hunter *et al.* (2018) conducted a study among farmers in Western Australia exposed to noise during work related to cereal cultivation and animal production. The research included 42 mixed-production farms. The authors reported that 32% of employees were exposed to a noise level exceeding the safe limit, recognized as 85 dB (A), during an 8-hour working day. For 37% of employees, very high peak noise levels of 140 dB (C) or more were noted. The authors observed that farmers are reluctant to use preventive measures. There has been a growing trend in the purchase of machinery with lower noise emissions. Similar research in Western Australia has been conducted by Williams *et al.* (2015), whose study included both women and men. No difference in exposure was found between the sexes. The average noise exposure was 1.09 Pa (2) h (LAeq, 8h = 85.3 dB) and was higher than in our study. Williams *et al.,* (2015) indicated that over 163,000 Australian workers employed in agricultural production are exposed to noise. The authors submitted their results in the form of farm audit reports so that corrective measures for this management could be introduced quickly.

Excessive noise poses a serious threat, as it can lead to hearing impairment. Franklin *et al.,* (2006) conducted research in various producer groups, looking for sources of noise in agriculture. The authors indicated machines as a potential source of noise, especially older tractors, which generated about 6 dB higher noise levels than those currently produced. The use of a closed cabin resulted in a noise reduction of as much as 16 dB. The results were a source of information for further actions in this environment to eliminate such high noise levels. Similarly, the results of our own research should be passed on to farm owners so that appropriate preventive measures can be implemented. This information should be included in the training materials of agri-environmental advisers or KRUS (Farmers' Social Security Fund) employees during meetings and discussions with farmers.

## CONCLUSIONS

The highest noise level during work in the piggery was noted during handling of piglets and lactating sows. Workers' level of exposure during handling of animals over an 8-hour workday was 81.9 dB, which exceeded the noise threshold. Analysis of the results indicates that the maximum acceptable sound level for exposure to noise during work was not exceeded. However, a slight increase of 0.1 dB would lead to exceedance of half of the maximum acceptable level. Therefore, it is essential to train farmers with regard to the risk associated with noise exposure and to specify sources of noise and means of eliminating them.

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# 6.10. EVALUATING AN ALTERNATIVE COOLING SYSTEM FOR THE TRACTOR CABIN

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**Keywords:** TEC, cooling load, coefficient of performance

## ABSTRACT

The cooling system in the tractors cabin consumes a significant power from the engine, besides it has a bad effect of gases on the environment, moreover it requires maintenance. The alternative cooling system that developed in this study depends on its work on the principle of Peltier effect by using Thermo-Electric Cooling system (TEC). The study includes two factors first is the fan speeds for air flow (1.2, 3.6)m\s and second is three levels of thermoelectric cooling unit (TEC) namely 2, 4, 6 units. The investigated properties in this study were: the temperature difference ($\Delta T$) between driver's cabin and ambient, cooling load (Qc) and coefficient of performance (COP). The results showed that decreasing the fan speed had a significant effect on the studied parameters. Using six units of TEC resulted in an increase in the difference between driver's cabin and ambient, cooling load and coefficient of performance (COP).

## INTRODUCTION

Recently we have noticed a great increase in the population, which is accompanied by an increase in the number of vehicles that are sold, it has known that the vehicle is necessary for all individuals; as a result, the vehicles must provide a comfortable conditions for people especially with heating and cooling. Therefore, many vehicles are equipped with air conditioning system. The widely-used air conditioning system is very efficient and reliable, but it has some disadvantages that are represented by the refrigerant medium, known locally as Freon gas. In addition, the current air conditioning system, consumes a large amount of the engine power, ranging from 5 - 10 hp, hence results in larger fuel consumption, shorter life time, it consisted of many parts and this leading to increase costs and maintenance (Raut & Walke, 2012). It has been observed over the past two decades that the ozone layer is slowly being destroyed by emissions of refrigerant intermediate gases such as Chlorofluorocarbons (CFC's) and hydroChlorofluorocarbons (HCFC's) used in refrigeration and air conditioning, in addition to other factors (Totala, Desai, Singh, Gangopadhyay, Yaqub, & Jane, 2014). These gases would create a significant impact on the ozone layer if they will spread to the atmosphere during the maintenance. The contribution of these gases on global warming reach to about 12% through the destruction of the ozone layer, while the impact on the destruction of the ozone layer is much greater up to 65% (Muhsen, 2007) and (Samman , 2004). About 0.5 ton of ozone could be damaged by 100g of HCFC and CFC, which in turn has an impact on the environment. For these reasons, alternative methods have to be found to reduce the cost and save the environment.

Thermal cooling based on the principle of (Peltier), is considered to be one of the alternative technologies for air conditioning and other uses. It is based on the principle of converting the DC current with low voltage to thermal energy by using semi-conductors. Nowadays they are used in most industrial, medical, aerospace, and agricultural fields that require precise temperature control, it has been also used to cool laser-generated elements. Yadav & Mehta, (2013) presented a theoretical and experimental study using a pair of thermal units type of TEC1-12703 with a maximum cooling power of 70W, at an ambient temperature of 37C$^o$, the temperature inside the model was reduced to 18C$^o$ after

40 minutes. Raut & Walke, (2012) concluded that the cooling load depends on the type and arrangement of TEC with cooling power about 300W by using six TEC1-12704 thermal units.

Abdulsalam, Santoso, & Aries, (2015) calculated the heat loads in the cabin which consisted of: person loads, direct solar radiation, diffused, reflex, surrounded, exhaust, engine, ventilation, and AC loads, by conducting analysis on the thermal load using the MATLAB simulation method. Cosnier, Fraisse, & Luo (2008) presented an experimental and digital study of the electrothermal cooling system and obtained COP of (1.5 - 2) using six TEC1-12706 thermal units with a maximum cooling capacity of 50W per unit. Jangonda, Patil, Kinikar, Bhokare, & Gavali, (2016) managed to cool a prototype refrigerant using a TEC system, they achieved a COP about 0.35-0.69. The system was equipped with a pair of TEC1-12706 units along with fans to expel the heat from the hot side.

The objective of this research is to study an air conditioning model for the tractor using electro thermal units, and then test it in terms of its effectiveness, efficiency and environmental suitability.

## MATERIALS AND METHODS

The system consisted of three sets of thermal units type of TEC1-12706 were used in the experiment; each group consisted of a pair of TEC as shown in figure (1).

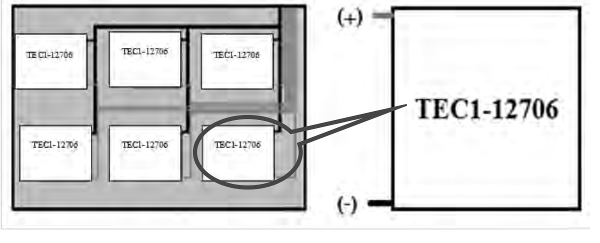


Fig. 1. TEC arrangement in the system

The system contains two main components, first is the main part, this piece is shaped in the form of a rectangle (figure 2) located in the upper side of the tractor cabin. This external part consisted of the TEC units with six fans that used to dissipate the heat from the hot side, while the cool side of the TEC is in contact with a small water tank and water pump to circulate the water to a small radiator.

The cooling device is fed by electric current, through the controlling panel, from the tractor battery source. The function of the control panel is to control the operation of thermal units level, the speed of air discharge from the fan and the water circulation pump. The panel also contains some gauges and sensors which are a pair of sensors type W1209 Temperature Control Switch), voltage gauges (LED Voltmeter DC) and current type (LED Ammeter DC) and voltmeter type (Multimetre DT830B). The function each of which is to measure the temperature inside and outside the cabin, voltage and current consumed by the battery respectively.

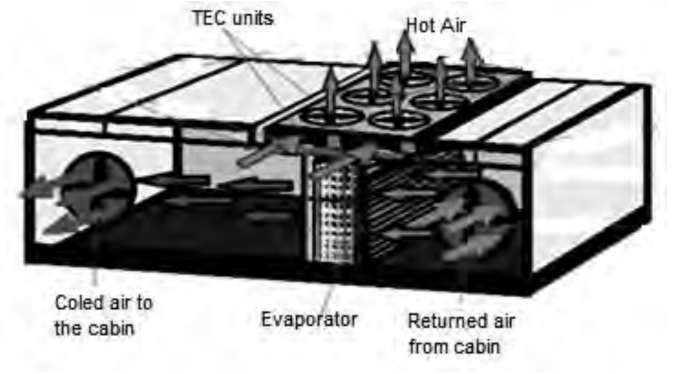


Fig. 2. The working principle of device

The secondary part is located inside the cabin and it consisted of:

1. A pair of internal fans (12V, 0.5A) their function is to circulate air between the cab and the device (main piece).

2. An air gate as in figure 3.

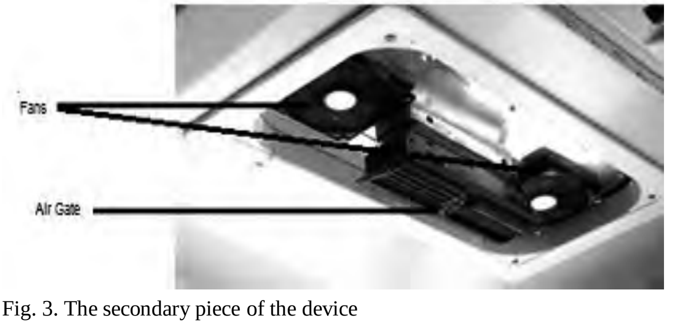


Fig. 3. The secondary piece of the device

The cold side of TEC units are turned on which in turn cooled the water inside the tank underneath, then the pump circulates the cooled water through the evaporator, since the system is closed, the water returns to the tank as a result of that the air passes through the evaporator is cooled and forced to the cabin by the secondary part fan.

The air temperature is directly dependent on both the fan speed of air discharge and the number of the operating thermal units (TEC), the lowering in air temperature is directly proportional to the fan air discharge speed, in other word, reducing the air speed leads to a decrease in air temperature and vice versa .the number of thermal levels is inversely proportional to the air temperature, thus increasing the number of working TEC units leads to lowering air temperature and vice versa. The hot side of the thermal units is cooled by finned panels along with fans installed on top of them that is by conducting air circulation between them and the outside environment. This process is done directly with the operation of the thermal units.

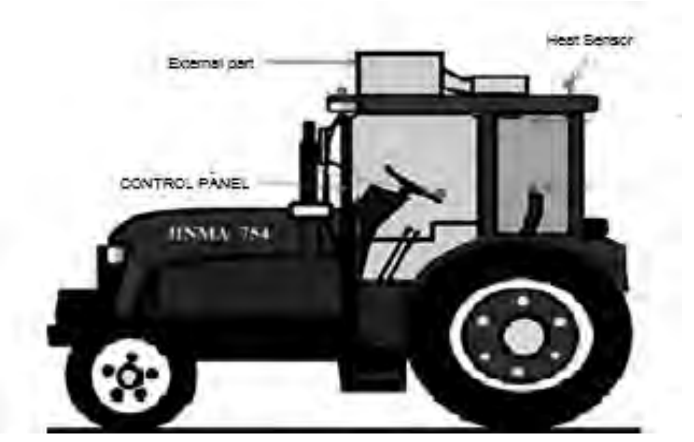

Fig. 4. The components and setting of the system devices

The temperature inside and outside the cabin was measured using a sensor of the W1209 type of temperature control switch. The following equation was adopted to calculate the difference:

$$\Delta T = T_{out} - T_{in} \tag{1}$$

where,

$\Delta T$: temperature difference (k).
$T_{out}$: outside temperature ($^oC$).
$T_{in}$: cabin temperature ($^oC$).

The cooling load was calculated from the following equation (Mohy, 2003):

$$Qc = M\ Cp\ \Delta T \tag{2}$$

where,

Qc: Cooling load (W).
M: mass flow rate of air (kg /s).
Cp: specific air temperature (J / kg.k).

The coefficient of performance is defined as the ratio of cooling load to the capacity of the battery (Raut & Walke, 2012):

$$COP = Qc / Pc \tag{3}$$

where,

Qc: Cooling load (W).
Pc: Input power of battery (W).

The results that gained from the test were statistically analysed by using SAS software, the treatments named as follow:

The number of TEC (C) with three levels: C1 for two units of TEC; C2 for four units of TEC and C3 for six units of TEC.

The fan speeds for air flow (B) with two levels: B1 for fan speed of 1.2 m/s and B2 for fan speed of 3.6 m/s

## RESULTS AND DISCUSSION

### Differences in heat temperature (ΔT)

The results showed significant differences in terms of the speed of air discharged from the fan (B), in the thermal differences, whereby the first speed (B1) recorded the higher differences in heat temperature of 7.23°C; the second fan speed recorded 6.39°C (Table 1). As for the levels of the thermal units (C), a significant difference in the heat differences was recorded, whereby the third level of thermal units (C3) registered the highest difference in heat temperature of 10.39°C in comparison with the first level of the thermal units (C1) that which recorded the least differences in heat temperature of 3.578°C, that's might due to the fact that increasing the levels of thermal units lead into saving of a higher cooling power, thus a better ability in decreasing the heat temperature of the air.

Table 1. Effect of TEC levels and fan speeds for air flow on temperature differences between outside and inside cab

| | | Differences in temperature |
|---|---|---|
| Number of TEC (C) | C1 | 3.58 |
| | C2 | 6.48 |
| | C3 | 10.39 |
| Fan speeds for air flow (B) | B1 | 7.23 |
| | B2 | 6.40 |

### Cooling power (Qc)

The results in Table 2 present that the speed of air discharge (B) indicted a significant differences in cooling power, whereby the first speed (B1) recorded the highest cooling power of 228.14 W in comparison with the second (B2) that registered the lowest cooling power of 205.47, due to the fact that air speed is inversely proportional to cooling power. Thus increasing air discharged leads to decreasing cooling power. The results also indicated that the levels of thermal units (C) showed significant differences in cooling power trait, whereby the third thermal unit- level (C3) recorded the highest cooling power of 425.19 W in comparison with the first level of the thermal unit (C1) that recorded the lowest cooling power of 48.81W.

Table 2. Effect of TEC levels and fan speeds for air flow on cooling power (cooling load)

| | | Cooling power (cooling load) |
|---|---|---|
| Number of TEC (C) | C1 | 48.81 |
| | C2 | 176.71 |
| | C3 | 425.19 |
| Fan speeds for air flow (B) | B1 | 228.14 |
| | B2 | 205.47 |

### Coefficient of performance (COP)

The results showed that the fan speed (B) indicated significant differences in the trait of COP, whereby the first speed (B1) recorded the highest performance efficiency of 0.547 in comparison with the second speed (B3) that recorded the lowest COP of 0.485 (Table 3). The results also showed that the levels of the thermal units (C) indicated significant differences in terms of COP trait, whereby the third level of thermal units (C3) recorded the higher COP of 0.826 in comparison with the first level of thermal units (C1) that recorded the lower COP of 0.238.

Table 3. Effect of TEC levels and fan speeds for air flow on coefficient of performance

| | | Coefficient of performance |
|---|---|---|
| Number of TEC (C) | C1 | 0.24 |
| | C2 | 0.48 |
| | C3 | 0.83 |
| Fan speeds for air flow (B) | B1 | 0.55 |
| | B2 | 0.48 |

## CONCLUSIONS

1. Air discharged speeds from the internal fan have a distinct impact on the studied traits, whereby decreasing the velocity of the fan led to increasing: difference of heat temperature, cooling power and coefficient of performance.
2. The levels of thermal units indicated an impact on all the studied properties, whereby the first level of the thermal unit recorded a distinct increasing in temperature differences, coefficient of performance along with a decreasing in the time consumed to cooling the cabin, vice versa in terms of the first level.

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# KEYWORDS INDEX

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