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Response of sugar beet to humic substances and foliar fertilization with potassium

Reakcja buraka cukrowego na substancje humusowe i dolistne nawożenie potasem

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Abstract

Sugar beet (*Beta vulgaris* L.) requires fertile soils with high biological activity, rich in minerals and organic nutrients. Biological properties of soil, such as enzymatic and microbial activity, can be effectively improved through the application of humic substances. This enables an increase in growth dynamics and, consequently, in the yield. The aim of this study was to assess sugar beet germination, depending on the soil application of the humic preparation Humistar (12% of humic acids, 3% of fulvic acids) as well as to assess the yield of sugar beet storage roots and the content of sugar in these storage roots, depending on soil applications of Humistar and/or foliar application of potassium fertilizer Drakar (31% K_2O, 3% N). The field experiment was conducted in the soil classified as Mesic Typic Hapludalfs. Soil application of Humistar contributed to a reduction in sugar beet germination, measured as % of plants germinated within 14 days after sowing. However, the growth of plants in soil with Humistar was more intensive than in the control. A significant, positive influence of Humistar and Drakar on the yield of sugar beet roots has been found. Application of the two treatments did not produce better results than the use of each of them separately. Sugar content in roots was not affected by experimental factor. The study showed that both soil application of humic substances and the use of foliar potassium fertilizer can improve the yield of sugar beet and, consequently, increase the biological yield of sugar from storage roots.

Keywords: Drakar, germination, Humistar, storage root yield

Streszczenie

Burak cukrowy (*Beta vulgaris* L.) wymaga żyznej gleby o wysokiej aktywności biologicznej, bogatej w składniki mineralne i organiczne. Biologiczne właściwości gleby, takie jak aktywność mikrobiologiczna i enzymatyczna, można skutecznie poprawić poprzez zastosowanie substancji humusowych. Pozwala to na poprawę dynamiki wzrostu, a w konsekwencji plonowania roślin. Celem niniejszych badań była ocena kiełkowania buraka cukrowego, w zależności od doglebowego stosowania preparatu humusowego Humistar (12% kwasów humusowych, 3% kwasów fulwowych), jak również ocena plonu korzeni spichrzowych buraka cukrowego oraz zawartości w nich cukru, w zależności od doglebowego stosowania Humistaru i/lub stosowania dolistnego nawozu potasowego Drakar (31% K_2O, 3% N). Doświadczenie polowe przeprowadzono na glebie płowej typowej. Doglebowe stosowanie Humistaru przyczyniło się do zmniejszenia zdolności kiełkowania buraka cukrowego, mierzonej jako % nasion, które wykiełkowały w ciągu 14 dni po wysiewie. Jednakże wzrost roślin w glebie traktowanej Humistarem był bardziej intensywny niż w kontroli. Stwierdzono istotny, pozytywny wpływ Humistaru i Drakaru na plon korzeni buraka cukrowego. Zastosowanie dwóch testowanych preparatów nie przyniosło jednak lepszych efektów niż zastosowanie każdego z nich osobno. Czynnik badawczy nie wpływał na zawartość cukru w korzeniach. Badania wykazały, że zarówno doglebowe stosowanie substancji humusowych, jak również wykorzystanie dolistnego nawozu potasowego może poprawić wydajność buraków cukrowych, a tym samym zwiększyć wydajność biologiczną cukru z korzeni spichrzowych.

Słowa kluczowe: Drakar, Humistar, kiełkowanie, plon korzeni spichrzowych

Introduction

Sugar beet (*Beta vulgaris* L.) is the most important crop which provides sugar in the area of temperate climate (Barłóg et al., 2010; Barłóg, 2013). The advantages of the beet plant include a high sugar content in the storage roots and low water consumption (Neseim et al., 2014). Due to its high productivity, sugar beet requires fertile soils with high biological activity, rich in mineral and organic nutrients, especially when grown in adverse weather conditions (Grzebisz et al., 2005). Previous studies show that the application of humic substances contributes to the improvement of soil microbial activity (Ulukan, 2008) and positively affects the uptake of most nutrients (Canellas and Olivares, 2014). It has a stimulating effect on the growth of plant cells (Nardi et al., 2002). In the current scientific literature, there are no research results on the impact of humic substances on nitrogen uptake from the soil and nutrition of sugar beet plants with this nutrient. This effect in relation to other plants has been demonstrated in studies by Panuccio et al. (2001). Humic substances cause an increase in the length and weight of shoots and roots, the number of lateral roots, seedling growth and germination (Ulukan, 2008). They have a greater impact on the root growth than aerial parts of plants (Cooper et al., 1998; Nardi et al., 2002), which suggests their particular importance in the cultivation of root crops. The use of a liquid, humic substance, which is the same as in this study, i.e. the extract of leonardite (naturally occurring, brown-black, oxidized form of lignite coal), contributed to a significant increase in the storage root yield of ordinary carrot (Dobrzański et al., 2008). Cooper et al. (1998) found an increase by 45% in weight of creeping bentgrass roots in 10 cm deep layer of soil as a result of foliar application of the extract from leonardite. The plant supply in potassium is also an important factor in shaping the quality and quantity of the yield of sugar beet storage roots (Salami and Saadat, 2013). The positive effect of potassium on the biochemical and physiological processes resulting in an increased yield of storage roots and leaves of sugar beet (Salami and Saadat, 2013; Neseim et al., 2014). Both humic substances and potassium can affect the nutrition of plants, which can be assessed by measuring the SPAD index (Soil and Plant Analysis Development) on currently developing leaves (Malavolta et al., 2004; Ghasemi et al., 2017). This index is positively correlated with the content of chlorophyll in the leaves. However, chlorophyll content usually has no stronger correlation with yield of sugar beet (Pulkrábek et al., 2001). According to the study by Ghasemi et al. (2017), the SPAD index measured on sugar beet leaves is significantly positively correlated with the sugar yield.

The aim of this study was to assess: germination of sugar beet, depending on the soil application of the humic substance (1); yield and concentration of sugar in the sugar beet roots depending on soil application of humic substance and foliar application of potassium (2); relationships between the values of leaf greenness (SPAD) in various sugar beet stages of growth and the yield of roots and leaves (3).

Materials and methods

The location and design of the study

The subject of research was sugar beet, 'Lubelska' variety. The study included field and laboratory experiments performed in 2006-2008. Field experiments were carried out in completely randomized blocks design, in Chrząstowo (17°35'E, 53°09'N) near Bydgoszcz, on the soil classified as Mesic Typic Hapludalfs (Soil Survey Staff, 2010). It was characterized by a very high content of available phosphorus, potassium and magnesium (172.8 mg P, 185 mg K and 93.3 mg Mg per kg of dry soil). The soil was moderately rich in organic carbon (8.03 $g \cdot kg^{-1}$) and was characterized by a neutral reaction (pH in 1 M KCl 6.71). Laboratory trials were performed at the Department of Agronomy UTP in Bydgoszcz.

Field experiment description

The factor of this field experiment was the type of treatment used in the cultivation of sugar beet: humic substance Humistar – the extract of leonardite (naturally occurring, brown-black, oxidized form of lignite coal), containing 12% of humic acids and 3% of fulvic acids (1), foliar fertilizer Drakar, containing 31% of K_2O and 3% of N (2), Humistar and Drakar (3) and the Control, not treated with any of these specimens (4). Plots with an area of 29.7 m^2 were scheduled according to the randomized block design with 4 replications. Sugar beet sowing was performed using a point seeder in 45 cm row spacing, on the 18th, 16th and 22th of April, respectively, in the years 2006, 2007 and 2008. Humistar was used in the form of spraying soil before sowing sugar beet at 40 $dm^3 \cdot ha^{-1}$. Drakar was applied as top dressing in two doses of 3 $dm^3 \cdot ha^{-1}$. The first dose was applied at the 6-12 leaf stage (6-16 June) and the second 10 days later. Each of the treatment was used upon dilution with water at 250 $dm^3 \cdot ha^{-1}$ solution. Pre-sown fertilization of sugar beet with mineral phosphorus and potassium was applied in the spring. Phosphorus was used at a rate of 80 $kg \cdot ha^{-1}$ P_2O_5 and potassium was used at a rate of 100 $kg \cdot ha^{-1}$ K_2O in the form of potassium salt (40%). Nitrogen was applied twice; 1^{st} as pre-sown rate (100 $kg \cdot ha^{-1}$ N) and 2^{nd}

rate as top dressing at the 6 leaf stage (20 kg·ha^{-1} N). On both dates ammonium nitrate was used. Chemical weed control was carried out using the preparation Pyramin 65 WG (chloridazon 65%) at a rate of 4 kg·ha^{-1}, immediately after the sowing of sugar beet. Measurements of the SPAD value were made four times during the growth of sugar beet (phase BBA: 22-24, 31-34, 35-38 and 39). Measurements were made on the youngest, fully developed leaves of 30 plants in each plot using chlorophyll meter SPAD-502.

Plants were collected manually on the 18th, 3rd, and 20th of October in the years 2006, 2007 and 2008, respectively. The yield of roots and leaves was measured in each plot. Moreover, the total number of roots, and the numbers of small (with a thickness of less than 4 cm), medium (thickness 4-8 cm) and large (having a thickness of greater than 8 cm) roots were counted. From each plot a sample of roots was taken for chemical analysis. Sugar content was determined using the polarimetric method. The determination was performed on VENEMA automatic analyzer in Nakło Sugar Factory. Biological yield of sugar (BYS) was calculated based on storage root yield (SRY) and sugar content (SC), according to the formula: BYS [Mg·ha^{-1}] = SRY [Mg·ha^{-1}] · SC [%]. Biological yield of sugar was calculated separately for each plot.

Laboratory experiment description

In laboratory trials conducted in parallel with the field tests in 2006-2008, the seed germination parameters of sugar beet 'Lubelska' were evaluated. Beet seeds were sown in the soil of the experimental field from Chrząstowo. One sample of soil was taken from the treatment with Humistar, after its application, and the other was taken at the same time from the control plots. The soil was placed in 4 plastic cuvettes of 60 x 40 cm with a layer thickness of approximately 5 cm and 50 seeds of the tested variety of sugar beet were placed to a depth of approximately 1 cm. Following the recommendations of International Seed Testing Association (1985), the cuvettes were placed in a room with a temperature of 20 °C. Soil moisture was maintained by spraying it with distilled water. The evaluation of the germination parameters was made 14 DAS (days after sowing). In each cuvette % of plant germinate was calculated (number of seedlings: number of seeds sown · 100%) and the FM (fresh mass) of 20 seedlings was weighed. The DW (dry weight) of the seedlings was determined after drying them in an electric dryer at a temperature of 50 °C and cooled in a desiccator. Weighing of the samples was carried out on a laboratory scale ensuring 0.001 g accuracy of reading.

Statistical analyses

Data from the field trials concerning the yield of sugar beets, sugar content and sugar yield, SPAD value, and the number of sugar storage roots in three classes of size were checked for the normal distribution by the Shapiro-Wilk's test at $P<0.05$. The normally distributed variables were proceeded by the one-way ANOVA in completely randomized block model (GLM with four replicates) to verify the working hypotheses regarding the impact of humic substance and/or foliar fertilizer on sugar beet. The F test was calculated for the data as the synthesis with the random effect of years

(MIXED PROC with three years). For significant effects from *F* test the dependent variable means were separated using HSD Tukey's test at P<0.05.

The germination capacity from sugar beet seeds in the control and treated with Humistar as well as the biomass (fresh and dry) of seedlings in laboratory trials were compared using *t*-Student test at P<0.05.

To determine the biological yield of sugar (Y) by the independent variables: X_1 – yield of sugar beet storage roots, X_2 – yield of sugar beet leaves, X_3 – number of large sugar beet storage roots, X_4 – SPAD value at 2-6 leaf stage, and X_5 – SPAD at 14-16 leaf stage, the multiple regression was used in the forward stepwise model for each of treatment. The goodness of fit of the regression equations were calculated using adjusted R^2, F ratio and RSEM. The results were processed using STATISTICA data analysis software system version 10 (StatSoft, 2011).

Results and discussion

Germination of sugar beet in the laboratory experiment

The germination of sugar beet in the laboratory was mediocre. The percentage of plant germinated 14 DAS was on average 83.6 relative to the seeds sown (Table 1). In a study by Mikita and Gutmański (2002), laboratory germination of sugar beet sown in filter paper ranged from 54 to 93% depending on soil and weather conditions of seed production. In a study by Sliwińska and Pedersen (1999), it was even 97-99%. Soil application of Humistar in the present work exerted an ambiguous effect on sugar beet germination. On the one hand, it contributes to reducing the germination of sugar beet plants measured as % of germination during 14 DAS (Table 1).

Table 1. Germination parameters of sugar beet 14 days after sowing – means for 2006-2008

Treatment	Germination [%]	Weight of 20 seedlings [g]	
		Fresh mass	Dry mass
Humistar	82.5b	1.19a	0.101a
Control	84.8a	1.1a	0.097b
Mean	83.6	1.14	0.099

a, b – values followed by the same letter within particular columns are not significantly different at P<0.05

On the other hand, the growth of plants in soil with Humistar was more intense than in the control, as shown through significantly higher DW of the seedlings in this treatment. In the current scientific literature, there are no results concerning the effect of humic substances on the parameters of seed germination of sugar beet. Response of other plants to this factor depends on the type of substance and the method of application (Matysiak et al., 2011; Traversa et al., 2013). Soil application of the same humic substances used in studies with corn had no significant effect on germination and on the DW of plant germ (Szczepanek and Wilczewski, 2016).

Yield of sugar beet in field experiment

The weather conditions were favorable for the yield of sugar beet in all years of the field study. Thermal conditions were generally similar to the long-term average for the area of research. Only in 2006, a substantially higher average monthly air temperature in July, September and October compared to the long-term average was stated (Table 2). Precipitation in vegetal seasons of 2006 and 2007 were above the long-term average while in 2008, slightly below average. In 2006, there was a shortage of rainfall in June and July, high total rainfall in August and very favorable thermal conditions in September and October. In 2008, a shortage of rainfall in May and June was stated. However, higher than average rainfall in March and April allowed collecting enough water in the soil for the initial plant growth.

Table 2. Air temperatures and precipitations during growing season of sugar beet

Month	Mean air temperature [˚C]				Total precipitations [mm]			
	2006	2007	2008	1980-2008	2006	2007	2008	1980-2008
March	-1	5.4	3.1	2.7	21.9	55.2	53.5	35
April	7.8	9	8	8.3	60.4	16.6	40	29.6
May	12.8	14.2	13.7	14	67.4	83.5	13.8	47.4
June	17.2	18.2	17.3	16.8	14.6	111.7	19.6	67.6
July	22.6	18	18.9	19.1	28.5	88.9	65	70.7
August	17.4	18.1	17.7	18.6	163.9	29.4	101.3	59.8
September	15.9	12.7	12.7	13.2	55.6	39.5	27.3	45.2
October	10.3	7.2	8.5	8.8	8.5	22.6	57.9	33.5
Mean/ Total	12.8	13.8	13.1	13.3	356.7	385.3	293.2	310.1

The results are presented as the mean of three years of the study, due to the lack of interaction between the experimental factor and years of research in relation to the yield of sugar beet. A significant, positive, and uniform impact of humic substances (Humistar) and foliar potassium fertilizer (Drakar) on the yield of sugar beet roots in relation to the control has been stated (Table 3). Application of the two treatments did not produce better results than the use of each of them separately. There was also a positive impact of Drakar and Humistar with Drakar on the yield of leaves (Table 3).

Table 3. Yield of sugar beet – means for 2006-2008

Treatment	Yield of storage roots [$Mg \cdot ha^{-1}$]	Yield of leaves [$Mg \cdot ha^{-1}$]
Humistar	77.7 ± 1.35a	40.4 ± 1.65ab
Humistar + Drakar	78.2 ± 1.42a	41.3 ± 1.58a
Drakar	78.7 ± 1.67a	41.1 ± 1.5a
Control	75.3 ± 1.02b	39.4 ± 1.62b
Mean	77.5 ± 0.7	40.5 ± 0.78

a, b – values followed by the same letter within particular columns are not significantly different at $P<0.05$

Table 4. The economic effect of the Humistar and Drakar application – means for 2006-2008

Treatment	Increase in yield compared to control [$Mg \cdot ha^{-1}$]	Value of additional yield* [$PLN \cdot ha^{-1}$]	Cost of preparations** and its application*** [$PLN \cdot ha^{-1}$]	Economic effect [$PLN \cdot ha^{-1}$]
Humistar	2.4	312	427	-115
Humistar + Drakar	2.9	377	613	-236
Drakar	3.4	442	186	+256

*the price of yield (storage roots together with value of the pulp) was assumed, according to data presented by the Agricultural Advisory Centre in Minikowo - 130 $PLN \cdot Mg^{-1}$ (http://www.ekonomika.kpodr.pl/attachments/article/178/Burak%20cukrowy.pdf)

**cost of preparations (196 PLN per 20 dm^3 of Humistar and 122 PLN per 5 dm^3 of Drakar), was assumed, according to the data presented on 11.11.2017 by “Shop of your plants” https://dlaroslin.pl/

***cost of preparations application 35 $PLN \cdot ha^{-1}$, was assumed, according to data presented by Top Agrar Polska (https://www.topagrar.pl/articles/top-technika/ceny-uslug-rolniczych-2017)

The financial value of the additional yield, obtained as a result of Humistar application amounted to PLN 312$\cdot ha^{-1}$. This amount was lower by 115 PLN per hectare than the cost of purchasing this product and its application (Table 4). However, Drakar's high profitability has been demonstrated. The financial value of the yield increase was higher by PLN 256·ha^{-1} than the cost incurred.

The studies showed no significant effect of the studied factor on the number of storage roots of sugar beet in particular size groups (Table 5). So far, there has not been any scientific literature referring field study effects of an extract from leonardite on the growth and yield of sugar beet.

Table 5. Number of storage roots [pcs per m^2] – means for 2006-2008

Treatment	Size of roots		
	Small*	Medium	Large
Humistar	0.4 ± 0.06a	3.7 ± 1a	5.1 ± 0.9a
Humistar + Drakar	0.3 ± 0.05a	3.6 ± 1a	5.1 ± 0.9a
Drakar	0.4 ± 0.05a	3.7 ± 1a	5 ± 0.9a
Control	0.4 ± 0.04a	3.7 ± 1a	4.9 ± 0.9a
Mean	0.4 ± 0.02	3.7 ± 0.5	5 ± 0.4

a, b – values followed by the same letter within particular columns are not significantly different at P<0.05

*division due to the thickness of storage roots: small – up to 4 cm; medium – 4-8 cm; large – above 8 cm

The results of field studies concerning the effect of preparations produced from leonardite on the root yield of other crops are overwhelmingly positive (Cooper et al., 1998; Dobrzański et al., 2008). In the study by Dobrzański et al. (2008), the soil and foliar application of liquid humic substances led to an increased commercial yield of common carrot storage roots from 1.2 to 8.6% compared to the control. The positive results obtained in this study, concerning the effect of leonardite extract used to soil on the growth of sugar beet seedlings in the laboratory and the yield of storage roots in the field, confirm the advantageous properties of this treatment. In this study, an increase in the yield of storage roots of sugar beet resulting from the application of Humistar was 3.2% higher to compare to the control. The yield-forming effect described here was significant, but relatively low compared to the findings for other plants (Cooper et al. 1998; Seyedbagheri, 2008; Canellas et al., 2013). According to Cooper et al. (1998), the effect of humic substances on the yield may be limited in case of a good supply of plants in minerals. In addition, according to research by Tóth et al. (2015), the effect of humic substances on the yield of sugar beet may increase significantly with increasing doses of this preparation up to 500 kg·ha^{-1}. Increasing the yield of storage roots resulting from the foliar application of potassium fertilizer Drakar amounted to 3,400 kg·ha^{-1}, that relatively means 4.5% increase in yield and increase by 567 kg of storage roots per 1 kg of fertilizer. In the study described by Nabila et al. (2014), effect of foliar spraying of sugar beet with 2% solution of K_2O allowed for an increase in the yield of storage roots by 4.8%

compared to the control. The effectiveness of Drakar in this study can be regarded as satisfying, cause the soil for field study had very high content of available forms of potassium. In addition, potassium was applied pre-sown to the soil in a dose of 100 kg·ha^{-1} K_2O substantially coincides with the plant needs for that nutrient.

Table 6. Leaf greenness index (SPAD) of sugar beet – means for 2006-2008

Treatment	Phase of sugar beet growth/BBA code			
	2-6 leaves/ BBA - 22-24	6-10 leaves/ BBA - 31-34	10-14 leaves/ BBA - 35-38	14-16 leaves/ BBA - 39
Humistar	30.8 ± 0.5ab	34.6 ± 0.5a	40.7 ± 0.8a	42.7 ± 1.4b
Humistar + Drakar	31.1 ± 0.4a	34.2 ± 0.6a	40.7 ± 0.7a	44.5 ± 1.8a
Drakar	30.3 ± 0.5b	33.9 ± 0.7a	39.9 ± 0.7a	43 ± 1.6b
Control	30.9 ± 0.4ab	34.5 ± 0.5a	40.5 ± 0.9a	42.5 ± 1.5b
Mean	30.8 ± 0.2	34.3 ± 0.3	40.4 ± 0.4	43.2 ± 0.8

a, b – values followed by the same letter within particular columns are not significantly different at $P<0.05$

The leaf greenness index increased with advancing of plants growth. Across the experiment it ranged from 30.8 at the 2-6 leaf stage to 43.2 at the 14-16 leaf stage (Table 6). That index hardly corresponded to the experimental factor. At the 2-6 leaf stage it was significantly higher in combined treatment (Humistar+Drakar), than in the treatment with Drakar only. At 6-10 and 10-14 leaf stages, there was no dependence of this index on the factor studied, whereas in the last measurement period, the leaf greenness index was significantly higher after the application of Humistar and Drakar than that in treatments with the Humistar and compared to the control. In the study by Tsialtas and Maslaris (2008), the SPAD value index in sugar beet was slightly modified even by different nitrogen fertilization. Increasing the fertilizing component in the range from 0 to 240 kg·ha^{-1} of N resulted in a significant increase of the SPAD index values in one of the three years of research. The authors observed the high dependence of the index on the time of measurement. Therefore significant differences in the value of this index at different stages of sugar beet growth (37.5-43.1%), found in the present study, and a slight variation under the influence of preparations used (2-4.5%), confirm the results of previous research in this area.

Content and biological yield of sugar in storage roots of sugar beet

Sugar content in fresh storage roots did not differ between the treatments and the control (Table 7). The lack of Humistar and Drakar effect on the sugar content may result from the higher yield of sugar beet storage roots that corresponded to the higher biological yield of sugar. Similar conclusions were also reported by

Wojciechowski et al. (2002), who explained that the biological yield of sugar to a greater extent depends on the increasing yield of roots than on sugar content.

Table 7. Content of sugar in storage roots and biological yield of sugar – means for 2006-2008

Treatment	Content of sugar in fresh roots [%]	Biological yield of sugar [$Mg \cdot ha^{-1}$]
Humistar	17.2 ± 0.48a	13.4 ± 0.36a
Humistar + Drakar	17.1 ± 0.39a	13.3 ± 0.36a
Drakar	17.1 ± 0.4a	13.4 ± 0.34a
Control	17.1 ± 0.46a	12.8 ± 0.27b
Mean	17.1 ± 0.21	13.2 ± 0.17

a, b – values followed by the same letter within particular columns are not significantly different at P<0.05

Table 8. Regression equations of biological yield of sugar (Y) depending on the characteristics of sugar beets

Treatment	Regression equation	R^2	$F_{(5,42)}$	p	RSEM
Humistar	$Y = 1.31+0.26x_1^*–0.09x_2^*–0.14x_3^*+0.17x_4^* –0.2x_5^*$	0.77	4.04	0.05	0.82
Humistar+Drakar	$Y = 4.79+0.16x_1^*–0.05x_2^*–0.19x_3^*+0.19x_4^*–0.15x_5^*$	0.84	6.26	0.02	0.67
Drakar	$Y = 3.5+0.2x_1^*–0.07x_2^*–0.19x_3^*+0.19x_4^*–0.17x_5^*$	0.91	11.7	0.005	0.49
Control	$Y = 1.03+0.16x_1–0.11x_2–0.03x_3+0.2x_4–0.06x_5$	0.42	2.61	0.05	0.72
For mean data	$Y = 1.71+0.2x_1^*–0.08x_2^*–0.12x_3^*+0.19x_4^*–0.14x_5^*$	0.8	29.7	0.001	0.57

x_1 – yield of sugar beet storage roots, x_2 – yield of sugar beet leaves, x_3 – number of large sugar beet storage roots, x_4 – SPAD in 2-6 leaf phase, x_5 – SPAD in 14-16 leaf phase.

The overall equation of multivariate regression $Y=1.71+0.2x_1^*–0.08x_2^*–0.12x_3^*+0.19x_4^*–0.14x_5^*$ for the biological yield of sugar (Y) revealed the significant positive effect of the sugar beet yield of storage roots (b=0.2) and the leaf greenness index at the 2-6 leaf stage (b=0.19). Meanwhile the negative effect corresponded to the yield of sugar beet leaves (b=-0.08) number of large beets storage roots (b=-0.12) as well as to greenness index at BBA 39 stage (b=0.14). Similar trends between particular b coefficients and Y variable were obtained in all equations, but they altered with the significant power in treatments (Table 8). From the strongest to the weakest the relationships measured by R^2 were discovered at: Drakar (0.91), Humistar+Drakar (0.84), Humistar (0.77) and for the control (0.42). This allows to infer that humic substances and the foliar fertilizer improved the biological yield of sugar by the indirect impact of sugar beet storage roots yield and the greenness of leaves at an early stage.

Conclusion

Soil application of humic substance contributed to a reduction in laboratory germination capacity of sugar beet, measured 14 days after sowing. However, the growth of plants in soil with the humic substance was more intensive than in the control. The yield of sugar beet storage roots and biological yield of sugar have been positively affected by humic substance Humistar and potassium foliar fertilizer Drakar. Application of the two treatments did not produce better results than the use of each of them separately. The use of Drakar was economically justified, while the cost of Humistar application exceeded the financial value of the yield increase. Sugar content in fresh storage roots was not affected by the experimental factor.

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