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PROXIMITY EFFECT OF SPRING CEREALS AND LEGUMES IN STRIP INTERCROPPING. PART IV. RESPONSE OF TRITICALE TO THE PROXIMITY OF WHEAT, BARLEY, PEA AND YELLOW LUPINE

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ABSTRACT

Background. Because of its relatively low soil requirements and resistance to abiotic stress spring triticale is potentially a good component of mixtures (intercropping). The technologically easiest to use type of this agricultural method, i.e. mixed intercropping, despite having many advantages is not, unfortunately, gaining in importance due to problems related to crop protection and the variable composition of yield. An alternative is strip intercropping, which combines the advantages of pure sowing and intercropping. The production value of such cultivation depends on mutual interactions at the junction of neighbouring rows of different plant species. The aim of the undertaken experiments was to find out the response of spring triticale to the neighbouring occurrence of wheat, barley, pea and yellow lupine and to estimate the production effects of strip intercropping of triticale in the vicinity of plants of these species.
Material and methods. This study uses the results of field experiments conducted as part of research on mixed sowings carried out in 2008–2010 in Mochełek near Bydgoszcz (53°13' N; 17°51' E). The experimental factor was the location of a plant row, within a strip, for the first four rows into the strip from the neighbouring species. The first row (contact row) was 12.5 cm away from the first row of the neighbouring species. The experimental unit was subsequent plant rows each four metres long.
Results. Proximity of spring wheat, spring barley and pea was unfavourable for the growth and yield of spring triticale, especially in the row directly adjacent to a stand of the indicated species. The estimated reduction in triticale yield in strip intercropping, with three-meter wide strips in the two-sided neighbourhood of wheat, barley and pea, would amount to 2.67%, 4.85% and 4.36%, respectively. On the other hand, the proximity of yellow lupine resulted in a slight increase in the plant mass, including straw, the number of grains per spike and in grain yield, but only in the first row. The estimated increase in the yield of spring triticale grown in strip intercropping with yellow lupine, in 3-m-wide strips, was small and only amounted to 1.45%.
Conclusion. The selection of plant species to neighbour with spring triticale in strip intercropping had a significant impact on the effect of spring triticale cultivation.

Key words: border effect, competition, interspecific effect, proximity effect, strip intercropping, vicinity effect

INTRODUCTION

Triticale is cultivated in over 30 countries and interest in it is growing (McGoverin *et al*., 2011). The spring form of this species has fewer soil requirements than both spring wheat and spring barley and it is also characterized by a relatively high resistance to abiotic stress. Therefore, in view of the perceived climate changes its cultivation is becoming even more important (Blum, 2014; Jaśkiewicz, 2017).

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Triticale is used primarily as animal feed (pigs, poultry and ruminants) both as grain and in the form of silage (Salmon *et al*., 2004; Vatandoost *et al*., 2007; Zarghi and Golian, 2009). The above mentioned values encourage composing multi-species mixtures (intercropping) with the participation of this cereal and this is supposed to increase the stability of feed production in adverse environmental conditions (Wysokiński and Kuziemska, 2019). Stabilization of the overall production level per unit area by using mixtures (Rudnicki, 2005; Tsubo *et al*., 2005; Sainju *et al*., 2010; Gałęzewski *et al*., 2012; Brooker *et al*., 2015) is, however, associated with a variable quality of the yield obtained in subsequent growing seasons despite the same cultivation assumptions being undertaken (Sobkowicz, 2005; Lamb *et al*., 2007; Gałęzewski, 2010a; b). As a consequence, it is difficult to balance feeds (Theunissen, 2004).

In mixed intercropping the species forming the mix are located in the same rows (Vandermeer, 1989) and this significantly limits the possibilities of optimizing fertilization and often limits or even prevents herbicidal protection. Analternative is strip intercropping, because with the right width of strips it is possible to optimize the cultivation technology for individual species (Burczyk, 2003; Sanchez *et al*., 2010; Głowacka, 2014; Gou *et al*., 2016; Liu *et al*., 2017). In addition, in the case of an adverse effect to the proximity of antagonisti species (Gałęzewski *et al*., 2017), neighbouring strips can be separated with a technological path that reduces the adverse phenomenon by using the border effect (Iragavarapuand Randall, 1996; Gałęzewski *et al*., 2013). Therefore, the hypothesis was adopted that the justification of growing spring triticale in strip intercropping will depend on the selection of neighbouring species.

The aim of this study was to investigate the response of spring triticale to the proximity of spring wheat, spring barley, pea and yellow lupine and to estimate its yields in strip intercropping with these plant species.

MATERIAL AND METHODS

The present study is a part of research on the effect of the proximity effect of spring cereals and legumes carried out in the Department of Agronomy of the University of Science and Technology in Bydgoszcz. The methodology coincides with previously published parts of a manuscript on this research (Gałęzewski *et al*., 2018a; b; c). Source material consists of the results of a multiple, one-factor field experiment aimed at finding the effect of growing spring triticale 'Dublet' in the direct vicinity of spring wheat 'Bombona', spring barley 'Antek', pea 'Ramrod' and yellow lupine 'Lidar'. The experiment was carried out at the Experimental Station of the Faculty of Agriculture and Biotechnology in Mochełek (53°13' N; 17°51' E) in a region of low average total precipitation – about 500 mm. The experiment was established in a split-block design in four replications. Plots were 150 cm wide and consisted of 12 plant rows with a spacing of 12.5 cm. The experimental factor was the location of a spring triticale plant row on the plot – four rows into the plot from the neighbouring species. The first row (contact row) was 12.5 cm away from the first row of the neighbouring species. The experimental unit was the subsequent plant rows each of which were four metres long (Fig. 1). Based on the results of a previous study (Gałęzewski *et al*., 2017), the fourth plant row was assumed as being free from any PE and, therefore, represented the interior of the field. Plots were situated with their longer sides on the north-south axis.

The experiment was conducted in 2008–2010. All plant species were sown at one date. Depending on the year, this was from 25th March to 5th April. In order to obtain an equal distance between plants in a given row, cereal grains were placed at points on sowing tapes (made from blotting paper) at a density of 45 plants per running m (360 grains$\cdot$m^{-2}). The sowing tapes were placed in the soil at a depth of 4 cm. Lupine and pea seeds were sown manually at a density of 10 plants per running m (80 seeds$\cdot$m^{-2}).

The experiments were located on light soil – Luvisol (LV), with the structure of loamy sand (IUSS Working Group WRB, 2015) in a field after winter oilseed rape. C_{org}content amounted to 6.2–6.6 g$\cdot$kg^{-1} DM of soil, depending on the year of the study, and the content of available forms of P and K was 63–69 and 94–172 mg$\cdot$kg^{-1}, respectively. Soil pH (1M KCl) was within the range 5.2–6.6. During spring soil cultivation, 30 kg P$\cdot$ha^{-1}, 66 kg K$\cdot$ha^{-1} and 34 kg N$\cdot$ha^{-1} were applied. Top-dressing nitrogen fertilization was applied only for cereals at a rate of 34 kg $N \cdot ha^{-1}$ at the tillering stage. Protection against weeds for all treatments was a foliar application of linuron – Afalon 450SC at a dosage of 1 $dm^3 \cdot ha^{-1}$.

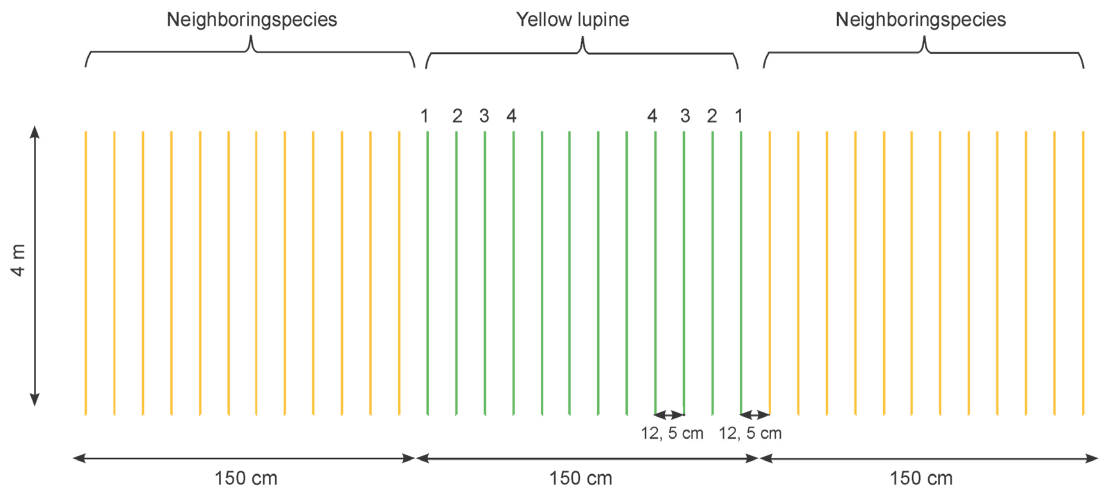

Fig. 1. Design of single experimental plot

Before harvest, triticale plant density was evaluated for the entire length of the particular rows. Plant harvest was carried out manually, separately in each row. The response of triticale plants to their location in relation to the neighbouring species was determined based on the following elements: height of the longest stem, straw mass, aboveground plant mass, spike density, grain number per spike, mass of 1000 grains and grain yield. All of the plants from the entire length of all the studied rows were used for the evaluation.

In the statistical processing of data from single experiments the analysis of variance was used, in the model appropriate for a split-block design, with Tukey's HSD test. In multiple experiments (synthesis), calculated F was determined based on recreated error extended by the interaction of the factor and the years. The statistical packet ANALWAR-5.2-FR based on Microsoft Excel was used. For every characteristic PE index was calculated as a quotient of the value of a characteristic that occurred, respectively, in one of the first three rows from the neighbouring species and in the fourth row (inside the field). PE = 1 indicated the lack of any proximity effect (neutrality of the tested species). PE < 1 indicated a negative effect of the neighbouring species on triticale. PE > 1 indicated a positive effect of the neighbouring species on triticale. Due to the lack of interaction between the factor and the study years, for the majority of the characteristics of the tested species, average results from the study years are presented in this study (Table 1).

Estimated yield for every running metre of 3 m-wide strips (24 rows), depending on the type of proximity, at row spacing 12.5cm, resulted from the following formulas:

– yield at no proximity = $24 \cdot x_4$,
– yield at one-sided proximity = $x_1+x_2+x_3+21 \cdot x_4$,
– yield at two-sided proximity = $2 \cdot x_1+2 \cdot x_2 +2 \cdot x_3+18 \cdot x_4$,

where:

$x_{1\text{-}4}$ – yield in the subsequent row away from the neighbouring species.

The width of 3 m assumed for the estimation is derived from the working width of the standard sowing machines used in agricultural practice. The actual plot width of 1.5 m resulted from minimizing the effect of soil changeability on the experiment and from the lack of necessity to duplicate the results from internal field rows.

Table 1. Significance of factor and significance of interaction factor and years in analysis of variance

Characteristic	Variation source	Species			
		wheat	barley	pea	lupine
Height	factor	–	–	–	*
	factor × year	–	–	–	–
Spike density	factor	*	**	–	**
	factor × year	–	–	–	–
Number of grains per spike	factor	**	**	**	**
	factor × year	–	–	–	–
Mass 1000 grains	factor	–	**	*	**
	factor × year	–	–	–	–
Grain yield	factor	*	*	*	**
	factor × year	–	–	**	–
Straw mass	factor	_	**	_	**
	factor × year	–	–	–	–
Plant mass	factor	*	**	**	**
	factor × year	–	–	–	–

*significant $P < 0.05$
** significant $P < 0.01$
– not significant

RESULTS

Triticale plants reacted similarly to the proximity of other plant species in all years of the research. This is evidenced by the lack of interaction between the factor and years in the analysis of variance for most cases (Table 1). The least susceptible feature to the PE was the height of the plants, only the proximity of lupine determined this trait.

The response of spring triticale to the proximity of spring wheat plants was mostly unfavourable. This is demonstrated by the PE index for most characteristics of plants in the first, second and third rows having values less than one, with the exception of mass of 1000 grains (Table 2). Any effect of the direct proximity of spring wheat on triticale plant height, mass of 1000 grains and straw mass was not proved. However, there was a tendency to increase the triticale straw mass in subsequent rows away from wheat. It was also found that triticale in the row directly neighbouring with wheat had a spike density lower by 18.3% and 18.7% fewer grains per spike than in the fourth row. The confirmed negative PE of wheat for triticale in respect of the number of grains per spike extended up to the third row, and in respect of spike density, up to the second row deep into the field of triticale. It was found that the yield of triticale grain in the first row, neighbouring directly with wheat, was 15.4% lower than in the fourth row and this negative PE of wheat was also confirmed in the second row. The negative PE of wheat was also observed in the mass of triticale plants, resulting in its reduction in the first row by 13.6% in relation to the fourth row.

Table 2. Response of spring triticale plants to the proximity of spring wheat

Characteristic	Unit	Subsequent plot row			
		1	2	3	4
Height	cm	93.9	92.6	95.8	99.5
	PE**	0.94	0.93	0.96	1.00
Spike density	(spike·running m^{-1})	60.7b*	69.0b	73.3a	71.8a
	PE	0.85	0.96	1.02	1.00
Number of grains per spike	grain	19.8c	21.6b	21.7b	23.5a
	PE	0.84	0.92	0.92	1.00
Mass of 1000 grains	g	31.5	32.0	31.9	31.5
	PE	1.00	1.02	1.01	1.00
Grain yield	(g·running m^{-1})	49.2b	49.8b	53.2ab	56.8a
	PE	0.87	0.88	0.94	1.00
Straw mass	(g·running m^{-1})	58.7	63.2	63.4	65.9
	PE	0.89	0.96	0.96	1.00
Plant mass	(g·running m^{-1})	108b	113ab	116.6ab	122.7a
	PE	0.88	0.92	0.95	1.00

* the same letter in a given row indicates the lack of significant diversification of the results
** proximity effect index, see Material and Methods

The PE index values indicate that the proximity of barley, similar to the previously discussed proximity of wheat, was not favourable to triticale (Table 3). This negative PE obtained statistical confirmation in most of the observed characteristics except for plant height and mass of 1000 grains. The direct proximity of barley resulted in a similar level of reduction in triticale spike density and in the number of grains per spike, i.e. by 37.2%, compared to the values in the fourth row. In the second and third rows this effect was only a statistically unconfirmed tendency for both characteristics. However, the increase in the mass of 1000 grains of triticale by 5.5% in the immediate vicinity of barley is quite surprising. Nevertheless, this positive effect did not have much significance in the overall assessment of the proximity effect because in the row neighbouring with barley the yield of grain, straw and biomass of triticale was lower by 37.1%, 26.4% and 31.1%, respectively, than it was in the fourth row. In rows 2 and 3 of triticale plants, the negative impact of barley in respect of the discussed characteristics was below statistical significance.

Also, the proximity of pea plants turned out to be unfavourable for triticale, because for most of the characteristics the PE index assumed values less than one (Table 4). There was a statistically unconfirmed tendency to develop lower stems and a smaller spike density and straw mass of triticale in rows neighbouring with pea, although the values of these characteristics improved in subsequent rows away from pea. The number of grains per spike of triticale plants neighbouring with pea was lower by 17.6% than in the fourth row, and this lowering effect reached to the third row. Also, the adverse impact of pea on the grain yield reached three rows deep into the triticale field, lowering it in these rows by 21.7% to 19.9% compared to the fourth row. A similar effect was obtained for triticale plant biomass and the corresponding values were 15.6% to 13.7%. The favourable PE of pea was found only for the mass of 1000 grains.

Table 3. Response of spring triticale plants to the proximity of spring barley

Characteristic	Unit	Subsequent plot row			
		1	2	3	4
Height	cm	92.3	91.8	93.8	96.1
	PE**	0.96	0.96	0.98	1.00
Spike density	(spike·running m^{-1})	51.3b*	62.8a	67.8a	70.4a
	PE	0.73	0.89	0.96	1.00
Number of grains per spike	grain	17.2b	21.2a	22.8a	23.6a
	PE	0.73	0.90	0.97	1.00
Mass of 1000 grains	g	33.0a	31.2b	31.0b	31.2b
	PE	1.06	1.00	0.99	1.00
Grain yield	(g·running m^{-1})	41.0b	45.1ab	49.8ab	56.2a
	PE	0.73	0.80	0.89	1.0
Straw mass	(g·running m^{-1})	52.6b	61.6a	62.0a	66.5a
	PE	0.79	0.93	0.93	1.00
Plant mass	(g·running m^{-1})	93.7c	106.7bc	111.8ab	122.8a
	PE	0.76	0.87	0.91	1.00

* the same letter in a given row indicates the lack of significant diversification of the results
** proximity effect index, see Material and Methods

Lupine turned out to be a favourable neighbourhood species for triticale; for each of the determined characteristics the PE index assumed values above one and this effect was confirmed statistically (Table 5). For almost each characteristic, however, the favourable effect of lupine on triticale was limited only to the first row where it increased the obtained values in the range from 8.0% to 44.4% in relation to the values obtained in the fourth row. The neighbourhood of lupine had the greatest effect (44.4%) on the increase in straw mass, while the favourable effect on grain yield was at the level of 15.5%.

Although the experiment showed a positive effect of lupine on triticale it did not result in significant production effects under the production conditions of strip intercropping (Table 6). With a row spacing of 12.5 cm, and assuming the strip width of 3 m, the estimated yields of spring triticale located between two strips of yellow lupine would increase by only 1.45% in relation to a single species field of triticale. One-sided proximity would give even smaller positive effects. When growing triticale in strip intercropping with pea, wheat or barley, one would expect a yield loss of about 1.34% (one-sided proximity with wheat) to 4.85% (two-sided proximity with barley).

Table 4. Response of spring triticale plants to the proximity of pea

Characteristic	Unit	Subsequent plot row			
		1	2	3	4
Height	cm	94.2	98.3	97.7	99.8
	PE**	0.94	0.98	0.98	1.00
Spike density	(spike· running m^{-1})	60.3	66.9	68.6	71.8
	PE	0.84	0.93	0.96	1.00
Number of grains per spike	grain	19.9b*	21.2b	21.2b	23.4a
	PE	0.85	0.91	0.91	1.00
Mass of 1000 grains	g	32.6a	31.0ab	30.7b	30.8b
	PE	1.06	1.01	1.00	1.00
Grain yield	(g·running m^{-1})	47.0b	47.0b	47.7b	57.2a
	PE	0.82	0.82	0.83	1.00
Straw mass	(g·running m^{-1})	59.4	61.1	60.1	65.7
	PE	0.90	0.93	0.91	1.00
Plant mass	(g·running m^{-1})	106.4b	108.1b	107.8b	122.9a
	PE	0.87	0.88	0.88	1.00

* the same letter in a given row indicates the lack of significant diversification of the results
** proximity effect index, see Material and Methods

Table 5. Response of spring triticale plants to the proximity of yellow lupine

Characteristic	Unit	Subsequent plot row			
		1	2	3	4
Height	cm	106.9a	91.8b	98.6ab	98.4ab
	PE**	1.09	0.93	1.00	1.00
Spike density	(spike·running m^{-1})	88.0a	74.9b	73.4b	70.9b
	PE	1.24	1.06	1.04	1.00
Number of grains per spike	grain	31.4a	26.7b	25.9b	23.1b
	PE	1.36	1.16	1.12	1.00
Mass of 1000 grains	g	34.2a	32.5ab	31.6b	30.9b
	PE	1.11	1.05	1.02	1.00
Grain yield	(g·running m^{-1})	65.3a	53.1b	56.8b	55.2b
	PE	1.18	0.96	1.03	1.00

Table 5 continue

Straw mass	(g·running m^{-1})	121.5a	85.2b	76.2b	67.5b
	PE	1.80	1.26	1.13	1.00
Plant mass	(g·running m^{-1})	186.8a	138.3b	133.0b	122.7b
	PE	1.52	1.13	1.08	1.00

* the same letter in a given row indicates the lack of significant diversification of the results
** proximity effect index, see Material and Methods

Table 6. Estimated spring triticale yield (g) for each running meter of 3-m-wide strips depending on the type of proximity

Proximity	Characteristic	Neighbouring species			
		wheat	barley	pea	lupine
No proximity	yield, g	1363	1348	1372	1324
One-sided proximity	yield, g	1345	1316	1342	1334
	difference in yield, g	-18.2	-32.7	-29.9	9.6
	difference in yield, %	-1.34	-2.42	-2.18	0.72
Two-sided proximity	yield, g	1326	1283	1313	1344
	difference in yield, g	-36.4	-65.4	-59.8	19.2
	difference in yield, %	-2.67	-4.85	-4.36	1.45

DISCUSSION

There are no reports in the literature about growing triticale in strip intercropping with other species, thus it is not possible to relate the present study results to the results obtained by other researchers. An analogy can be found in the responses of triticale plants growing in mixed intercropping with other species. Despite the fact that there is a relatively large amount of current data in the world literature referring to mixed intercropping in the species spectrum understood in this text, in most cases both the methodology and the aim of the studies by other authors do not correspond with this research, hence the discussion mainly refers to information from a decade or more ago.

The present study results indicate that the vicinity of wheat plants in strip intercropping negatively affected spring triticale plants and this was manifested to varying degrees for individual characteristics. The present results partly confirm the conclusions of Oleksy and Szmigiel (2001), who found that triticale in mixed intercropping with wheat developed smaller grain, fewer grains per spike and lower grain mass per spike. Those authors also showed the greater competitiveness of wheat than triticale. For winter forms of these species they also found that winter triticale grown in mixed intercropping with wheat developed fewer grains in spikes than was the case in pure sowing, also the greater the percentage of wheat in the seed mix the fewer grains per spike of triticale were found (Oleksy and Szmigiel, 2005). However, it should be taken into account that in both of these cited studies the plants of both species co-existed in one field, while in the present study the fields of both species were separated by a 12.5 cm wide inter row, which should mitigate the effect of interspecific competition. Despite this space separating the species the present results indicate competitive effects between wheat and triticale. Unfortunately, the divergence of the methodology between the present study and those of other authors does not allow for a direct comparison of the intensity of the competitive effects depending on the method of cultivating such mixtures.

The data obtained by the author show that spring barley turned out to be a stronger competitor for triticale than spring wheat. This can be said because, for most characteristics, the PE index assumed lower values when triticale was in the neighbourhood of barley rather than wheat. The phenomenon of interspecific competition between barley and triticale in mixed intercropping was studied by Sobkowicz and Podgórska-Lesiak (2009). The authors showed the dominance of barley over triticale. This dominance, however, depended on nitrogen fertilization. In conditions of fertilizing with this element the competitive advantage of barley was marked at the beginning and the end of growth. In the absence of fertilization, it took place in the ninth week after emergence. Tobiasz-Salach *et al.* (2011) also claims that barley was a stronger competitor for triticale in the mixture they used.

In the present study it was found that, as in the case of wheat and barley, the proximity of pea cultivation was unfavourable for triticale. However, while both barley and wheat are morphologically similar to triticale, pea differs from it in this respect. Since the competitive ability depends to a large extent on the structure of the aboveground and underground organs and their ability to collect water, nutrients and light (Schwartz *et al*., 2016), one could expect a vicinity effect that would differ significantly from that obtained for wheat and barley. However, in the present study the negative PE of pea on triticale did not differ much from the effect obtained for wheat and barley. The data presented by Ceglarek *et al*. (2007) show that the yield of triticale grain in mixed intercropping with pea is lower (than would have been expected from the proportions in the sowing) in relation to the yield of triticale in pure sowing. Because individual pea cultivars are characterized by high morphological diversity, Rudnicki and Wenda-Piesik (2002) hypothesized that their effect on triticale and the production effect of mixtures of these species depend on the choice of the pea cultivar. The pea cultivars studied by these authors, used as a component with triticale in mixed intercropping, showed both favourable and unfavourable traits. Therefore, in the multi-criteria assessment, relatively small differences in their suitability for mixed intercropping were found. However, in mixed intercropping with triticale, pea proved to be a weaker competitor (Rudnicki and Wenda-Piesik, 2002). Wenda-Piesik and Rudnicki (2007) found significant pea plant losses from the pea-triticale mixed intercropping field during the growing season, shortening of the stems, formation of a small number of pods and lower plumpness of seeds. These all led to pea yields in mixed intercropping that were mostly small, but clearly associated with individual varietal responses to such cultivation. Although the studies by the cited authors prove that pea is a weaker competitor than triticale, its presence in mixed intercropping has an impact on triticale. Such reactions are also indicated in the study by Vlachostergios *et al*. (2015) in which red pea (*Lathyruscicera* L.) resulted in a slower growth rate and productivity of triticale. Pea also negatively affects other cereal species, as evidenced in the studies by Tofinga *et al.* (1993), Ghaley *et al*. (2005), Corre-Hellou *et al.* (2006), Lauk and Lauk (2008) Michalska *et al*. (2008) and Wanic *et al*. (2012).

Both pea and yellow lupine fix atmospheric nitrogen. Initially, these plants use two sources of nitrogen, i.e. the mineral form contained in the soil and reserves accumulated in seeds, then atmospheric nitrogen is added to this (Dayoub *et al*., 2017). Thus, the competition between pea or lupine and triticale for soil nitrogen may be limited mainly to the early developmental stages. Slow root growth resulting from the construction of atmospheric nitrogen fixing structures and the expenditure of large amounts of energy on this process is the cause of the low ability of legumes to absorb minerals from the soil (Warembourg, 1983) and limits their competitive ability in relation to other neighbouring species (Carton *et al*., 2018). However, despite the common trait of atmospheric nitrogen fixation by pea and lupine, the PE of these species for triticale is quite different. The results of the present study show a favourable PE of yellow lupine cultivation for triticale, which confirms a previous study (Gałęzewski *et al*., 2017). This indicates a different response of plants of each species in strip intercropping (present study) than in mixed intercropping. Rudnicki and Kotwica (2007) in mixed intercropping showed the greater competitive strength of a single lupine plant for triticale than of a single triticale plant for lupine. It should be emphasized, however, that the presence of triticale in such mixtures has an impact on the legume component of the mixture, since Kotwica and Rudnicki (2004) show the negative effects of such a neighbourhood also on yellow lupine. In the present study it was shown that the presence of pea was unfavourable for triticale, and the presence of lupine was favourable. This is consistent enough with the results of the cited authors that in mixed intercropping yellow lupine was less able to compete with spring triticale than pea.

The present results show low production justification for growing triticale in strip intercropping with wheat, barley and pea. Taking into account previous reports (Gałęzewski *et al.*, 2017) about the unfavourable response of lupine to the proximity of triticale, in terms of production such cultivation of triticale and lupine is also not justified. The solution to this problem is to separate the fields of competing species with a technological path that reduces negative interactions, while losses resulting from the presence of unmanaged space can be compensated for by the border effect (Romani *et al.*, 1993; Gałęzewski *et al.*, 2013).

CONCLUSIONS

1. The proximity of spring wheat, spring barley and pea was unfavourable to the growth and development of spring triticale. Plant mass and grain yield in a row that was directly neighbouring with these species were significantly lower than from those inside the field.
2. Spring triticale in the row located directly next to yellow lupine responded favourably to its proximity. This was manifested in a significant increase in the value of all of the measured biometric characteristics of those plants.
3. Estimated increase in the yield of spring triticale grown in strip intercropping with yellow lupine, with 3-m-wide strips, would amount to only 1.45% at two-sided proximity and by half less at one-sided proximity. Wheat, barley and pea neighbouring with triticale caused a reduction in its yield for two-sided proximity by 2.67%, 4.85% and 4.36%, respectively.

REFERENCES

Blum, A. (2014). The abiotic stress response and adaptation of Triticale – A review. Central Res. Com., 42(3), 359–375. DOI:10.1556/CRC.42.2014.3.1.

Brooker, R.W., Karley, A.J., Newton, A.C., Pakeman, R.J., Schöb, C., Pugnaire, F. (2015). Facilitation and sustainable agriculture: a mechanistic approach to reconciling crop production and conservation. Funct. Ecol., 30(1), 98–107. DOI:10.1111/1365-2435.12496.

Burczyk, P. (2003). Zalety upraw pasowych z wsiewką roślin motylkowatych a możliwość ograniczenia strat azotu. Post. Nauk Roln., 50(2), 15–24.

Carton, N., Naudin, C., Piva, G., Baccar, R., Corre-Hellou, G. (2018). Differences for traits associated with early N acquisition in a grain legume and early complementarity in grain legume-triticale mixtures. AoB Plants, 10(1). DOI:10.1093/aobpla/ply001.

Ceglarek, F., Płaza, A., Buraczyńska, D. (2007). Zmienność plonowania mieszanek odmian grochu siewnego z pszenżytem jarym. Fragm. Agron., 2(94), 66–73.

Corre-Hellou, G., Fustec, J., Crozat, Y. (2006). Interspecific competition for soil N and its interaction with N_2 fixation, leaf expansion and crop growth in pea–barley intercrops. Plant Soil, 282, 195–208. DOI:10.1007/s11104-005-5777-4.

Dayoub, E., Naudin, C., Piva, G., Shirtliffe, S.J., Fustec, J., Corre-Hellou, G. (2017). Traits affecting early season nitrogen uptake in nine legume species. Heliyon, 3(2). DOI:10.1016/j.heliyon.2017.e00244

Gałęzewski, L. (2010a). Competition between oat and yellow lupine plants in mixtures of these species. Part I. Intensity of competition depending on soil moisture. Acta Sci. Pol. Agricultura, 9(3), 37–44.

Gałęzewski, L. (2010b). Competition between oat and yellow lupine plants in mixtures of these species. Part II. Intensity of competition depending on species ratio in mixture. Acta Sci. Pol. Agricultura, 9(3), 45–52.

Gałęzewski, L., Jaskulska, I., Piekarczyk, M. (2018a). Proximity effect of spring cereals and legumes in strip intercropping. Part I. Response of wheat to the proximity of triticale, barley, pea, and yellow lupine.

Acta Sci. Pol. Agricultura, 17(1), 23–32. DOI: 10.37660/aspagr.2018.17.1.3.

Gałęzewski, L., Jaskulska, I., Piekarczyk, M., Jaskulski, D. (2017). Strip intercropping of yellow lupine with oats and spring triticale: proximity effect. Acta Sci. Pol. Agricultura, 16(2), 67–75. DOI: 10.37660/aspagr.2017.16.2.2.

Gałęzewski, L., Jaskulska, I., Piekarczyk, M., Wasilewski, P. (2012). Oddziaływania wzajemne roślin w agrocenozach. W: Biologiczne, ekologiczne i środowiskowe uwarunkowania produkcji rolniczej, R. Rolbiecki, T. Barczak (red.), Bydgoszcz: Wyd. UTP, 75–86.

Gałęzewski, L., Jaskulski, D., Kotwica, K., Wasilewski, P. (2018b). Proximity effect of spring cereals and legumes in strip intercropping. Part II. Response of barley to the proximity of wheat, triticale, pea and yellow lupine. Acta Sci. Pol. Agricultura, 17(4), 195–204. DOI: 10.37660/aspagr.2018.17.4.2.

Gałęzewski, L., Kotwica, K., Piekarczyk, M. (2018c). Proximity effect of spring cereals and legumes in strip intercropping. Part II. Response of pea to the proximity of wheat, triticale, barley, and yellow lupine. Acta Sci. Pol. Agricultura, 17(2), 81–89. DOI: 10.37660/aspagr.2018.17.2.3.

Gałęzewski, L., Piekarczyk, M., Jaskulska, I., Wasilewski, P. (2013). Border effects in the growth of chosen cultivated plant species. Acta Sci. Pol. Agricultura, 12(3), 3–12, old-agric.act.pl/12(3)2013_1.

Ghaley, B.B., Hauggaard-Nielsen, H., Høgh-Jensen, H., Jensen, E.S. (2005). Intercropping of wheat and pea as influenced by nitrogen fertilization. Nutr. Cyc. Agroecosys., 73, 201–212. DOI:10.1007/s10705-005-2475-9.

Głowacka, A. (2014). The effect of strip cropping and weed control methods on yields of dent maize, narrow-leafed lupin and oats. Int. J. Plant Prod., 8(4), 505–529. DOI:10.22069/ijpp.2014.1722.

Gou, F., van Ittersum, M.K., Wang, G., van der Putten, P.E.L., van der Werf, W. (2016). Yield and yield components of wheat and maize in wheat–maize intercropping in the Netherlands. Europ. J. Agron., 76, 17–27. DOI:10.1016/j.eja.2016.01.005.

Iragavarapu, T.K., Randall, G.W. (1996). Border effect on yields in a strip – intercropped soybean, corn, and wheat production system. J. Prod. Agric., 9(1), 101–107.

IUSS Working Group WRB. (2015). Word Reference Base for Soil Resources 2014, update 2015 International soil classification system for naming soil and creating legends for soil maps. World Soil Resources Reports No. 106. Rome: FAO.

Jaśkiewicz, B. (2017). Wpływ technologii produkcji na plonowanie pszenżyta jarego w warunkach zmiennego udziału zbóż w strukturze zasiewów. Fragm. Agron., 34(2), 7–17.

Kotwica, K., Rudnicki, F. (2004). Efekty uprawy jarych mieszanek zbożowych i zbożowo-strączkowych na glebie kompleksu żytniego dobrego. Acta Sci. Pol. Agricultura 3(1), 149–156, old-agric.acta.pl.

Lamb, E.G., Shore, B.H., Cahill, J.F. (2007). Water and nitrogen addition differentially impact plant competition in a native rough fescue grassland. Plant Ecol., 192, 21–33. DOI:10.1007/s11258-006-9222-4.

Lauk, R., Lauk, E. 2008. Pea-oat intercrops are superior to pea-wheat and pea-barley intercrops. Acta Agric. Scand., Soil Plant Sci., 58, 139–144. DOI:10.1080/09064710701412692.

Liu, X., Rahman, T., Song, C., Su, B., Yang, F., Yong, T., Wu, Y., Zhang, C., Yang, W. (2017). Changes in light environment, morphology, growth and yield of soybean in maize-soybean intercropping systems. Field Crops Res., 200, 38–46. DOI:10.1016/j.fcr.2016.10.003.

McGoverin, C.M., Snyders, F., Muller, N., Botes, W., Fox, G., Manley, M. (2011). A review of triticale uses and the effect of growth environment on grain quality. J. Sci. Foof & Agric, 91(7), 1155–1165. DOI:10.1002/jsfa.4338.

Michalska, M., Wanic, M., Jastrzębska, M. (2008). Konkurencja pomiędzy jęczmieniem jarym a grochem siewnym w zróżnicowanych warunkach glebowych. Cz. II. Intensywność oddziaływań konkurencyjnych. Acta Sci. Pol., Agricultura, 7(2), 87–99, old-agric.acta.pl.

Oleksy, A., Szmigiel, A. (2001). Reakcja odmian pszenżyta na uprawę w mieszance z pszenicą w zależności od udziału komponentów. Biul. IHAR, 218/219, 285–292.

Oleksy, A., Szmigiel, A. (2005). Wielkość i struktura plonu mieszanek pszenżyta z pszenicą ozimą w zależności od udziału komponentów. Biul. IHAR, 236, 65–74.

Romani, M., Borghi, R., Alberici, R., Delogu, G., Hesselbach, J., Salamini, F. (1993). Intergenotypiccompetition and border effect in bread wheat and barley. Euphytica, 69, 19–31. DOI:10.1007/BF00021722.

Rudnicki, F. (2005). Porównanie reakcji jęczmienia jarego i owsa na warunki opadowo-termiczne. Fragm. Agron., 3(47), 21–32.

Rudnicki, F., Kotwica, K., (2007). Oddziaływanie konkurencyjne między zbożami jarymi i łubinami w mieszankach oraz efekty produkcyjne uprawy mieszanek na glebie kompleksu żytniego bardzo dobrego. Fragm. Agron., 4(96), 145–152.

Rudnicki, F., Wenda-Piesik, A. (2002). Przydatność odmian grochu do mieszanek ze zbożami jarymi na glebach kompleksów pszennych. Część II. Przydatność odmian grochu do mieszanek z pszenżytem jarym. Biul. IHAR, 221, 199–206.

Sainju, U.M., Stevens, W.B., Caesar-Ton That, T., Jabro, J.D., (2010). Land use and management practices impact on plant biomass carbon and soil carbon dioxide emission. Soil Sci. Soc. Am. J., 74, 1613. DOI:10.2136/sssaj2009.0447.

Salmon, D., Mergoum, M., Gomex-Macpherson, H. (2004). Triticale production and management. In: Triticale Improvement and Production, M. Mergoun, H. Gomez-Macpherson (eds), Rome: Food and Agriculture Organization of the United Nations, 27–48.

Sanchez, D.G.R., Silva, J.T.E., Gil A.P., Corona, J.S.S., Wong, J.A.C., Mascorro, A.G. (2010). Forage yield and quality of intercropped corn and soybean in narrow strips. Spanish J. Agic. Res., 8(3), 713–721.

Schwartz, L.M., Gibson, D.J., Young, B.G. (2016). Do plant traits predict the competitive abilities of closely related species? AoB Plants 8, plv147, DOI:10.1093/aobpla/plv147/2609501.

Sobkowicz, P. (2005). Shoot and root competition between spring triticale and field beans during early growth. Acta Sci. Pol. Agricultura, 4(1), 117–126, old-agric.acta.pl.

Sobkowicz, P., Podgórna-Lesiak, M. (2009). Ocena oddziaływania jęczmienia uprawianego w mieszance z pszenżytem lub grochem w zależności od dawki nawożenia azotem. Fragm. Agron., 26(1), 115–126.

Theunissen, J. (2004). Application of intercropping in organic agriculture. Biol. Agric. Hortic., 15(1), 251–259. DOI:10.1080/01448765.1997.9755200.

Tobiasz-Salach, R., Boberecka-Jarmo, D., Szpunar-Krok, E. (2011). Assessment of the productivity and mutual interactions between spring cereals in mixtures. Fragm. Agron., 4(28), 116–122.

Tofinga, M.P., Paolini, R., Snaydon, R.W. (1993). A study of root shoot interactions between cereals and peas in mixtures. J. Agric Sci. Camb., 120, 13–24. DOI:10.1017/S0021859600073548.

Tsubo, M., Walker, S., Ogindo, H.O. (2005). A simulation model of cereal – legume intercropping systems for semi-arid regions: II. Model application. Field Crops Res., 93, 23–33. DOI:10.1016/j.fcr.2004.09.003.

Vandermeer, J. (1989). The ecology of intercropping. Cambridge University Press, Cambridge. DOI:10.1017/CBO9780511623523.

Vatandoost, M., Mesgaran, M.D., Valizadeh, R., Moghaddam, H.N. (2007). Effect of whole crop silages (triticale or barley) versus corn silage on performance of holstein lactating 820 dairy cows. J. Anim. Vet. Adv., 6, 344–348.

Vlachostergios, D.N., Dordas, C.A., Lithourgidis, A.S. (2015). Forage yield, protein concentration and interspecific competition in red pea-cereal intercrops. Exp. Agric., 51(4), 635–650. DOI:10.1017/S0014479714000519.

Wanic, M., Michalska, M., Myśliwiec, M. (2012). Competition for nitrogen between spring barley (*Hordeum vulgare* L.) and pea (*Pisumsativum*L.*sensulato*) in diversified soil conditions. Acta Sci. Pol. Agricultura, 11(3), 95–106, www.agricultura.acta.utp.edu.pl.

Warembourg, F.R. (1983). Estimating the true cost of dinitrogen fixation by nodulated plants in undisturbed conditions. Canadian Journal of Microbiology, 29, 930–937. DOI:10.1139/m83-149.

Wenda-Piesik, A., Rudnicki, F. (2007). Znaczenie doboru zbóż jarych i odmian grochu do mieszanek na glebie kompleksu żytniego dobrego. Zesz. Probl. Post. Nauk Roln., 516, 277–290.

Wysokiński, A., Kuziemska, B. (2019). The sources of nitrogen for yellow lupine and spring triticale in their intercropping. Plant Soil Environ., 65, 145–151. DOI:10.17221/644/2018-PSE.

Zarghi, H., Golian, A. (2009). Effect of triticale replacement and enzyme supplementation on performance and blood chemistry of broiler chickens. J. Anim. Vet. Adv., 8, 1316–1321.

Gałęzewski, L. (2020). Proximity effect of spring cereals and legumes in strip intercropping. Part IV. Response of triticale to the proximity of wheat, barley, pea and yellow lupine. Acta Sci. Pol. Agricultura, 19(2), 55–67. DOI: 10.37660/aspagr.2020.19.2.1

ODDZIAŁYWANIA SĄSIEDZKIE ZBÓŻ JARYCH I ROŚLIN BOBOWATYCH GRUBONASIENNYCH W UPRAWIE PASOWEJ ROŚLIN. CZ. IV REAKCJA PSZENŻYTA NA SĄSIEDZTWO PSZENICY, JĘCZMIENIA, GROCHU I ŁUBINU ŻÓŁTEGO

Streszczenie

Ze względu na stosunkowo małe wymagania glebowe i odporność na stresy abiotyczne pszenżyto jare jest potencjalnie dobrym komponentem mieszanek. Niestety z powodu problemów związanych z ochroną łanu i zmiany składu plonu technologicznie najłatwiejszy rodzaj takich upraw, tj. uprawa współrzędna, pomimo wielu zalet nie zyskuje na znaczeniu. Alternatywą jest uprawa pasowa, która łączy zalety siewów czystych i upraw współrzędnych. Produkcyjne walory takiej uprawy zależą od oddziaływań wzajemnych na styku sąsiadujących ze sobą rzędów różnych gatunków roślin. Celem eksperymentów było poznanie reakcji pszenżyta jarego na sąsiedzkie występowanie pszenicy, jęczmienia, grochu i łubinu żółtego oraz oszacowanie efektów produkcyjnych uprawy pasowej pszenżyta w sąsiedztwie roślin tych gatunków. W pracy wykorzystano wyniki doświadczeń polowych wykonanych w ramach badań nad siewami mieszanymi realizowanymi w latach 2008–2010 w Mochełku k. Bydgoszczy (53^{o}13’ N; 17^{o}51’ E). Czynnikiem doświadczalnym było położenie rzędu roślin na poletku – cztery rzędy w głąb poletka od gatunku sąsiedzkiego. Rząd pierwszy (stykowy) – oddalony był o 12,5 cm od pierwszego rzędu gatunku sąsiedzkiego. Jednostką doświadczalną były kolejne rzędy roślin o długości czterech metrów każdy. Sąsiedztwo pszenicy jarej, jęczmienia jarego i grochu było niekorzystne dla wzrostu i plonowania pszenżyta jarego, zwłaszcza w rzędzie występującym bezpośrednio obok łanu wskazanych gatunków. Szacowane zmniejszenie plonu pszenżyta w uprawie pasowej, przy pasach szerokości trzech metrów i dwustronnym sąsiedztwie pszenicy, jęczmienia i grochu, wyniosłoby odpowiednio 2,67%, 4,85% i 4,36%. Bezpośrednie sąsiedztwo łubinu żółtego wpłynęło na niewielkie zwiększenie masy roślin, w tym słomy, liczby ziaren w kłosie i plonu ziarna, ale tylko w pierwszym rzędzie. Natomiast oszacowany wzrost plonu pszenżyta jarego uprawianego pasowo z łubinem żółtym, przy pasach szerokości 3 m, był niewielki i wyniósłby zaledwie 1,45%. Dobór gatunków roślin sąsiadujących z pszenżytem jarym w uprawie pasowej ma istotny wpływ na efekty jego uprawy.

Słowa kluczowe: efekt bliskości, efekt brzegowy, efekt sąsiedztwa, konkurencja, oddziaływania międzygatunkowe, uprawa pasowa roślin