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# 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

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**ABSTRACT**

**Background.** Strip intercropping brings together the advantages of pure sowing and intercropping, but its production value depends on the reciprocal effect of the various species at the contact point of adjacent rows. The aim of the experiment was to establish the response of spring wheat to the neighbouring occurrence of spring triticale, barley, pea, and yellow lupine and the estimation of the production effect of strip intercropping of wheat in the proximity of those species.
**Material and methods.** In the experiment, the results of field experiments on mixed sowings carried out in the years 2008–2010 at the experimental station in Mochełek near Bydgoszcz (53°13' N; 17°51' E) were used. Experimental factor was the position of plant row on the plot: four rows into the plot away from the neighbouring species. First row (contact row) was situated 12.5 cm away from the first row of the neighbouring species. Experimental unit was subsequent plant rows, each 4 meters long.
**Results.** Proximity of spring triticale and spring barley was unfavourable to the growth and yield of spring wheat, especially in the row directly adjacent to the field with the above species. Estimated wheat yield decrease in strip intercropping, with 3-m-wide strips and bilateral proximity of triticale and barley, would amount to 1.4% and 1.8%, respectively. No significant positive or negative effect was found of the vicinity of pea to spring wheat, with the exception of favourable effect on its plant height. Direct vicinity of yellow lupine caused, on the other hand, an increase in plant mass, including straw, grain number per spike, and grain yield, but only in the first row. Estimated increase in the yield of spring wheat grown in strip intercropping with yellow lupine, with 3-m-wide strips, would amount to 3.6%.
**Conclusion.** Selection of plant species adjacent to spring wheat in strip intercropping has a significant effect on its cultivation.

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

## INTRODUCTION

Simultaneous cultivation of several plant species in one field, called mixed sowing, has numerous advantages. It increases agroecosystem biodiversity (Knudsen *et al*., 2004; Corre-Hellou *et al*. 2006; Li *et al*., 2009) and makes it possible to use environmental resources better, especially in the conditions of high changeability of soil in the field and weather throughout years (Fukai and Trenbath, 1993; Hauggaard-Nielsen *et al*., 2001; Sainju *et al*., 2010; Gałęzewski *et al*., 2012; Brooker *et al*., 2015). This type of cultivation usually ensures more stable field than pure sowings of the particular mixture components (Rudnicki, 2005; Tsubo *et al*., 2005). However, due to the changeability of habitat conditions, proportion of the particular species in

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mixture yield is different in every growth season and is often significantly different from the proportion of their sowing. This fact results mostly from diversified competitive potential of the species that form the mixture depending on the growth conditions (Sobkowicz, 2005; Lamb *et al*., 2007; Gałęzewski, 2010a, b). Understanding of interspecific effects that occur in mixed sowings on the one hand may be a premise for setting species proportion in the sowing material, but on the other hand it is difficult because the evaluation of this occurrence is based on different methodological assumptions and is expressed through numerous factors (Weigelt and Jolliffe, 2003; Gałęzewski *et al*., 2012).

Mixture yield is mostly used as fodder. Its variable composition makes it even more difficult, or even impossible to standardize the fodder, which, according to Theunissen (2004) is a major cause of low interest in this method of plant growth in intensive European agriculture. Another disadvantage of mixed sowing is different agricultural engineering of every species in pure sowing. Many agricultural engineering processes must be omitted or modified, which often limits its effectiveness.

Method of plant growth that limits the disadvantages of mixtures and at the same time partly maintains its advantages is strip intercropping (Burczyk, 2003; Gałęzewski *et al*., 2017). Occurrence of strips of different plant species next to each other increases biodiversity within the field and makes the appearance of positive interspecific effects possible (Burczyk, 1999; Głowacka, 2010; Sanchez, *et al*. 2010; Głowacka, 2014; Gou *et al*., 2016; Liu *et al*., 2017). The term ‘strip intercropping’ also corresponds to the sowing of single-species plants in the interrows of a second species, for example pea or soya in maize (Yang *et al*., 2014; Hu *et al*., 2016). If strips of given plant species are standardized to the working width of machines, then treatments suitable for their pure sowings may be applied, and yield may be harvested separately. However, it is important to know intraspecific effects between the plants that grow directly next to each other in order to use the positive effect of proximity, as close proximity may also limit the growth and yield of both or one of the growing species (Fortin *et al*., 1994, Iragavarapu and Randall, 1996; Jurik and Van, 2004). Potential negative effect may be limited by splitting plant strips with a path and using the border effect (Braun, 1978; Stawiana-Kosiorek *et al*., 2003; Gałęzewski *et al*., 2013).

The aim of the experiment was to establish the response of spring wheat to the neighbouring occurrence of spring triticale, spring barley, pea, and yellow lupine and the estimation of wheat yield in strip intercropping.

## MATERIAL AND METHODS

The present work is part of studies on the proximity effect of spring cereals and legumes carried out at the Department of Plant Production and Experimenting of the University of Science and Technology in Bydgoszcz. Therefore, the applied methodology was analogous to the one from earlier publications by the authors (Gałęzewski *et al*., 2017). Source material consisted of the results of multiple, one-factor field experiments, carried out in the years 2008-2010, the aim of which was finding the proximity effect of growing spring wheat in the direct vicinity of spring triticale, spring barley, pea, and yellow lupine. The experiment was carried out at the Experimental Station of the Faculty of Agriculture and Biotechnology in Mochełek (53°13’ N; 17°51’ E). Experimental plots were set up in a split-block design in four repetitions. One repetition consisted of two directly adjacent plots with two different plant species. Plots were 150 cm wide and consisted of 12 plant rows at the density of 12.5 cm. The experimental factor was the location of a plant row on the plot: four rows into the plot of the neighbouring species. The first row (contact row) was separated by 12.5 cm from the first row of the neighbouring species. The experimental unit was subsequent plant rows, each of which was 4 meters long. On the basis of the results of previous research (Gałęzewski *et al*., 2017), fourth plant row was assumed as being free from the proximity effect, representing field interior. Plots were situated with their longer side on a north-south axis.

All plant species were sown on one date. Depending on the year, sowing took place between March 25$^{th}$ and April 5$^{th}$. In order to obtain equal distance between plants in a given row, cereal grain was placed in points on sowing tapes (made from blotting paper) at the density of 45 plants per linear meter (360 plants·m$^{-2}$). Sowing tapes were placed in the soil at the depth of 4 cm. Lupine and pea seeds were sown manually at the density of 10 plants per linear meter (80 plants·m$^{-2}$).

The experiments were located on class IVa–IVb soil on the post after winter rapeseed. During spring soil cultivation, 30 kg·ha$^{-1}$ P, 66 kg·ha$^{-1}$ K and 34 kg·ha$^{-1}$ N were applied. Top-dressing nitrogen fertilization was applied only for cereals at the dose of 34 kg·ha$^{-1}$ N at the tillering stage.

Before harvest, wheat plant density was evaluated for the entire length of the particular rows. Plant harvest was carried out manually, separately for each row. Response of wheat plants to its location in relation to the neighbouring species was determined on the basis of the following elements: height of the longest blade, straw mass, plant mass, spike density, grain number per spike, mass of 1000 grains and grain yield. For the evaluation, all the plants from the entire length of all the studied rows were used.

In the statistical processing of data from single experiments, analysis of variance was used, model appropriate for split-block design, with the Tukey's HSD test. In multiple experiments (synthesis), calculated F was determined on the basis of recreated error extended by the interaction of factor and years. The packet of statistical programs ANALWAR-5.2-FR was used. For every characteristic, proximity effect (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 proximity effect (neutrality of the tested species). PE < 1 indicated negative effect of the neighbouring species on wheat. PE > 1 indicated positive effect of the neighbouring species on wheat. Lack of interaction between the factor and the study years, for the majority of the characteristics of the tested species, caused the presentation in the work of average results from the study years.

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

- yield at no proximity = $24 \cdot x4$,
- 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 meters, set for the estimation, resulted from the working width of standard sowing machines used in agricultural practice. Plot width of 1.5 m resulted from minimalizing the effect of soil changeability on the experiment and from the lack of necessity to manifold the results from internal field rows.

## RESULTS

Response of spring wheat to the proximity of spring triticale was mostly unfavourable. This is demonstrated by the values of the PE index of the characteristics of plants in the first, second and third row, which mostly amounted to less than one (Table 1). Effect on the direct proximity of spring triticale on spring wheat plant height was not confirmed (1$^{st}$ and 2$^{nd}$ row). However, plants from the third row, on average for the study years, were significantly lower (by 7.96%) than in the fourth row. In the row neighbouring with triticale, lower by 17.5% straw mass and by 16.2% biomass of wheat plants were obtained than in the fourth row. The response was, however, limited only to the first row, and in the subsequent rows the differences in relation to the fourth row were small and insignificant. The effect may have resulted, among others, from lower spike density by 8.8% in the contact row with triticale than in the middle of the field. No significant effect of triticale proximity was found on the number of grains per spike and the mass of 1000 wheat grains. On the other hand, lower wheat grain yield was found in the row directly neighbouring with triticale than in the subsequent rows. The difference, in relation to grain yield from the fourth row, amounted to 14.3%.

PE index values below 1.0 demonstrated, like in the case of triticale effect, negative effect of the proximity of barley on wheat (Table 2). In the direct proximity of barley, wheat (first row) formed blades lower by 11.1% than in the middle of the field. Also, significantly lower wheat straw mass was found in the contact row in relation to the fourth row, and the effect, although not statistically confirmed, was marked also in the second row. Lower plant biomass was noted only in the first row but the difference in relation to the fourth row amounted to 19.4%. Negative effect of the proximity of barley on spike density, grain number per spike, or the mass of 1000 wheat grains was not statistically confirmed. However, for spike density and the mass of 1000 wheat grains, a tendency for exhibiting lower values in the row neighbouring with barley than in the far-away rows was visible. Those tendencies were confirmed by significantly lower (by 15.9%) grain yield obtained from the first row than from the fourth row.

In the case of wheat and pea proximity, the PE index for cereals usually reached > 1.0, which indicated favourable wheat response to the proximity of pea (Table 3). The results, however, did not obtain statistical confirmation for the majority of biometric characteristics.

Proximity of yellow lupine ought to be acknowledged as favourable for wheat. PE index for all the biometric characteristics, except plant height, reached > 1.0 (Table 4). Wheat in the row directly neighbouring with lupine was significantly lower (by 5.54%) than in the fourth row. Both straw mass and the above-ground part mass of wheat in the first row was, on the other hand, significantly higher than in further rows, and in relation to the fourth row, the difference amounted to, respectively, 43.5% and 40.6%. Wheat spike density in the first row was higher than in the second row but it did not differ significantly in relation to the subsequent rows. Spikes of wheat grown in the direct vicinity of lupine had a higher grain number by 16.9% than spikes from the fourth row. However, no significant effect was found of the vicinity of lupine on the mass of 1000 wheat grains. Grain yield from the first row, directly neighbouring with yellow lupine, was higher by 35.9% than in the fourth row. The above positive effect of the vicinity of lupine on wheat yield was, however, limited to the first row.

**Table 1.** Response of spring wheat plants to the vicinity of triticale

| Characteristic | Unit | Subsequent plot row | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| Height | cm | 66.2ab* | 66.2ab | 64.7b | 70.3a |
| | PE** | 0.94 | 0.94 | 0.92 | 1.00 |
| Spike density | (spike·running $m^{-1}$) | 55.7b | 59.5a | 60.3a | 61.1a |
| | PE | 0.91 | 0.97 | 0.99 | 1.00 |
| Number of grains per spike | grain | 27.8a | 23.6a | 24.1a | 24.1a |
| | PE | 1.15 | 0.98 | 1.00 | 1.00 |
| Mass of 1000 grains | g | 29.4a | 30.4a | 30.0a | 30.2a |
| | PE | 0.97 | 1.00 | 0.99 | 1.00 |
| Grain yield | (g·running $m^{-1}$) | 37.7b | 43.2a | 43.7a | 44.0a |
| | PE | 0.86 | 0.98 | 0.99 | 1.00 |
| Straw mass | (g·running $m^{-1}$) | 59.1b | 71.3a | 71.4a | 71.7a |
| | PE | 0.82 | 0.99 | 1.00 | 1.00 |
| Plant mass | (g·running $m^{-1}$) | 96.9b | 114.5a | 115.1a | 115.7a |
| | PE | 0.84 | 0.99 | 0.99 | 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 2.** Response of spring wheat plants to the vicinity of barley

| Characteristic | Unit | Subsequent plot row | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| Height | cm | 61.4b* | 68.2a | 65.4ab | 69.1a |
| | PE** | 0.89 | 0.99 | 0.95 | 1.00 |
| Spike density | (spike·running $m^{-1}$) | 55.0a | 56.7a | 59.9a | 61.3a |
| | PE | 0.90 | 0.93 | 0.98 | 1.00 |
| Number of grains per spike | grain | 26.9a | 25.1a | 25.8a | 25.9a |
| | PE | 1.04 | 0.97 | 1.00 | 1.00 |
| Mass of 1000 grains | g | 26.9a | 29a | 29.6a | 30.2a |
| | PE | 0.89 | 0.96 | 0.98 | 1.00 |
| Grain yield | (g·running $m^{-1}$) | 37b | 41.6ab | 43.8a | 44.0a |
| | PE | 0.84 | 0.95 | 1.00 | 1.00 |
| Straw mass | (g·running $m^{-1}$) | 56.6b | 68.1ab | 72.2a | 72.2a |
| | PE | 0.78 | 0.94 | 1.00 | 1.00 |
| Plant mass | (g·running $m^{-1}$) | 93.6b | 109.6a | 116a | 116.1a |
| | PE | 0.81 | 0.94 | 1.00 | 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 3.** Response of spring wheat plants to the vicinity of pea

| Characteristic | Unit | Subsequent plot row | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| Height | cm | 68.3a* | 66.5b | 66.4b | 65.5b |
| | PE** | 1.04 | 1.01 | 1.01 | 1.00 |
| Spike density | (spike·running $m^{-1}$) | 55.8a | 57.1a | 57.5a | 62.8a |
| | PE | 0.89 | 0.91 | 0.92 | 1.00 |
| Number of grains per spike | grain | 24.8a | 23.2a | 27.5a | 24.8a |
| | PE | 1.00 | 0.93 | 1.11 | 1.00 |
| Mass of 1000 grains | g | 32.7a | 30.3a | 30.7a | 30.5a |
| | PE | 1.07 | 0.99 | 1.00 | 1.00 |
| Grain yield | (g·running $m^{-1}$) | 48.6a | 41.9a | 43.3a | 43.6a |
| | PE | 1.12 | 0.96 | 0.99 | 1.00 |
| Straw mass | (g·running $m^{-1}$) | 80.3a | 72.8a | 68.7a | 73a |
| | PE | 1.10 | 1.00 | 0.94 | 1.00 |
| Plant mass | (g·running $m^{-1}$) | 128.9a | 114.7a | 112.0a | 116.5a |
| | PE | 1.11 | 0.98 | 0.96 | 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 4.** Response of spring wheat plants to the vicinity of yellow lupine

| Characteristic | Unit | Subsequent plot row | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| Height | cm | 63.5c* | 65.7bc | 69.2a | 67.2ab |
| | PE** | 0.95 | 0.98 | 1.03 | 1.00 |
| Spike density | (spike·running $m^{-1}$) | 78.1a | 61.8b | 65.5ab | 64.1ab |
| | PE | 1.22 | 0.96 | 1.02 | 1.00 |
| Number of grains per spike | grain | 29.7a | 25.6b | 25.2b | 25.4b |
| | PE | 1.17 | 1.01 | 0.99 | 1.00 |
| Mass of 1000 grains | g | 31.4a | 30.6a | 30.1a | 30.1a |
| | PE | 1.04 | 1.01 | 1.00 | 1.00 |
| Grain yield | (g·running $m^{-1}$) | 59.8a | 46.3b | 44.9b | 44b |
| | PE | 1.36 | 1.05 | 1.02 | 1.00 |
| Straw mass | (g·running $m^{-1}$) | 104.6a | 78.6b | 72.9b | 72.9b |
| | PE | 1.43 | 1.08 | 1.00 | 1.00 |
| Plant mass | (g·running $m^{-1}$) | 164.4a | 124.9b | 117.8b | 116.9b |
| | PE | 1.41 | 1.07 | 1.01 | 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

Vicinity effect of wheat neighbouring with other species may be of practical significance in the case of strip intercropping. Assuming that, for this type of cultivation, 3-m-wide sowing machine is used, estimated yield of wheat grown in a strip between yellow lupine may be higher by 3.6% in relation to pure sowing of wheat (Table 5). In the case of one-sided vicinity, estimated yield increase would amount to 1.8%. The above differences may not be assumed as large. Two-sided vicinity of barley and triticale would decrease wheat yield by, respectively, 1.8% and 1.4%.

**Table 5.** Estimated spring wheat yield [g] for every running meter of 3-m-wide strips depending on the type of proximity

| Proximity | Characteristic | Neighbouring species | | | |
|---|---|---|---|---|---|
| | | triticale | barley | pea | lupine |
| No proximity | yield | 1056 | 1055 | 1046 | 1056 |
| One-sided proximity | yield | 1049 | 1045 | 1049 | 1075 |
| | difference in yield g | -7.4 | -9.5 | 3.1 | 19.0 |
| | difference in yield % | -0.70 | -0.90 | 0.29 | 1.80 |
| Two-sided proximity | yield | 1041 | 1036 | 1052 | 1094 |
| | difference in yield g | -14.8 | -19.0 | 6.2 | 38.0 |
| | difference in yield % | -1.40 | -1.80 | 0.58 | 3.60 |

## DISCUSSION

In literature, there is a lack of information that would make it possible to directly relate the present results to the results obtained by other authors. Most often, there is information on strip intercropping with the participation of such species as maize, soya, oats, and barley (Pendelton *et al*., 1963; West and Griffith, 1992; Fortin *et al*., 1994). Present results may, however, be indirectly related to the interspecific effects of wheat in mixed sowings. Treder *et al*. (2008a, b), on the basis of a pot experiment, demonstrated that barely is a stronger competitor for wheat than wheat is for barley. In mixed sowing with barley, in relation to pure sowing, dry matter of wheat underwent continuous reduction from tillering to earing and included blade and leaves to a similar degree. This unfavourable effect of barley was evident to the highest degree, however, in generative organ mass and yield. Also in the research by Tobiasz-Salach *et al*. (2011), barley was a stronger competitor for wheat than wheat was for barley. The quoted results may explain unfavourable effect of barley on wheat grown in neighbouring rows in the present research. Tobiasz-Salach *et al*. (2011) also demonstrated that in mixed sowings wheat was a stronger competitor than triticale. In the present research, the vicinity of triticale was not favourable to wheat, which could indicate the dominance of interspecific competition with triticale over intraspecific wheat competition. Romani *et al*. (1993) indicate that it is valid to split neighbouring wheat and barley fields with a 30-cm--wide path. Split of plants that unfavourably affect one another should result not only in the elimination of this phenomenon, but also in the compensation of unsown area thanks to the border effect (Gałęzewski *et al*., 2013). In national studies, there is a lack of results on wheat and pea competition, but there is no shortage of research on pea and barley mixture (Wanic *et al*., 2007; Michalska *et al*., 2008). Global research indicates that an increase in pea sowing density in the mixture with wheat decreases the participation of its grain in the yield (Lauk and Lauk, 2008). Competitiveness of wheat against pea increases, however, in the conditions of greater nitrogen fertilization (Ghaley *et al*., 2005). Lower nitrogen fertilization, on the other hand, makes it possible for competing plants to use light better in a dense field (Bedoussac and Justes, 2010). Due to high differences in the soil requirements of spring wheat and yellow lupine, there is a lack of scientific information on the proximity or coordinate effects of those plants in mixed sowing. Yellow lupine may, however, be cultivated on soils where wheat is cultivated. Results of the present study indicate in this case favourable effect of Fabaceae on wheat. Similar results were obtained by the authors in earlier research on the proximity effect of oats and triticale on yellow lupine (Gałęzewski *et al*., 2017).

## CONCLUSIONS

1. Vicinity of spring triticale and spring barley was unfavourable to the growth and yield of spring wheat plants. Plant and straw mass, as well as grain yield in the row directly neighbouring with those species, were significantly lower than inside the field.
2. No significant effect of the vicinity of pea on spring wheat plants was found, with the exception of plant height.
3. Spring wheat plants that grew directly next to yellow lupine responded favourably to its vicinity. Increase in plant mass, including straw, number of grains per spike, and grain yield occurred, however, only in the first row.
4. Estimated increase in the yield of spring wheat grown in strip intercropping with yellow lupine, at 3-m-wide strips, would amount to 3.6% at two--sided vicinity and would be lower by a half at one-sided vicinity. Triticale and barley, at two--sided vicinity with wheat, would cause a reduction in the yield of the cereal by, respectively, 1.4% and 1.8%.

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

### Streszczenie

Uprawa pasowa łączy ze sobą zalety siewów czystych i upraw współrzędnych, jednak jej produkcyjne walory zależą od oddziaływań wzajemnych na styku sąsiadujących ze sobą rzędów różnych gatunków. Celem eksperymentów było poznanie reakcji pszenicy jarej na sąsiedzkie występowanie pszenżyta jarego, jęczmienia, grochu i łubinu żółtego wraz z oszacowaniem efektów produkcyjnych uprawy pasowej pszenicy w sąsiedztwie tych gatunków. W pracy wykorzystano wyniki doświadczeń polowych wykonanych w ramach badań nad siewami mieszanymi realizowanymi w latach 2008–2010 w Mochełku koło 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 przeżyta jarego i jęczmienia jarego było niekorzystne dla wzrostu i plonowania pszenicy jarej, zwłaszcza w rzędzie występującym bezpośrednio obok łanu wskazanych gatunków. Szacowane zmniejszenie plonu pszenicy w uprawie pasowej, przy pasach szerokości trzech metrów z dwustronnym sąsiedztwem pszenżyta i jęczmienia, wyniosłoby odpowiednio 1,4% i 1,8%. Nie stwierdzono istotnego pozytywnego bądź negatywnego wpływu sąsiedztwa grochu na rośliny pszenicy jarej, z wyjątkiem korzystnego oddziaływania na wysokość jej roślin. Bezpośrednie sąsiedztwo łubinu żółtego spowodowało natomiast zwiększenie masy roślin, w tym słomy, liczby ziaren w kłosie i plonu ziarna, ale tylko w pierwszym rzędzie. Oszacowany wzrost plonu pszenicy jarej uprawianej pasowo z łubinem żółtym, przy pasach szerokości 3 m, wyniósłby 3,6%. Dobór gatunków roślin sąsiadujących z pszenicą jarą w uprawie pasowej ma istotny wpływ na efekty jej uprawy.

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