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COMPARISON OF THE COMPETITIVE ABILITY OF LEGUMES AGAINST WEEDS

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ABSTRACT

Background. Legumes are a very important element of crop rotation, they have a high potential for protein production. Reducing weed infestation of these plants during the critical period of competition is essential for crop success, previous crop value and high seed yields. Evaluation of the competitive ability of legumes grown in Poland against weeds can be a valuable indication of which species to grow in conditions of increased weed infestation of fields, reduced doses of herbicides, unfavorable weather conditions, or systemic limitations of weed control technology.
Material and methods. In a two-factor field experiment carried out in 2014–2015, the competitive ability of edible and fodder peas, yellow and white lupines and soybean against weeds was assessed. The reaction of these plants to chemical weed control and its lack was compared.
Results. Abandonment of herbicide protection, compared to the application of a mixture of soil herbicides containing linuron and clomazone immediately after sowing, significantly increased the number and weight of weeds. Lack of weed control of selected legume plants resulted in a proven decrease in seed yield of: edible pea by 20%, fodder pea by 23%, yellow lupine by 32%, white lupine by 23% and soybean by 77%%. The yield of the tested legume plants was negatively correlated with the weight and number of weeds.
Conclusion. The tested legume plants – edible pea, fodder pea, yellow lupine, white lupine and soybean – differed in their competitive ability against weeds. Soybean was the most sensitive to the presence of weeds, followed by yellow and white lupines, and the least sensitive were edible and fodder peas. In conditions of high weed infestation of fields and difficulties in keeping stands clean, the legume plant most recommended for cultivation is pea. Its cultivation allows obtaining seed yields of more than 3 $Mg \cdot ha^{-1}$, even in the absence of weed control.

Key words: pea, soybean, weed infestation, white lupine, yellow lupine

INTRODUCTION

Legumes are a very important element of crop rotation, they have a high potential for protein production, and their yielding depends to a large extent on precipitation and thermal conditions during the growing season (Podleśny and Bieniaszewski, 2012; Małecka-Jankowiak *et al*., 2016). An important factor affecting the yield of legumes is effective weed control (Vivian *et al*., 2013, Gugała *et al*., 2014; Rychcik *et al*., 2015). Reducing weed infestation of these plants during the critical period of competition is essential for crop success, previous crop value and high seed yields (Gugała and Zarzecka, 2011; Gugała *et al*., 2014, Sepat *et al*., 2017). Non-chemical methods are of fundamental importance in keeping weed-free fields for legume cultivation (Bakht *et al*., 2009; Gugała and Zarzecka, 2009, 2012b; Blecharczyk *et al*., 2011;

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Rychcik *et al*., 2015). However, the most effective weed control in the stands of these plants is obtained by applying soil herbicides (Bujak and Frant, 2009; Gugała and Zarzecka, 2011, 2012a), supported if necessary with foliar preparations (Szwejkowska, 2006; Sekutowski and Badowski, 2011; Younesabadi *et al*., 2013).

Problems with maintaining weed-free legume plantations are increasing. This is due to the withdrawal of highly effective and important active substances of herbicides (Directive 2009; Matyjaszczyk and Sobczak, 2017), the growing importance of pro-environmental cultivation technologies, including the organic system, as well as the often unfavorable weather conditions for effective weed control of legume plants. In the available literature, there are few works dealing with the subject of comparing the differentiated response of legumes to weed infestation. Difficulties with effective control of weed populations in stands of these crops often discourage the cultivation of these highly valuable plants in terms of nutritional value and crop rotation. Evaluation of the competitive ability of legumes grown in Poland against weeds can be a valuable indication of which species to grow in conditions of increased weed infestation of fields, reduced doses of herbicides, unfavorable weather conditions, or systemic limitations of weed control technology.

The aim of this study was to evaluate the competitive ability of edible and fodder peas, yellow and white lupines and soybeans against weeds. The reaction of these plants to chemical weed control and its lack was compared. The research hypothesis was adopted in the study that legume species differ in their sensitivity to the presence of weeds, which has a direct impact on the level of their yield.

MATERIAL AND METHODS

The assumed aim of the study was carried out by conducting a two-factor field experiment in a randomized split-plot design in four replications. The size of the plots for sowing and harvesting was 15 m^2. The experiment assessed the effect of chemical weed control and its absence on weed infestation and yield of edible and fodder peas, yellow and white lupines and soybean.

The experimental factors were:

A – method of protection (herbicides, no herbicides),

B – legume plant species (edible pea, fodder pea, yellow lupine, white lupine, soybean).

The study was carried out in 2014 and 2015 at the Research Station in Mochełek (53°13’ N; 17°51’ E), belonging to the Faculty of Agriculture and Biotechnology of the Bydgoszcz University of Technology, Poland. The study was carried out on lessive soil with fine-grained loamy sand grain size, soil quality class IVa, good rye complex. The previous crop for cultivated legumes was winter wheat.

Before sowing, phosphorus-potassium fertilization was applied in rates of 30.5 kg P·ha^{-1} and 66.4 kg K·ha^{-1}. Peas and lupines were sown in the first ten days of April, and soybean in the second ten days of April, with a row spacing of 21 cm and a depth of 4 cm. The sowing rate was: edible pea ('Akord'), fodder pea ('Turnia'), yellow lupine ('Perkoz') – 100 germinating seeds·m^{-2}. The sowing rate of white lupine (‘Butan’) and soybean (‘Merlin’) was 80 germinating seeds·m^{-2}. A mixture of soil herbicides Afalon Dyspersyjny 450 SC (linuron) at a dose of 1.0 dm^3·ha^{-1} and Command 480 SC (clomazone) at a dose of 0.2 dm^3·ha^{-1} was used for weed control, applied directly after sowing. The assessment of the state and degree of weed infestation was carried out about 7–8 weeks after weed control (BBCH 68-69) using the frame-weight method from an area of 1 m^2 in each plot (Domaradzki *et al*., 2001; Efficacy evaluation; Praczyk and Skrzypczak, 2004). Harvest was made from an area of 15 m^2 at the full seed maturity stage.

The results of the study were statistically processed using the analysis of variance, and the significance of differences between the means was estimated with the Tukey test, at the significance level of $P < 0.05$. The FR-ANALWAR 5.2 statistical software package was used in the calculations. The simple correlation coefficients between the number and air-dry matter of weeds and the yield of legume seeds were calculated using a Microsoft Office Excel spreadsheet. Correlation coefficients were verified at the significance level of $p = 0.05$ and $p = 0.01$ (Rudnicki 1992).

RESULTS

The course of weather conditions during the growth in the years of the study is presented in Table 1. In 2014, the average air temperatures were slightly higher compared to the average for 1981–2010, while the precipitation totals at the beginning of the growing season that year were higher than average, which was conducive to the growth of legumes and created good conditions for the action of applied soil herbicides. Meteorological conditions in the second period of the study were less favorable for the effectiveness of the applied herbicides and plant yield. Very small total rainfall at the beginning of the growing season had a negative effect on the growth and development of legume plants. Small precipitation totals in the spring of this year made it difficult for herbicides to penetrate into the soil solution and weeds. The weather conditions in 2015 prevented the revealing of the yielding potential of the cultivated plants and lowered the results of the synthesis.

Table 1. Weather conditions at Mochełek in during 2014–2015

Month	Year					
	Average temperature, °C			Precipitation, mm		
	2014	2015	1981–2010	2014	2015	1981–2010
March	5.6	4.1	2.5	49.7	35.7	31.9
April	9.9	7.5	7.9	40.7	15.6	27.0
May	13.3	12.4	13.3	65.7	21.6	49.3
June	16.0	15.7	16.1	44.9	33.0	52.8
July	21.5	18.5	18.6	55.4	50.4	69.8
August	17.2	20.9	17.9	57.3	20.3	62.6
September	14.4	13.8	13.1	25.9	52.4	46.0
Average	14.0	13.3	12.8			
Total				339.6	229.0	339.4

The dominant weed species in cultivated legume plants were: field violet (*Viola arvensis*), white goose-foot (*Chenopodium album*), small bugloss (*Lycopsis arvensis*), volunteer plants of winter oilseed rape (*Brassica napus*) and field horse-tail (*Equisethum arvense*). In total, 12 species of weeds were identified in the experiment.

Abandonment of herbicide protection, compared to the application of a mixture of soil herbicides containing linuron and clomazone immediately after sowing, significantly increased the number and weight of weeds by 124.9 pcs·m^{-2} (641%) and 136 g·m^{-2} (756%), respectively. A significant increase in the number and weight of weeds was found on average for all cultivated legumes and for each species separately (Tables 2 and 3). Significant differences in the number and weight of weeds in cultivated legumes were observed in the experiment. The lowest weed infestation was observed in field and fodder peas, higher in yellow and white lupines, and the highest in soybean. In the presented field experiment, interaction of the weeding method with legume plant species on weed infestation was proved. In weed-treated plots, the weed number was not significant (Table 2), but a higher weight of weeds was found in the weeded soybean (43.5 g·m^{-2}) compared to the weeded pea (3.1 and 5.7 g·m^{-2}) (Table 3). The maximum differentiation in the number and weight of weeds was found when chemical weed control was abandoned. The largest number of weeds was recorded in non-weeded soybean and white lupine, smaller in yellow lupine, and the smallest in field pea (Table 2). Also, the weight of weeds in non-weeded soybean was the highest in comparison to the weight of weeds in white and narrow-leaved lupines and peas (Table 3). Abandonment of weed control of selected legume plants resulted in a proven decrease in seed yield of: edible pea by 20%, fodder pea by 23%, yellow lupine by 32%, white lupine by 23% and soybean by 77% (Fig. 1). The yield of the tested legume plants was negatively correlated with the weight and number of weeds, and in the case of the correlation between the yield and the weight of weeds, it was a highly significant negative relationship (Table 4).

Table 2. Weed number (plants·m^{-2}) (average from 2014–2015)

Species (B)	Weed control methods (A)		Average
	herbicides	without herbicides	
Pea	8.4	80.1	44.2
Field pea	7.4	64.5	35.9
Yellow lupine	31.6	149.4	90.5
White lupine	17.4	211.5	114.5
Soybean	32.9	216.3	124.6
Average	19.5	144.4	81.9
$LSD_{(0.05)}$	A – 12.71; B – 28.50; B/A – 40.31; A/B – 28.42		

Table 3. Air-dried matter of weeds (g·m^{-2}) (average from 2014–2015)

Species (B)	Weed control methods (A)		Average
	herbicides	without herbicides	
Pea	3.1	55.3	29.2
Field pea	5.7	51.4	28.5
Yellow lupine	17.4	161.1	89.3
White lupine	20.3	197.2	108.8
Soybean	43.5	305.2	174.3
Average	18.0	154.0	86.0
$LSD_{(0.05)}$	A – 10.44; B – 23.4; B/A – 33.12; A/B – 23.353		

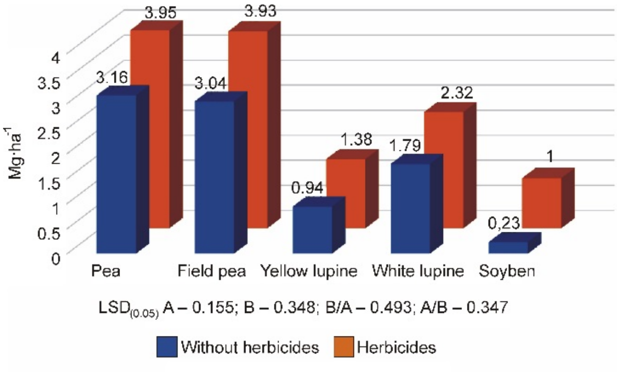

Fig. 1. Seed yield (Mg·ha^{-1}) of legumes (B) under the influence of weed control methods (A) (average from 2014–2015)

Table 4. Simple correlation coefficient between the seed yield and weed infestation

Seed yield	Weed infestation	
	weed number	air-dried matter of weeds
Pea	–0.316	–0.635**
Field pea	–0.522*	–0.741**
Yellow lupine	–0.681**	–0.671**
White lupine	–0.443	–0.611**
Soybean	–0.887**	–0.921**

Significance of the correlation coefficient r: *p = 0.05; **p = 0.01

DISCUSSION

Weeds are a major threat to legumes due to their slow initial growth. Therefore, the removal of competition from undesirable plants is essential to guarantee the conditions for obtaining high yields of high-quality seeds (Małecka-Jankowiak *et al*., 2016). The most effective method of weed control in legume cultivation is the use of herbicides, which is confirmed by the results of conducted studies, showing high yield protection efficiency of the applied mixtures of soil herbicides containing linuron and clomazone (Luboiński, 2017; Szymańska *et al*., 2017). The condition for the effective action of soil preparations is the optimal soil moisture, close to field water capacity (Sekutowski and Badowski, 2011). For this reason, the early sowing date of peas and lupines usually determines the good effectiveness of the herbicides used; it may be worse – as confirmed by conducted studies – in soybean sown later (Piekarczyk, 2006; Gugała *et al*., 2017). Difficulties in maintaining the purity of legume stands increase with reduction in the range of herbicide active substances (Directive, 2009; Matyjaszczyk and Sobczak, 2017), reducing the doses of herbicides (Domaradzki and Sadowski, 2002; Jędruszczak *et al*., 2010; Piekarczyk *et al*., 2019, 2020), in fields heavily infested with weeds (Rychcik *et al*., 2015), or under systemic control restrictions (Gołębiowska and Domaradzki, 2010). In such conditions, as confirmed by the completed study, it is best to grow pea. It allows obtaining seed yields of more than 3 Mg·ha^{-1} even in the absence of weed control. Early sowing date and short growing period, as well as good coverage of the soil surface by pea, result in lower yield losses due to the presence of weeds (Piekarczyk *et al*., 2020). Yields of yellow and white lupine and soybean in the case of heavy weed infestation are less favorable, these plants are more exposed to the negative impact of weeds and require effective weed control in stands (Luboiński, 2017). Thus, the production effects of legume cultivation depend to a large extent on cultivation methods and species diversity of weed communities (Rychcik *et al*., 2015).

CONCLUSIONS

1. The tested legume plants – edible pea, fodder pea, yellow lupine, white lupine and soybean – differed in their competitive ability against weeds.
2. Soybean was the most sensitive to the presence of weeds, followed by yellow and white lupines, and the least sensitive were edible and fodder peas.
3. In conditions of high weed infestation of fields and difficulties in keeping stands clean, the legume plant most recommended for cultivation is pea. Its cultivation allows obtaining seed yields of more than 3 Mg·ha^{-1}, even in the absence of weed control.

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PORÓWNANIE KONKURENCYJNOŚCI ROŚLIN BOBOWATYCH WOBEC CHWASTÓW

Streszczenie

Rośliny bobowate są bardzo ważnym elementem zmianowania, mają duży potencjał produkcji białka. Ograniczanie zachwaszczenia tych roślin w krytycznym okresie konkurencji ma zasadnicze znaczenie dla powodzenia upraw, ich wartości przedplonowej i dużych plonów nasion. Ocena zdolności konkurencyjnych uprawianych w Polsce roślin bobowatych wobec chwastów może być cenną wskazówką, które gatunki uprawiać w warunkach zwiększonego zachwaszczenia pól, obniżonych dawek herbicydów, niesprzyjających warunków atmosferycznych czy systemowych ograniczeniach technologii odchwaszczania. W doświadczeniu polowym dwuczynnikowym zrealizowanym w latach 2014–2015 oceniano zdolność konkurencyjną grochu siewnego jadalnego i pastewnego, łubinu żółtego i białego oraz soi wobec chwastów. Porównano reakcję tych roślin na zwalczanie chemiczne chwastów i jego brak. Zaniechanie ochrony herbicydowej w porównaniu z zastosowaniem bezpośrednio po siewie mieszaniny herbicydów doglebowych zawierających linuron i chlomazon zwiększyło istotnie liczbę i masę chwastów. Brak odchwaszczania wybranych roślin bobowatych spowodował udowodnione obniżenie plonu nasion: grochu siewnego jadalnego o 20%, grochu siewnego pastewnego o 23%, łubinu żółtego o 32%), łubinu białego o 23% oraz soi o 77%. Wielkość plonu testowanych roślin bobowatych była ujemnie skorelowana z masą i liczbą chwastów. Testowane rośliny bobowate – groch siewny jadalny, groch siewny pastewny, łubin żółty, łubin biały oraz soja – różniły się zdolnościami konkurencyjnymi wobec chwastów. Najbardziej wrażliwą na obecność chwastów była soja, następnie łubin żółty i biały, a najmniej groch siewny jadalny i pastewny. W warunkach dużego zachwaszczenia pól i trudności w utrzymywaniu czystości zasiewów najbardziej wskazaną do uprawy rośliną bobowatą jest groch siewny. Jego uprawa pozwala na uzyskiwanie plonów nasion w wysokości ponad 3 $Mg \cdot ha^{-1}$, nawet przy braku odchwaszczania.

Słowa kluczowe: groch siewny, łubin biały, łubin żółty, soja, zachwaszczenie