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RESPONSE OF DIVERSIFIED DOSES OF HERBICIDE MIXTURE ON WEED CONTROL AND YIELD IN WHITE LUPINE

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ABSTRACT

Background. The chemical weed control method plays a fundamental role in clean cultivation of white lupine. However, due to the threats caused by the active substances of herbicides in the natural environment, safer methods of weed control for white lupine plants should be sought. Among others, through the possibility of using in-soil herbicides in reduced doses.
Material and methods. A field experiment was carried out in the years 2014–2015, to evaluate the effect of herbicide mixture Dispersive Afalon 450 SC and Command 480 EC (contain linuron and clomazone), applied in various doses, on weed control and yield of white lupine.
Results. Application of in-soil herbicide mixture Dispersive Afalon 450 SC (linuron) + Command 480 EC (clomazone) in a mention the applied dose and a reduced by 25% dose decreased weed number and mass, as well as weed species diversity, which was reflected in an increased white lupine seed yield. In the experiment, no harmful phytotoxic effect of the applied doses of herbicides containing linuron and clomazone on the emerging plants of white lupine cultivar Butan was found.
Conclusion. Doses of herbicide mixtures containing linuron and clomazone decreased by 25% made it possible to obtain relatively less weed infestation and provide a high level of white lupine seed yield. Dose reduction of the tested herbicides by 50% significantly affected the growth and yield conditions of white lupine.

Key words: herbicide phytotoxicity, *Lupinus albus* L., seed yield, weed control

INTRODUCTION

White lupine (*Lupinus albus* L.) is one of Polish native legume species that have a high protein production potential, although it depends on the precipitation and thermal conditions during the growth season (Podleśny and Bieniaszewski, 2012; Małecka-Jankowiak *et al*., 2016). A very important factor that shapes legume yield, including lupine, is limiting infestation (Gugała *et al*., 2014; Rychcik *et al*., 2015). Effective weed control in the critical period at the beginning of crop growth protects these plants from harmful competition, ensuring optimal seed yield (Gugała and Zarzecka, 2011; Gugała *et al*., 2014). Non-chemical methods are essential for maintaining weed-free fields for lupine cultivation (Bakht *et al*., 2009; Gugała and Zarzecka, 2009; Blecharczyk *et al*., 2011; Gugała and Zarzecka, 2012b; Rychcik *et al*., 2015). However, the most effective weed control in the cultivation of this species is obtained with the application of in-soil herbicides (Gugała and Zarzecka, 2011, 2012a), complemented, if needed, by foliar treatments (Szwejkowska, 2006; Sekutowski and Badowski, 2011). The need to protect the natural environment is the reason for the withdrawal of other very effective and important active substances of herbicides (Directive 2009, Matyjaszczyk and Sobczak, 2017), which directly

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limits the possibility of the effective weeding of cultivated plants. Negative environmental effects of in-soil herbicide application (Domaradzki and Sadowski, 2002, Praczyk and Skrzypczak, 2004) may, however, be decreased, among others, through the decrease in herbicide doses (Piekarczyk, 2006; Jędruszczak *et al*., 2010; Piekarczyk *et al*., 2019). In the available literature, there is little research on the reduction of herbicide doses in legume plants. Reducing the intensity of chemical weed control must be introduced carefully, based on the knowledge of the weed infestation status, in order to prevent overpopulation of the fields by weeds and the development of weed resistance to the active substances of herbicides (Adamczewski, 2017). Due to the dominant traditional plough cultivation in Poland, the dominance of cereals in the cropping system, and the lack of practice of growing legumes one after the other, such a practice can be considered small.

The aim of the conducted research was to evaluate the possibility of weed management in white lupine using a mixture of herbicides containing linuron and clomazone (Dispersive Afalon 450 SC and Command 480 EC) in doses reduced by 25% and 50%. The research hypothesis was adopted in the study that reduced doses of those preparations would make it possible to maintain a low level of weed infestation and ensure a high level of white lupine yield.

MATERIAL AND METHODS

The adopted study goal was achieved through a one-factor field experiment in a split-bloc design in four repetitions. Plot size for sowing and harvest was 15 m^2. In the experiment, the effect of herbicide mixtures Dispersive Afalon 450 SC (linuron) and Command 480 SC (clomazone), applied in various doses, on weed infestation and white lupine yield was evaluated. The studied factors were the maintenance methods:

1) Control plot – no weeding,
2) Dispersive Afalon 450 SC (1.0 $dm^3 \cdot ha^{-1}$) + Command 480 EC (0.2 $dm^3 \cdot ha^{-1}$) – full dose,
3) Dispersive Afalon 450 SC (0.75 $dm^3 \cdot ha^{-1}$) + Command 480 EC (0.15 $dm^3 \cdot ha^{-1}$),
4) Dispersive Afalon 450 SC (0.5 $dm^3 \cdot ha^{-1}$) + Command 480 EC (0.1 $dm^3 \cdot ha^{-1}$).

Research was carried out in the years 2014 and 2015 at the Experimental Station in Mochełek, which is part of the Faculty of Agriculture and Biotechnology of the University of Science and Technology in Bydgoszcz, Poland. Study was carried out on lessive soil with fine-grained clay sand, class IVa, good rye complex. Winter wheat was the forecrop for white lupine.

Before sowing, phosphorus and potassium fertilization was applied in the doses of 30.5 kg $P \cdot ha^{-1}$ and 66.4 kg $K \cdot ha^{-1}$. Sowing was carried out in the first 10 days of April at the row spacing of 21 cm, at the depth of 4 cm. The number of sown white lupine plants cultivar Butan was 80 germinating $seeds \cdot m^{-2}$. It is an early fodder cultivar, the first one insensitive to sowing delay, plants with short side shoots, not showing excessive luxuriance. It has a shorter vegetation period by 2–14 days and a reduced sensitivity to fusarium diseases. The 'Butan' has a reduced alkaloid content of approximately 30–40%, and a high protein (32–37%) and fat (10–12%) content (https://www.hrsmolice.pl/pl/straczkowe/lubin-bialy/174-butan). In-soil herbicides were applied according to the scheme of the experiment directly after sowing. Herbicide phytotoxicity was determined after plant emergence (BBCH 12–13) with the valuation method in a nine-degree scale (Efficacy evaluation, Praczyk and Skrzypczak 2004). Evaluation of infestation condition and degree was carried out about 7-8 weeks after weeding (BBCH 68–69) with the frame-weight method from the area of 1m^2 on every plot (Domaradzki *et al*., 2001). The number and dry weight of weeds were determined. Before harvest, plant density and seed mass per plant were determined. Harvest was carried out from the area of 15 m^2 at full seed ripeness, and then mass of 1000 white lupine seeds was established.

Study results were statistically evaluated with the use of analysis of variance, and the significance of differences between the average values was estimated with the Tukey's test at the significance level of $P < 0.05$. In the data evaluation, statistical program package FR – ANALWAR 5.2 was used. The experimental area was not irrigated. Weather conditions were measured at an agrometeorological station about 400 m away from the experiment.

RESULTS

Weather conditions during plant growth in the study years are presented in Table 1. In 2014, average temperatures were slightly higher in comparison with the average from the years 1981–2010, whereas precipitation sums at the beginning of growth were higher than average, which was conducive to in-soil herbicide effect and white lupine plant growth. Weather conditions in 2015 were less favourable to the effectiveness of the applied in-soil herbicides and lupine yield. Low precipitation sums during the spring of that year made penetration of the applied herbicides into the soil solution. Very low precipitation sums at the beginning of growth also negatively affected the growth and development of white lupine plants.

Dominating weed species in white lupine were: field pansy (*Viola arvensis*), goose foot (*Chenopodium album*), small bugloss (*Lycopsis arvensis*), winter rapeseed self-seeding (*Brassica napus*), and field horsetail (*Equisethum arvense*). In total, 11 species of weeds were identified in the experiment, and the application of herbicide mixtures Dispersive Afalon 450 SC (linuron) and Command 480 EC (clomazone) limited weed biodiversity to 3–5 taxa, and totally eliminated six species (Table 2).

Application of in-soil herbicide mixture Dispersive Afalon 450 SC + Command 480 EC directly after sowing in white lupine cultivar Butan, in full and reduced doses by 25% and 50%, significantly decreased weed number and mass in comparison with the control plot with no weeding (Table 3). As a result of the application of herbicide mixture doses lowered by 25% in comparison with the full dose, a small and statistically insignificant increase in weed number and mass was found. Decrease in the dose of linuron and clomazone mixture by 50%, in comparison with the plot where the full dose was applied, caused a significant increase in weed number and mass by 47.4 plants$\cdot$m^{-2} (272%) and 46.0 plants$\cdot$m^{-2} (227%), respectively. No phytotoxic effect of the applied doses of preparations with linuron and clomazone on the emerging white lupine plants was found. Weeding white lupine with herbicide mixture Dispersive Afalon 450 SC + Command 480 EC applied in a full and a lowered dose by 25% significantly increased white lupine seed yield in comparison with the control plot. Reduction of linuron and clomazone doses by 25% and 50%, in comparison with the control plot, caused a decrease in white lupine seed yield by 0.15 t$\cdot$ha^{-1} (6.5%) and 0.35 t$\cdot$ha^{-1} (15.1%), respectively. However, statistically significant differences were found between the full and the reduced by 50% dose.

Table 1. Weather conditions at Mochełek in 2014–2015

Month	Year					
	Mean 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
Mean	14.0	13.3	12.8			
Total				339.6	229.0	339.4

Table 2. Weed communities in white lupine agrocenosis (cultivar Butan) depending on the dose of linuron (Dispersive Afalon 450 SC) and clomazone (Command 480 EC), in the years 2014–2015 [plants·m^{-2}]

Weed species	Control	Dispersive Afalon 450 SC + Command 480 EC		
		Herbicide mixture doses, dm^3·ha^{-1}		
		1.0 + 0.20	0.75 + 0.15	0.50 + 0.10
Viola arvensis	200.8	16.8	28.9	61.5
Chenopodium album	3.4	–	0.7	1.1
Lycopsis arvensis	1.5	0.3	0.5	0.5
Brassica napus	1.3	0.3	0.5	0.7
Equisetum arvense	2.1	–	–	1.0
Capsella bursa-pastoris	1.0	–	–	–
Erodium cicutarium	0.2	–	–	–
Centaurea cyanus	0.3	–	–	–
Lamium amplexicaule	0.2	–	–	–
Matricaria inodora	0.5	–	–	–
Poa annua	0.2			
Number of species	11	3	4	5

Table 3. Infestation of white lupine cultivar Butan and phytotoxicity (mean from 2014–2015)

Weed control methods	Doses dm^3·ha^{-1}	Weed number plants·m^{-2}	Air-dried matter of weeds g·m^{-2}	F (1:9)*
Control plot	–	211.5	197.2	1
Dispersive Afalon 450 SC + Command 480 EC	1.0 + 0.20	17.4	20.3	1
Dispersive Afalon450 SC + Command 480 EC	0.75 + 0.15	30.6	37.0	1
Dispersive Afalon 450 SC + Command 480 EC	0.50 + 0.10	64.8	66.3	1
Mean	–	81.1	80.2	1
$LSD_{(0.05)}$	–	36.21	29.11	ns

* F – phytotoxicity – susceptibility of plants to herbicide in scale 1–9, where: 1 – no reaction of crop, 9 – crop damaged
ns – non significant differences

The main reason for the reduction in white lupine yield under the increased pressure of weed competition was the reduction of the final plant density and seed weight per plant. In the conducted research, no significant effect of herbicide mixture doses and abandonment of weeding on the mass of 1000 white lupine seeds was found (Table 4).

Table 4. Yield components and yield of white lupine cultivar Butan (mean from 2014–2015)

Weed control methods	Dos $dm^3 \cdot ha^{-1}$	Plant number $plants \cdot m^{-2}$	Mass of seeds per plant, g	Mass of 1000 seeds, g	Seed yield $Mg \cdot ha^{-1}$
Control plot	–	62.9	3.17	275	1.79
Dispersive Afalon 450 SC + Command 480 EC	1.0 + 0.20	76.3	3.74	287	2.32
Dispersive Afalon 450 SC + Command 480 EC	0.75 + 0.15	74.8	3.55	283	2.17
Dispersive Afalon 450 SC + Command 480 EC	0.50 + 0.10	68.0	3.21	281	1.97
Mean	–	70.5	3.42	281	2.06
$LSD_{(0.05)}$	–	5.87	0.212	ns	0.342

ns – non significant differences

DISCUSSION

The results of the conducted research confirm the high crop protection efficiency of the applied in-soil herbicide mixture Dispersive Afalon 450 SC + Command 480 EC (linuron + clomazone) in the cultivation of legumes (Luboiński, 2017, Szymańska *et al*., 2017), although their herbicidal activity in 2015 was not fully satisfactory due to unfavourable weather conditions. Optimal soil moisture, close to the field water capacity, is a requirement for the effective operation of in-soil preparations (Sekutowski and Badowski, 2011). For this reason, the early sowing date of white lupine usually determines the good effectiveness of the applied herbicides (Piekarczyk, 2006, Gugała *et al*., 2017). In this situation, decreasing the doses of linuron and clomazone mixture is advisable, and the possible increase in infestation does not significantly affect the decrease in lupine yield (Piekarczyk *et al*. 2019). Due to the slow initial growth and development of legumes, undesirable segetal plants are a great threat to them, hence the applied chemical methods of care should be effective for species diversified weed communities. In the conducted experiments, the presence of 11 weed species was found. Many more species can be found in legumes, including very burdensome species, such as wild buckwheat (*Fallopia convolvulus*), cleavers (*Galium aparine*), creeping thistle (*Cirsium arvense*), couch grass (*Elymus repens*), and corn chamomile (*Matricaria inodora*) (Rychcik *et al*., 2015). This, however, does not exclude the possibility of reducing herbicide doses, since even with a greater degree and species diversity of weeds, it is justified to use herbicides in reduced doses (Piekarczyk, 2006; Jędruszczak *et al*., 2010; Piekarczyk *et al*. 2019). Such a procedure is very important in terms of limiting the potentially harmful impact of pesticides on the natural environment (Gołębiowska and Domaradzki, 2010) and may help to audit plans of withdrawing consecutive very effective and necessary for agriculture active substances of herbicides (Gugała and Zarzecka, 2009; Rychcik *et al*., 2015). In the situation of the growing threat of the occurrence of herbicide-resistant weed ecotypes, the reduction of the doses of active substances of herbicides must be introduced very carefully. It cannot cause an increase in this phenomenon due to the selection of resistant ecotypes and the risk of inducing gene mutations, which may be fostered by the use of sub-lethal herbicide doses (Adamczewski and Dobrzański, 2012; Adamczewski, 2017). However, legumes are not cultivated one after the other and the risk of weed compensation and resistance is relatively low. The results of the conducted research indicate a real possibility of reducing the doses of the applied herbicides by 25%, while greater reduction poses a significant threat to the conditions of the growth and yield of white lupine.

CONCLUSIONS

1. Application of in-soil herbicide mixture Dispersive Afalon 450 SC (linuron) + Command 480 EC (clomazone) in a full and a reduced by 25% dose decreased weed number and mass, as well as weed species diversity, which was reflected in the increase in white lupine seed yield.
2. No harmful phytotoxic effect of the applied herbicide doses with linuron and clomazone was found on the emerging white lupine plants cultivar Butan.
3. Doses of herbicide mixture with linuron and clomazone reduced by 25% make it possible to maintain relatively low infestation and ensure a high level of white lupine seed yield. Reducing the doses of the tested herbicides by 50% significantly increases the threat to white lupine growth and yield conditions.

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WPŁYW ZRÓŻNICOWANYCH DAWEK MIESZANIN HERBICYDÓW NA ZACHWASZCZENIE I PLONOWANIE ŁUBINU BIAŁEGO

Streszczenie

W jednoczynnikowym doświadczeniu polowym zrealizowanym w latach 2014–2015 badano wpływ zróżnicowanych dawek mieszanin herbicydów zawierających linuron (Afalon Dyspersyjny 450 SC) i chlomazon (Command 480 EC) na zachwaszczenie i plonowanie łubinu białego. Stwierdzono, że aplikacja mieszaniny herbicydów doglebowych Afalon Dyspersyjny 450 SC (linuron) + Command 480 EC (chlomazon) w dawkach pełnej i zredukowanej o 25% zmniejszyła w porównaniu z obiektem kontrolnym liczbę i masę chwastów oraz ich różnorodność gatunkową, co znalazło odzwierciedlenie w zwiększeniu plonu nasion łubinu białego. Nie stwierdzono szkodliwego fitotoksycznego oddziaływania aplikowanych dawek herbicydów zawierających linuron i chlomazon na wschodzące rośliny łubinu białego odmiany Butan. Obniżone o 25% dawki mieszaniny herbicydów zawierającej linuron i chlomazon pozwalają utrzymać stosunkowo małe zachwaszczenie i zapewnić wysoki poziom plonu nasion łubinu białego. Redukcja dawek testowanych herbicydów o 50% zwiększa istotnie zagrożenie dla warunków wzrostu i plonowania łubinu białego.

Słowa kluczowe: chwasty, *Lupinus albus* L., plon nasion, sposoby pielęgnacji