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WEED CONTROL IN LEGUMES WITH REDUCED DOSES OF LINURON AND CLOMAZONE

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ABSTRACT

Background. In the search for more environmentally friendly and effective weed control methods in legumes, the possibility of in-soil herbicide application at lowered doses ought to be considered.
Material and methods. In field experiments carried out in the years 2014-2015, the effect of the application of an in-soil herbicide mixture containing linuron and clomazone was studied at various doses on the weed infestation and yield of pea and soybean.
Results. Application of the herbicides Dispersive Afalon 450 SC (linuron) + Command 480 EC (clomazone) at full and reduced doses, by 25% and 50%, decreased weed number and mass as well as weed biodiversity in comparison with the control. The applications also increased pea and soybean yields. In the experiment, no harmful phytotoxic effects were found from the applied herbicide doses containing linuron and clomazone on the emerging plants of pea and soybean.
Conclusion. Limiting the negative effects of in-soil herbicides containing linuron and clomazone on the environment may be achieved through their application at reduced doses. Application of the reduced doses of linuron and clomazone is more suitable for pea than for soybean.

Key words: in-soil herbicides, pea, soybean, weed infestation

INTRODUCTION

Weeds are among crop agro-phages and they reduce crop economic yield by 10 to 15% yearly, according to the Food and Agriculture Organization of the United Nations (Zhang *et al.*, 2009). Legumes are hard to cultivate and their yield varies according to the year and to a large extent depends on weather conditions (Podleśny and Bieniaszewski, 2012; Śliwa *et al.*, 2015, Małecka-Jankowiak *et al.*, 2016). Due to the slow initial growth of pea and soybean, effective weed control is essential to their yield and without it economic seed yield is impossible to obtain (Vivian *et al.*, 2013; Gugała *et al.*, 2014; Rychcik *et al.*, 2015). Proper crop rotation, basic cultivation (Gawęda *et al.*, 2015; Rychcik *et al.*, 2015), mulching (Bakht *et al.*, 2009), and mechanical tending (Gugała and Zarzecka, 2009) all play a significant part in limiting weed infestation of legume plantations. However, the most important role in weed management of pea and soybean crops is played by in-soil herbicides applied directly after sowing (Gugała and Zarzecka, 2011; Sepat *et al.*, 2017), complemented by foliar post emergence application if needed (Szwejkowska, 2006; Sekutowski and Badowski, 2011; Younesabadi *et al.*, 2013). In-soil herbicides control most weed species, are long-acting and liberate pea and soybean from weeds in the most difficult period for the plants, namely during their emergence and initial growth (Bujak and Frant,

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2009). The above preparations, however, pose a significant threat to the environment (Domaradzki and Sadowski, 2002; Praczyk and Skrzypczak, 2004). Therefore, there is great pressure to withdraw the consecutive use of effective active substances (Directive, 2009; Matyjaszczyk and Sobczak, 2017), which are of paramount importance in keeping plantations of many cultivated plants clear of weeds.

A very important role in limiting the negative environmental effects of the chemical control of pea and soybean, as well as in increasing the profitability of their cultivation by reducing weed control costs while maintaining yield levels, may be played by the application of the very effective herbicides linuron and clomazone (Luboiński, 2017) at reduced doses. In the situation of plough tillage and the low level of monoculture cultivation of pea and soybean, which are dominant in Poland, the procedure of reducing the doses of the applied herbicides does not pose a real threat of weed resistance to those herbicides, which is a serious danger in simplified systems (Vivian *et al.*, 2013; Sepat *et al.*, 2017). In the literature there are only a few works on the topic of the effectiveness of reduced herbicide doses in legumes.

The aim of the research was to evaluate the effect of the herbicide mixture of linuron and clomazone, applied at full dose and at doses reduced by 25% and 50%, on the weed infestation and yield of pea and soybean. The study hypothesis assumed that it is possible to apply in-soil herbicides at reduced doses and still keep the plantations clear of weeds and plant yield satisfactory.

MATERIAL AND METHODS

Field conditions

Two one-factor field experiments in a split-block design in four repetitions were carried out, with a plot size of 15 m^2 for sowing and harvest.

The research was carried out in the years 2014 and 2015 at the Experimental Station in Mochełek (53°13' N; 17°51' E), which is part of the Agriculture and Biotechnology Faculty of the Science and Technology University in Bydgoszcz. The field experiment was situated on lessive soil with a fine-grained loamy sands granulation, class IVa, good rye complex. Winter wheat was the direct forecrop for both soybean and pea.

Before sowing, phosphorus and potassium fertilizers were applied in the amount of 30.5 kg $P \cdot ha^{-1}$ and 66.4 kg $K \cdot ha^{-1}$, respectively. Sowing was carried out in the first (pea) and second (soybean) ten days of April with a row spacing of 21 cm and a sowing depth of 4 cm. The sowing amount was 80 germinating $seeds \cdot m^{-2}$ for the soybean cultivar Merlin and 100 germinating $seeds \cdot m^{-2}$ for the pea cultivar Akord.

Herbicides application

In the research, the effect of herbicide mixture doses with linuron (Dispersive Afalon 450 SC) and clomazone (Command 480 EC) on the weed infestation and yield of soybean and pea was studied. The treatments of the experiment included:

1) Control – without herbicide,
2) linuron + clomazone (1.0 + 0.20 $dm^3 \cdot ha^{-1}$ – full dose),
3) linuron + clomazone (0.75 + 0.15 $dm^3 \cdot ha^{-1}$),
4) linuron + clomazone (0.5 + 0.1 $dm^3 \cdot ha^{-1}$).

Linuron and clomazone herbicides were applied directly after sowing according to the schedule. After plant emergence (BBCH 12–13), herbicide phytotoxicity was determined using the site method in a 9-degree scale (Efficacy evaluation, Praczyk and Skrzypczak, 2004). The evaluation of the condition and degree of weed infestation was carried out around 7–8 weeks after weeding (BBCH 68–69) with a botanical-gravimetric analysis from an area of 1 m^2. Harvest was carried out with the use of a harvester at the stage of full seed ripeness. Subsequently, the 1000 seed weight was determined.

Statistical methods

For significant effects from ANOVA the dependent variables means were separated using HSD Tukey's test at $P < 0.05$. The results were processed using STATISTICA data analysis software system version 12.5 (StatSoft; Tulsa, Oklahoma. USA).

RESULTS

Table 1 presents the weather conditions during growth in the study years. In the year 2014 the temperature was slightly higher in comparison to the long term average for the years 1981–2010 and precipitation at the beginning of growth was higher than the long term average, which was favourable for the action of the in-soil herbicides and for soybean and pea plants growth. Unfortunately, weather conditions in the year 2015 were unfavourable in regard to the effectiveness of the applied in-soil herbicides and plant yield.

For the pea cultivar Akord, the use of linuron and clomazone at the full dose and at doses reduced by 25% and 50% caused a significant decrease in weed number and mass, in comparison with the control (Table 2). On the other hand, a decrease in the doses of the applied herbicides by 25% and 50%, in comparison with the full dose, resulted in a small increase, not proven statistically, in weed number and mass. The effectiveness of weed control in pea with the full dose of herbicides was 89.5% for the number of weeds and 94.4% for the weight of weeds. Along with reducing the dose of herbicides by 25% and 50%, the effectiveness of weed control decreased to 86.6% and 89.2% and 77.3% and 79.0%, respectively. In the experiment no harmful phytotoxic effects were found from the applied preparation doses on pea plants. Application of the herbicides Dispersive Afalon 450 SC + Command 480 EC at all of the tested doses significantly increased pea seed yield in comparison with the control. However, as the amount of the applied herbicides decreased by 25% and 50%, in comparison with the full dose, the pea seed yield decreased by 0.21 Mg·ha^{-1} (5.3%) and 0.28 Mg·ha^{-1} (7.1%), respectively. In the experiment, no effect of the applied levels of the experimental factor was found on the mass of a 1000 seeds of the pea cultivar Akord (Table 2). The dominant weed species in the experiment were: field pansy (*Viola arvensis*), goose foot (*Chenopodium album*), small bugloss *(Lycopsis arvensis)*, and rapeseed volunteers (*Brassica napus*). Altogether, nine weed species were identified in pea, and herbicide application limited weed biodiversity to 2-4 taxa. The dominant species, namely field pansy (*Viola arvensis*), small bugloss (*Lycopsis arvensis*), and rapeseed (*Brassica napus*), demonstrated to be the most resistant to linuron and clomazone (Table 3).

Table 1. Weather conditions in 2014–2015

Month	Year					
	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. Evaluation of linuron (Dispersive Afalon 450 SC) and clomazone (Command 480 EC) effectiveness applied in pea (cultivar Akord) depending on the dose (mean from the years 2014–2015)

Treatment	Dose $dm^3 \cdot ha^{-1}$	Weed number $plant \cdot m^{-2}$	Air-dry matter of weeds, $g \cdot m^{-2}$	F (1:9)*	Seed yield $Mg \cdot ha^{-1}$	1000 seeds weight, g
Control	–	80.1	55.3	1	3.16	222
Dispersive Afalon 450 SC + Command 480 EC	1.0 + 0.20	8.4	3.1	1	3.95	223
Dispersive Afalon 450 SC + Command 480 EC	0.75 + 0.15	10.7	6.0	1	3.74	221
Dispersive Afalon 450 SC + Command 480 EC	0.50 + 0.10	18.2	11.6	1	3.67	224
Mean	–	29.3	19.0	1	3.63	223
$HSD_{(0.05)}$	–	30.39	8.92	ns	0.344	ns

* F – phytotoxicity – plant susceptibility to herbicide in the scale 1:9, where: 1 – no effect on the crop, 9 – crop damage
ns – non-significant differences

Table 3. Weed communities in the agrocenosis of pea (cultivar Akord) depending on the doses of linuron (Dispersive Afalon 450 SC) and clomazone (Command 480 EC), in the years 2014–2015 [$plants \cdot m^{-2}$]

Weed species	Control	Dispersive Afalon 450 SC + Command 480 EC, $dm^3 \cdot ha^{-1}$		
		1.0 + 0.20	0.75 + 0.15	0.50 + 0.10
Viola arvensis	74.7	8.2	10.0	16.1
Chenopodium album	2.1	–	–	1.1
Lycopsis arvensis	0.8	–	0.2	0.3
Brassica napus	0.8	0.2	0.5	0.7
Capsella bursa-pastoris	0.2	–	–	–
Erodium cicutarium	0.2	–	–	–
Centaurea cyanus	0.3	–	–	–
Lamium amplexicaule	0.5	–	–	–
Matricaria inodora	0.5	–	–	–
Number of species	9	2	3	4

Application of the in-soil herbicide mixture Dispersive Afalon 450 SC + Command 480 EC directly after sowing in the soybean cultivar Merlin at the full dose and at the doses reduced by 25% and 50% caused a significant decrease in weed number and mass, in comparison with the control (Table 4). A decrease in the dose of the applied herbicides by 25% in soybean, in comparison with the full dose, resulted in a small increase, not proven statistically, in weed number and mass. The reduction in the dose of linuron and clomazone mixture by 50% resulted in a significant increase in weed number and mass, by 86 plants·m^{-2} (261%) and 81.7 g·m^{-2} (188%), respectively. The effectiveness of weed control in soybean at the full dose of the herbicides was 85.1% for the number and 85.7% for the weight of weeds. Along with reducing the dose of herbicides by 25% and 50%, the effectiveness of weed control decreased to 69.0% and 74.5% and 45.0% and 59.0%, respectively. In the experiment no phytotoxic effects of the applied preparation doses on the emerging soybean plants were found. Weed control in soybean with the herbicides Dispersive Afalon 450 SC + Command 480 EC at all of the tested doses significantly increased soybean seed yield, in comparison with the control. Decreasing the amount of linuron and clomazone by 25% and 50%, in comparison with the full dose, caused a decrease in soybean seed yield by 0.21 Mg·ha^{-1} (21%) and 0.35 Mg·ha^{-1} (35%), respectively. In the experiment a lower mass of 1000 seeds was found for the soybean cultivar Merlin with no weed control, in comparison with the full dose of the applied herbicides (Table 4). The dominant weed species in soybean were: field pansy (*Viola arvensis*), goose foot (*Chenopodium album*), and rapeseed volunteers (*Brassica napus*). Altogether, 10 weed species were identified with this plant and the application of the herbicide mixture of linuron and clomazone limited weed biodiversity to 3–5 taxa (Table 5).

Table 4. Evaluation of linuron (Dispersive Afalon 450 SC) and clomazone (Command 480 EC) effectiveness applied in soybean (cultivar Merlin) depending on the dose (mean from the years 2014–2015)

Treatment	Dose dm^3·ha^{-1}	Weed number pcs·m^{-2}	Air-dry matter of weeds, g·m^{-2}	F (1:9)*	Seed yield Mg·ha^{-1}	1000 seeds weight, g
Control	–	216.3	305.2	1	0.23	118
Dispersive Afalon 450 SC + Command 480 EC	1.0 + 0.20	32.9	43.5	1	1.00	125
Dispersive Afalon 450 SC + Command 480 EC	0.75 + 0.15	67.0	77.9	1	0.79	123
Dispersive Afalon 450 SC + Command 480 EC	0.50 + 0.10	118.9	125.2	1	0.65	121
Mean	–	108.8	137.9	1	0.67	122
HSD $_{(0.05)}$	–	54.09	62.93	ns	0.148	4.8

*F – phytotoxicity – plant susceptibility to herbicide in the scale 1:9, where: 1 – no effect on the crop, 9 – crop damage
ns – non-significant differences

Table 5. Weed communities in the agrocenosis of soybean (cultivar Merlin) depending on the doses 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, dm^3·ha^{-1}		
		1.0 + 0.20	0.75 + 0.15	0.50 + 0.10
Viola arvensis	206.7	32.2	65.6	116.2
Chenopodium album	4.6	0.2	0.7	1.2
Brassica napus	1.8	0.5	0.7	1.0
Lycopsis arvensis	0.8	–	–	0.3
Capsella bursa-pastoris	0.5	–	–	–
Erodium cicutarium	0.3	–	–	–
Centaurea cyanus	0.6	–	–	0.2
Lamium amplexicaule	0.2	–	–	–
Matricaria indora	0.2	–	–	–
Triticum aestivum	0.6	–	–	–
Number of species	10	3	3	5

DISCUSSION

The results obtained in the study confirmed the enormous yield-protection role of the applied in-soil herbicide mixture Dispersive Afalon 450 SC + Command 480 EC for the cultivated legumes (Luboiński, 2017), although their effectiveness was not totally satisfactory due to water shortage in the soil in the year 2015 (Luboiński and Markowicz, 2017). Adequately high soil moisture is a condition for the effective weed-control action of in-soil preparations (Sekutowski and Badowski, 2011). Therefore, the earlier pea sowing date usually enables a higher effectiveness of the applied herbicides than is the case in the later-sown soybean (Bujak and Frant, 2009). Hence, decreasing the doses of the linuron and clomazone mixture is more advisable for pea, and the potential increased weed infestation is not so dangerous for the yield of the earlier-harvested pea. Due to the high pea and soybean plant sensitivity to the presence of weeds, the applied methods, especially chemical weed control, must be effective. This does not indicate, however, that there is little possibility for a reduction in herbicide doses, since even with a higher level and biodiversity of weed infestation there is still the possibility of applying herbicides at lowered doses (Hamilll *et al.*, 1995, Jędruszczak *et al.*, 2010). The use of reduced doses of herbicides in agriculture is therefore possible, provided that it does not cause a significant increase in weed infestation and the risk of a significant loss of the crop yield. Numerous sources have shown that limiting the amount of herbicides on farmland is possible in the cultivation of barley (Miklaszewska and Kierzek, 2013), wheat (Haliniarz, 2013), potato (Ciesielska and Wysmułek, 2012), blue lupine (Piekarczyk, 2006), yellow lupine and fodder pea (Piekarczyk *et al.*, 2019). The above practice is very important from the aspect of limiting the harmful effects of the applied pesticides on the environment (Gołębiowska and Domaradzki, 2010), without the necessity of withdrawing from the consecutive use of the very effective and important to agriculture active substances of herbicides (Gugała and Zarzecka, 2009, Rychcik *et al.*, 2015, Luboiński, 2017). However, in the situation of the presently increasing threat from the emerging ecotypes of weeds that are resistant to herbicides, any reduction in the doses of active substances must be implemented very carefully in order not to cause an increase in the occurrence of this phenomenon (Adamczewski, 2017). Legumes, however, are not cultivated in monocultures and the risk of weeds becoming resistant in their typical cultivation conditions is relatively low.

CONCLUSIONS

1. Application of the herbicides Dispersive Afalon 450 SC (linuron) + Command 480 EC (clomazone) at the full dose and at the doses reduced by 25% and 50% decreased weed number and weight as well as weed biodiversity, in comparison to the control, and this caused an increase in pea and soybean seed yield.
2. In the experiment, no harmful phytotoxic effects of the applied herbicide doses with linuron and clomazone on the emerging pea and soybean plants were found.
3. Limiting the negative effects of in-soil herbicides containing linuron and clomazone on the environment may be obtained through their application at reduced doses. The application of reduced doses of linuron and clomazone is more suitable for pea than for soybean.

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ZWALCZANIE CHWASTÓW W ROŚLINACH STRĄCZKOWYCH ZREDUKOWANYMI DAWKAMI LINURONU I CHLOMAZONU

Streszczenie

Poszukując bardziej przyjaznych dla środowiska i skuteczniejszych metod zwalczania chwastów w roślinach strączkowych, należy rozważyć możliwość stosowania herbicydów doglebowych w obniżonych dawkach. W doświadczeniach polowych przeprowadzonych w latach 2014–2015 badano wpływ stosowania doglebowej mieszanki herbicydowej zawierającej linuron i chlomazon w różnych dawkach na zachwaszczenie oraz plonowanie grochu i soi. Zastosowanie herbicydów Afalon Dyspersyjny 450 SC (linuron) + Command 480 EC (chlomazon) w dawkach pełnych i zredukowanych o 25% i 50% zmniejszyło liczbę i masę chwastów oraz bioróżnorodność chwastów w porównaniu z kontrolą. Ich zastosowanie zwiększyło również plony grochu i soi. W doświadczeniu nie stwierdzono szkodliwych skutków fitotoksycznych stosowanych dawek herbicydów zawierających linuron i chlomazon na wschodzące rośliny grochu i soi. Ograniczenie negatywnego wpływu herbicydów doglebowych zawierających linuron i chlomazon na środowisko można osiągnąć poprzez ich stosowanie w dawkach zredukowanych. Zastosowanie obniżonych dawek linuronu i chlomazonu jest bardziej zasadne w grochu niż w soi.

Słowa kluczowe: herbicydy doglebowe, groch, soja, zachwaszczenie