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Effectiveness of the application of metamitron in lacy phacelia (*Phacelia tanacetifolia* Benth.) crops

Efektywność stosowania metamitronu w zasiewach facelii błękitnej (*Phacelia tanacetifolia* Benth.)

Summary. A field experiment on the application of the herbicide Lawina 700 SC (the active ingredient metamitron – under different application regimes) was carried out in Priluki near Minsk, Belarus, over the period 2011–2013. It was proved that herbicide application in lacy phacelia crops is not always justified. With intensive growth, the crop plant itself competes with weeds and the application of herbicides is not advisable. It was only in one out of the three years that the weeds delayed and disturbed the growth of phacelia, their harmfulness proved to be significant, and herbicide application had a measurable effect. It turned out that the difference in biological and economic effectiveness between a single and double application of metamitron was insignificant and the phytotoxic effect was not found to increase. The most appropriate herbicide application regime that protected lacy phacelia against annual dicotyledonous weeds was a single application of metamitron (1.4 l·ha^{-1}) at the 1–2 true leaf pair stage. The study also showed that the herbicide metamitron, applied both before emergence and after emergence of phacelia, may exhibit phytotoxic activity against the cultured crop, slowing down plant growth and causing a decrease in the seed yield. The effectiveness of metamitron application before emergence – both at the rate of 1.4 l·ha^{-1} and at a higher rate (2.1 l·ha^{-1}) – proved to be very unstable, in particular in the aspect of direct phytotoxicity of the herbicide on the crop plant, but also in the aspect of periodic accumulation of the biologically active substance in the soil.

Key words: lacy phacelia, metamitron, weed infestation, productivity

INTRODUCTION

Under Polish conditions, lacy phacelia (*Phacelia tanacetifolia* Benth.) is a popular phytosanitary crop grown as a stubble crop (ploughed under as green manure or after cutting left over winter as mulch) [Nowakowski and Szymczak-Nowak 1999, Wilczewski et al. 2012, Kwiatkowski et al. 2014, Kwiatkowski et al. 2016]. In different areas of the

Republic of Belarus, on the other hand, it enjoys great interest and is a popular honey plant that is also grown for seed. Under favorable weather conditions, phacelia effectively competes with weeds and the use of herbicides in a plantation becomes unnecessary. But in years with a cold spring, it competes more poorly with weeds and phacelia plants are sometimes crowded out by weeds to a significant extent. In growing phacelia for seed, it is very important to eliminate weeds because later on it is difficult to separate weed seeds from phacelia seeds. In the literature of the subject, we find views that lacy phacelia plants can tolerate some active ingredients of herbicides, e.g. linuron, metamitron, pendimethalin, lenacil, isoproturon, matazochlor, chloroproturon and graminicides [Spiridonov 2006, Zagumennikov 2006].

The honey potential of lacy phacelia in the Republic of Belarus is high; on an annual basis, it is 200–700 kg·ha^{-1}, depending on the region and weather conditions. Phacelia is a plant that is characterized by intensive growth, but in spite of this in years characterized by a cold spring weeds compete with this crop culture and cause a reduction in yield. Phacelia crops are then infested especially with annual dicotyledonous weeds. Weed control technology in a phacelia plantation is poor in terms of the range of herbicides that can mitigate the harmfulness of individual weed species which reduce the productivity of the crop plant [Klimenkova 1980, Ribalko 2005].

The aim of this research was to determine the possibility of using the herbicide Lawina (metamitron) under different application regimes in lacy phacelia crops grown for seed.

MATERIALS AND METHODS

The experiment in growing lacy phacelia (cv. Asta) was conducted during the period 2011–2013 in an experimental field belonging to the Institute of Plant Protection Priluki near Minsk, Belarus, on slightly sandy grey-brown podzolic soil derived from loess. The soil content of major nutrients is shown in Table 1.

Table 1. Soil characteristics before the experiment
Tabela 1. Charakterystyka gleby pod doświadczeniem

Year Lata	pH in 1 M KCl pH w 1 mol KCl	Content/ Zawartość			
		P (mg·1 kg^{-1} soil/gleby)	K (mg·1 kg^{-1} soil/gleby)	Mg (mg·1 kg^{-1} soil/gleby)	Humus Próchnica (%)
2011	5.8	120	167	60	1.21
2012	6.0	141	172	66	1.33
2013	5.9	135	170	61	1.29

In 2011 the experimental design included various metamitron application regimes (herbicide Lawina 700 SC):

A – control treatment (without herbicide application);

B – metamitron applied before emergence of phacelia (1.4 l·ha^{-1});

C – metamitron applied before emergence of phacelia (2.1 l·ha^{-1});

D – metamitron applied at the beginning of plant growth, at the 1–2 true leaf pair stage ($1.0\ l\cdot ha^{-1}$);

E – metamitron applied at the beginning of plant growth, at the 1–2 true leaf pair stage ($1.4\ l\cdot ha^{-1}$);

In the years 2012–2013, the experimental design was expanded to include a double application of the herbicide metamitron:

A – control treatment (without herbicide application);

B – metamitron applied before emergence of phacelia ($1.4\ l\cdot ha^{-1}$);

C – metamitron applied before emergence of phacelia ($2.1\ l\cdot ha^{-1}$);

D – metamitron applied at the beginning of plant growth, at the 1–2 true leaf pair stage ($1.0\ l\cdot ha^{-1}$);

E – metamitron applied at the beginning of plant growth, at the 1–2 true leaf pair stage ($1.4\ l\cdot ha^{-1}$);

F – metamitron applied twice – before emergence of phacelia ($1.4\ l\cdot ha^{-1}$) and at the 1–2 true leaf pair stage ($1.4\ l\cdot ha^{-1}$);

G – metamitron applied twice – before emergence of phacelia ($2.1\ l\cdot ha^{-1}$) and at the 1–2 true leaf pair stage ($1.4\ l\cdot ha^{-1}$);

H – metamitron applied twice during plant growth – at the 1–2 true leaf pair stage in 2 split doses ($1.0\ l\cdot ha^{-1}$ and $1.4\ l\cdot ha^{-1}$ – a week after the first application);

I – metamitron applied twice during plant growth – at the 1–2 true leaf pair stage in 2 split doses ($1.4\ l\cdot ha^{-1}$ and $1.4\ l\cdot ha^{-1}$ – a week after the first application).

Lacy phacelia sowing dates were as follows: May 19, 2011, May 4, 2012 and May 13, 2013. Lacy phacelia was sown at a wide row spacing, with an interrow width of 45 cm. The seeding rate was $10\ kg\cdot ha^{-1}$. Before sowing, mineral fertilization was applied at the following amounts: N – 60 (2012), 70 (2013), 90 (2011); P – 60 (2012), 80 (2013), 90 (2011); K – 90 (2012), 100 (2013), 110 (2011) $kg\cdot ha^{-1}$. The differences in mineral NPK fertilizer rates were due to the different initial soil nutrient availability during the study years (Table 1). The area of a single plot was 10 m^2. The experiment was established in a randomized block design with 4 replicates.

The efficacy of the herbicide was evaluated using the standard method (the dry-weight-rank method) by randomly placing in the plots a 0.25 m^2 quadrat frame in four replicates. The phytotoxicity of the herbicide on the crop plant was evaluated using a 9-point scale, where 1 means no phytotoxicity, while 9 – complete destruction of phacelia plants. Observations to evaluate the efficacy and phytotoxicity of metamitron were carried out 24 days after post-emergence treatment (2011), 28 days after post–emergence treatment (2012), and 23 days after herbicide treatment in 2013. The differences in the timing of observation during the study years resulted from different weather conditions and different growth rates of the crop plant and weeds.

The lacy phacelia crop was harvested by hand (in the third 10 days of August) and subsequently the above–ground fresh weight (in $g\cdot m^{-2}$) and seed yield (in $dt\cdot ha^{-1}$) of phacelia were estimated, after the seeds had been dried and brought to a moisture content of 14%.

All study results were statistically tested by analysis of variance, determining the significance of differences using Tukey's test at a significance level of $p = 0.05$.

Habitat conditions

In 2011 during the period before application of the herbicide (the third 10 days of May – the first 10 days of June), a soil moisture deficit was observed. The entire growing season of lacy phacelia in this year can be characterized as warm and dry. In 2012 the ambient temperature promoted plant growth and development, and a decrease in air temperature was only recorded in the first 10 days of June. A rainfall deficit occurred in the first and third 10 days of May, the second and third 10 days of June as well as in the second 10 days of July. The amount of rainfall in the second 10 days of May was different from normal rainfall (the long-term average) by 59%. In 2013 the soil moisture was high and the conditions throughout the entire growing season were the following: the total rainfall in May and in the first 10 days of June exceeded the long-term average by 1.5 times, while in turn from the middle of June a period of drought began. During this time, the air temperature was clearly higher than the normal temperature range for this period. Weather conditions during the growing season of phacelia in particular years are shown in Table 2.

Table 2. Rainfall and air temperature in May–August of 2011–2013 as compared to the long-term mean figures (1979–2009) in Priluki
Tabela 2. Opady i temperatura powietrza w okresie maj–sierpień w latach 2011–2013 na tle danych z wielolecia (1979–2009) w Priłukach

Year Lata	Rainfall/ Opady (mm)					
	May maj	June czerwiec	July lipiec	August sierpień	total ogółem V–VIII	total ogółem I–XII
2011 2012 2013	36.3 32.8 80.4	42.8 55.0 82.4	75.3 71.9 52.3	53.7 70.1 41.5	208.1 229.8 256.6	609.2 615.8 681.4
Mean Średnia 1979–2009	62.8	77.3	80.1	68.2	288.4	633.7
Year Lata	Temperature/ Temperatura (ºC)					
	May maj	June czerwiec	July lipiec	August sierpień	mean średnia V–VIII	mean średnia I–XII
2011 2012 2013	17.0 16.2 16.5	18.1 16.5 17.8	18.7 17.9 18.6	18.2 18.0 18.7	18.0 17.1 17.9	7.8 7.4 7.9
Mean Średnia 1979–2009	13.4	17.2	17.8	17.6	16.5	7.3

RESULTS

In 2011 the herbicide metamitron was applied on May 22 (before emergence) and on June 8 (the beginning of plant growth). Under the weather conditions in 2011, lacy phacelia showed a very high growth rate and was sufficiently competitive to weeds. The observations made on June 14 revealed that both in the control treatment without herbicide application and in the herbicide–treated plots the number of weeds was insignificant, ranging from 2.9 to 4.0 plants·m^{-2}, whereas the weight of weeds was 53.2–81.4 g·m^{-2} (significant differences).

Therefore, under such conditions the evaluation of herbicide effectiveness was not reliable (and practically the herbicide was not found to show any phytotoxicity on phacelia), whereas the weeds were dominated by the crop. This was translated into a record fresh weight yield of phacelia. At the same time, the vegetative biomass of lacy phacelia did not differ significantly between the weed control treatments compared and it was 6979.6 g·m^{-2} in the control treatment, 6224.4–7271.7 g·m^{-2} in the case of application of metamitron before emergence, and 6998.5–7475.7 g·m^{2} when metamitron was applied at the beginning of plant growth. The phacelia seed yield was also high; it was 2.60 dt·ha^{-1} in the control plots (A), while in the other treatments (B–E) it ranged from 2.55 to 2.66 dt·ha^{-1}, without showing statistically significant differences (tab. 3).

In 2012 the experimental design was expanded. Treatments with a double application of the herbicide (before emergence – beginning of plant growth, and a double application at the beginning of plant growth). The herbicide metamitron was applied on May 4 (before emergence), on May 4 and 21 (before emergence – at the beginning of plant growth), May 14 (beginning of plant growth), May 14 and 21 (twice at the beginning of plant growth).

If applied before emergence of the crop plant, metamitron practically did not affect the level of weed infestation in the crop, which may be associated with soil dryness. The number of weeds in the experimental plots was 40.7–97.3 plants·m^{-2} and thus significantly higher than in 2011. The field observations made on June 18 revealed that in the treatment without herbicide application (control treatment A) the number of weeds resulted from natural competition of the weeds with the crop plant and it was 97.3 plants·m^{-2}, whereas their weight was 2088.0 g·m^{-2}. In the treatments with application of the herbicide metamitron before emergence of phacelia (treatments B–C), the number and weight of weeds was at the level of the control treatment (83.3–92.6 plants·m^{-2} with a weight of 1902.0–1986.0 g·m^{-2}). In these herbicide application treatments, metamitron was not found to have a phytotoxic effect on the crop plant, either.

The number of weeds in the treatments with application of metamitron according to the experimental design (treatments D–I) was practically at one level and ranged between 40.7 and 52.0 plants·m^{-2}, while the weight of weeds was 762.0–961.0 g·m^{-2}. Thus, the weed infestation rates in treatments D–I were significantly lower than those found in treatments A–C. However, the phytotoxicity of metamitron on phacelia plants was found to be significantly higher in treatments F–I, in particular in the treatments with a double application of the herbicide at the beginning of plant growth (tab. 3).

The aboveground biomass productivity of lacy phacelia and its seed yield in all treatments with application of metamitron at the beginning of plant growth or with its double application were at a similar statistically insignificant level – the phacelia seed yield was 2.35–2.69 dt·ha^{-1} (treatments D–I). The seed yield obtained from these treatments (D–I) was significantly higher (more than twice) than in treatments A–C (tab. 3).

In 2013 metamitron was applied on May 16 (the treatments before emergence), on May 16 and 5 June (treatments: before emergence – beginning of plant growth), on May 27 (treatments with application of the herbicide at the beginning of plant growth), and on May 27 and June 5 (treatments with a double application of the herbicide at the beginning of plant growth).

Table 3. Effectiveness of application of metamitron in lacy phacelia crops
Tabela 3. Efektywność stosowania metamitronu w zasiewach facelii błękitnej

Year Lata	Treatment Wariant	Herbicide rate Dawka herbicydu ($l \cdot ha^{-1}$)	Time of application Termin stosowania	Phytotoxicity on phacelia plants/ Fitotoksyczność dla roślin facelii (scale/ skala 1–9°)*	Number of weeds plants ($pcs. \cdot m^{-2}$) Liczba chwastów ($szt. \cdot m^{-2}$)	Weed weight Masa chwastów ($g \cdot m^{-2}$)	Fresh weight yield of phacelia Plon świeżej masy facelii ($g \cdot m^{-2}$)	Seed yield of phacelia Plon nasion facelii ($dt \cdot ha^{-1}$)
2011	A	–	–	–	4.0 a	81.4 a	6979.6 a	2.60 a
	B	1.4	BE	1 a	3.0 a	76.7 a	7271.7 a	2.65 a
	C	2.1	BE	1 a	2.9 a	53.2 b	6224.4 a	2.55 a
	D	1.0	BG	2 a	3.3 a	76.6 a	6998.5 a	2.60 a
	E	1.4	BG	2 a	2.9 a	75.5 a	7475.7 a	2.66 a
2012	A	–	–	–	97.3 a	2088.0 a	1751.3 a	0.81 a
	B	1.4	BE	1 a	92.6 a	1986.0 a	1960.3 a	0.99 a
	C	2.1	BE	1 a	83.3 a	1902.0 a	2273.3 a	0.96 a
	D	1.0	BG	2 a	52.0 b	961.0 b	3742.0 b	2.35 b
	E	1.4	BG	2 a	48.3 b	840.0 b	4118.0 b	2.46 b
	F	1.4–1.4	BE–BG	3 a	46.0 b	896.0 b	4161.0 b	2.58 b
	G	2.1–1.4		5 b	42.6 b	809.3 b	4239.7 b	2.69 b
	H	1.0–1.4	BG Twice	4 b	44.0 b	846.0 b	4001.7 b	2.51 b
	I	1.4–1.4		5 b	40.7 b	762.0 c	4187.0 b	2.45 b
2013	A	–	–	–	26.7 a	303.1 a	1634.8 a	1.72 a
	B	1.4	BE	1 a	20.7 b	292.4 b	1052.6 b	1.59 a
	C	2.1	BE	1 a	11.3 c	131.0 c	1176.5 b	1.58 a
	D	1.0	BG	1 a	19.3 b	95.3 d	1025.6 b	1.91 a
	E	1.4	BG	2 a	15.3 c	72.3 d	1029.0 b	1.91 a
	F	1.4–1.4	BE–BG	2 a	14.0 c	143.0 c	1016.3 b	1.48 a
	G	2.1–1.4		4 b	12.0 c	130.0 c	1103.0 b	1.69 a
	H	1.0–1.4	BG Twice	4 b	16.0 c	70.0 d	836.5 c	1.60 a
	I	1.4–1.4		4 b	15.3 c	61.0 d	676.3 c	1.57 a

Explanations/ Objaśnienia:
* 1 – no symptoms of phacelia destruction/ brak oznak zniszczenia facelii; 9 – total destruction of phacelia plants/ całkowite zniszczenie roślin facelii, BE – before emergence/ do wschodów, BG – beginning of growth/ początek wegetacji
Means in columns with different letters (a–d) are significantly different ($p = 0.05$)/ Wartości liczbowe oznaczone w kolumnach różnymi literami (a–d) różnią się istotnie ($p = 0,05$)

During the observations conducted on June 28, it was found that the number of weeds in the control (A) was 26.7 plants·m^{-2}. The weed-killing effect of the herbicide in the treatments with its application before emergence of phacelia (treatments B–C) could be seen in the decrease in the number of weeds by 22.5–57.7% relative to the control, whereas in the treatments with herbicide application at the beginning of plant growth (treatments D–I) the decrease in their number compared to treatment A was 27.8–55.1%. In 2013, even more distinct differences due to herbicide application related to the weed biomass – in the control treatment it was significantly higher than in treatments B–I. Moreover, it should be noted that the highest reduction in weed biomass (3.2–4.9 times) relative to the control resulted from the application of metamitron at the beginning of plant growth of phacelia (treatments D, E, H, I). At the same time, with the double application of metamitron (treatments G–I), the phytotoxicity of this herbicide on phacelia plants was found to be significantly higher

The fresh weight yield of lacy phacelia was significantly higher in the control treatment (A) relative to the other treatments (B–I). Furthermore, as far as the above–mentioned treatments are concerned, the lowest vegetative biomass of phacelia was found in treatments H–I and thus in the plots where metamitron had been applied twice at the beginning of plant growth and where this herbicide had the most phytotoxic effect on the crop plant. The phacelia seed yield harvested in 2013 did not differ significantly between treatments compared (A–I). We can only speak of a trend of higher phacelia yield in treatments D–E (a single application of metamitron at the beginning of plant growth) and lower yield in treatments B–C and F–I, hence in the treatments where the herbicide was applied before emergence of the crop plant or was applied twice. This demonstrates that in 2013 the application of this herbicide in phacelia crops was not very rational (tab. 3).

Table 4. Number of dominant weed species in the lacy phacelia crop under the influence of different metamitron application system (control treatment A = 100%) – mean for 2011–2013
Tabela 4. Liczebność dominujących gatunków chwastów w łanie facelii błękitnej pod wpływem różnych systemów aplikacji metamitronu (obiekt kontrolny A = 100%) – średnie z lat 2011–2013

Weed species Gatunek chwastów	Treatments/ Obiekty								
	A	B	C	D	E	F	G	H	I
Matricaria maritima ssp. *inodora*	100	25	21	14	12	9	7	4	3
Viola arvensis	100	43	39	34	30	28	26	18	16
Stellaria media	100	51	46	38	36	31	29	19	15
Galinsoga parviflora	100	35	29	24	20	16	15	13	10
Lamium purpureum	100	40	38	35	30	25	21	16	12
Chenopodium album	100	29	27	18	15	11	9	3	3
Myosotis arvensis	100	9	9	7	6	5	0	0	0
Spergula arvensis	100	10	8	6	6	4	1	0	0
Polygonum aviculare	100	16	14	11	9	6	4	0	0
Galium aparine	100	66	62	53	48	43	35	32	30
Cirsium arvense	100	102	99	95	89	145	152	158	163
Taraxacum officinale	100	105	102	96	91	150	157	160	166

Among the weed flora in the lacy phacelia crops, the following 12 weed species: *Matricaria maritima* ssp. *inodora*, *Viola arvensis*, *Stellaria media*, *Galinsoga parviflora*, *Lamium purpureum*, *Chenopodium album*, *Myosotis arvensis*, *Spergula arvensis*, *Polygonum aviculare*, *Galium aparine*, *Cirsium arvense* and *Taraxacum officinale*, were clearly dominant in each year of the study. Metamitron caused the most effective reduction in the numbers of weed species such as: *Myosotis arvensis*, *Spergula arvensis*, *Polygonum aviculare* as well as *Matricaria maritima* ssp. *inodora* and *Chenopodium album* (especially the double application – treatments F–I). In the case of *Lamium purpureum* and *Galinsoga parviflora*, on the other hand, a satisfactory reduction in their numbers was achieved under the influence of metamitron. Species that showed certain resistance to metamitron (in particular during the single application – treatments B–E) were as follows: *Galium aparine*, *Stellaria media* and *Viola arvensis*. The efficacy of metamitron was highest when weeds were at the initial growth stages (2–3 leaf pairs). However, it should be noted that metamitron application (especially the double application) contributed to noticeable compensation of *Cirsium arvense* and *Taraxacum officinale* but at the same time to an almost complete reduction of *Matricaria maritima* ssp. *inodora* and a satisfactory reduction of the other dominant species (tab. 4).

DISCUSSION

In Poland, metamitron is registered as an herbicide used to kill dicotyledonous weeds in sugar beet, fodder beet, beetroot and strawberry crops. In many European countries, metamitron is used to control undesired plants in many less common crops. In the United Kingdom, this substance can be used to control weeds in rhubarb, in the Czech Republic and the Netherlands in ornamental bulbous plants such as lilies, tulips and irises, while in Germany in spinach crops [Matyjaszczyk and Dobrzański 2013, 2015, 2016, Zalecenia ochrony roślin 2014]. Eriksson [1988] obtained very promising results for post-emergence application of metamitron in *Salix* crops, while Dixon and Clay [2004] proved that this active substance can be used in weed management in forest nurseries. Attempts to use metamitron in small-scale crops for which there are no registered weed control agents have also been made in Poland. Borkowska and Molas [2008] applied metamitron in the form of the herbicide Goltix 70 WG in Virginia mallow. Despite that it was applied twice (soil-applied before sowing and after emergence), Goltix 70 WG showed unsatisfactory phytotoxic activity, killing weeds only in 30%. Similarly as in this experiment, it exhibited high efficacy in the case of *Galinsoga parviflora.* This herbicide significantly reduced the emergence of Virginia mallow plants, but a lower density did not have an adverse effect on the yield obtained.

In the literature of the subject, we find views that lacy phacelia plants tolerate some herbicides based on linuron, metamitron, isoproturon or metazachlor. Application of the above-mentioned herbicides allows phacelia to compete more effectively with weed flora, which in consequence is translated into higher productivity of the crop plant [Radziszewski and Rola 1999, Kaczmarek and Adamczewski 2007, Paradowski 2010, Facelia błękitna… 2014].

The study conducted by Yakimovich [2014] reveals that where no herbicides are used in crops of some herbal plants, the competition of weeds is so high that herbage yield decreases significantly, in spite of using mechanical weed control treatments. This thesis is also confirmed by the results of the studies by Kwiatkowski [2007, 2008, 2009] on the example of common valerian, sweet basil and garden thyme. However, Yakimovich [2014] demonstrates that lacy phacelia is more competitive to weeds than herbal plants. Damage is caused by weeds in phacelia crops (lower plant density, weaker foliage, a lower number of inflorescences and as a consequence a lower seed yield) especially in years with adverse weather conditions (e.g. an excessively long drought) when phacelia has a lower biomass growth rate [Yakimovich 2015]. The above view is confirmed by the results of this study.

Experiments on herbicide weed control in lacy phacelia crops were also conducted in Poland [Radziszewski and Rola 1999]. Similarly as in this experiment, the herbicide metamitron (at a rate of 700 $g \cdot kg^{-1}$) was applied in a lacy phacelia crop before emergence or at the beginning of plant growth. On average over the study period, the seed yield was found to increase by 0.6 $dt \cdot ha^{-1}$ when metamitron had been applied before emergence of the crop, while the seed yield increased by 1.0–1.1 $dt \cdot ha^{-1}$ when this herbicide had been applied at the beginning of plant growth. The 1000 seed weight of phacelia was also found to increase by 0.16 g (metamitron applied before phacelia emergence) and 0.19 g (metamitron applied at the beginning of plant growth). The average reduction in weeds was 79% (the herbicide applied before phacelia emergence) and 63–73% (the herbicide applied at the beginning of plant growth). Damage to phacelia leaves and a slower growth rate of the crop plant were only found in the treatment with application of the herbicide at the beginning of plant growth [Radziszewski and Rola 1999]. Similar findings can be drawn from the present study – the phytotoxic effect of metamitron on phacelia plants was primarily found when larger doses of the herbicide were applied, in particular at the higher rate and in the case of the double application.

Another field experiment carried out in Poland [Kaczmarek and Adamczewski 2007] shows that application of the herbicide Goltix 700 WG (metamitron) at a rate of 4.0 $kg \cdot ha^{-1}$ before emergence of phacelia resulted in a high level of destruction of the dominant weeds in the crop (*Viola arvensis, Matricaria maritima* ssp. *inodora, Stellaria media*). Similarly as in the present experiment, metamitron contributed to the elimination of *Matricaria maritima* ssp. *inodora,* which was the dominant weed species in the crop. Moreover, the above-mentioned researchers observed metamitron to have a phytotoxic effect on emerging plants of lacy phacelia and found their subsequent growth to be slower. In consequence, the reduction in seed yield of phacelia, compared to the control treatment (without herbicides), was about 15% [Kaczmarek and Adamczewski 2007].

CONCLUSIONS

1. Herbicide application in lacy phacelia crops is not always profitable. With active vegetative growth, this crop plant effectively competes with weeds and the use of herbicides is not necessary. Over the 3-year study period, only in one year the weeds delayed

and disturbed the growth of phacelia, their harmfulness was significant, and herbicide application was justified.

2. The effectiveness of application of metamitron at a rate of 1.4–2.1 l·ha^{-1} before emergence of lacy phacelia can be assessed to be unstable, since a large part of the spray solution is unproductively absorbed by the soil.

3. Under the climatic and soil conditions of the present experiment, our observations show that in the case of post-emergence application (a double application of the herbicide) metamitron may prove to be phytotoxic on the cultured crop, slowing down its growth and decreasing the seed yield.

4. The most appropriate herbicide application regime that protected lacy phacelia against annual dicotyledonous weeds (in particular *Myosotis arvensis, Spergula arvensis, Polygonum aviculare, Galinsoga parviflora*) proved to be a single application of metamitron (1.0 l·ha^{-1} or 1.4 l·ha^{-1}) at the 1–2 true leaf pair stage, which coincides with the initial growth stages of weeds.

5. Metamitron, in particular in a double application, caused compensation of the following perennial weeds: *Cirsium arvense* and *Taraxacum officinale,* while *Galium aparine* exhibited high resistance to this herbicide.

REFERENCES

Borkowska H., Molas R., 2008. Zachwaszczenie oraz obsada roślin ślazowca pensylwańskiego w zależności od herbicydów. Annales UMCS, sec. E, Agricultura 63 (1), 10–16.

Dixon F.L., Clay D.V., 2004. Effect of herbicides applied pre- and post-emergence on forestry weeds grown from seed. Crop Prot. 23 (8), 713–721.

Eriksson S., 1988. Postemergence herbicides in Swedish willow stands. Biomass 15 (1), 55–66.

Facelia błękitna: NATRA [Electronic resource]. Mode of access:http://www.ewentualnie.nazwa.pl/kalnas/images/stories/_kalnas/pozostale/facelia.pdf [date of access: 05.10.2016].

Kaczmarek S., Adamczewski K., 2007. Weed control efficacy and selectivity of herbicides in *Phacelia tanacetifolia* cultivation. Prog. Plant Prot. 47 (3), 125–128.

Kwiatkowski C.A., 2007. Evaluation of chemical and mechanical ways for weed control in garden thyme (*Thymus vulgaris* L.) growing for herbs. Herba Pol. 53 (3), 202–207.

Kwiatkowski C.A., 2008. Influence of selected herbicides on weed infestation on yielding of common valerian (*Valeriana officinalis* L.). Herba Pol. 54 (2), 13–21.

Kwiatkowski C.A., 2009. Ocena przydatności niektórych narzędzi oraz herbicydów w regulacji zachwaszczenia bazylii pospolitej (*Ocimum basilicum* L.) uprawianej na surowiec zielarski. Annales UMCS, sec. E, Agricultura 64 (3), 58–68.

Kwiatkowski C.A., Harasim E., Wesołowski M., 2016. Effects of catch crops and tillage system on weed infestation and health of spring wheat. J. Agr. Sci. Tech. 18, 999–1012.

Kwiatkowski C.A., Wesołowski M., Pałys E., Kraska P., Haliniarz M., Nowak A., Andruszczak S., Kwiecińska–Poppe E., 2014. Aspekty proekologicznego gospodarowania w agroekosystemach. Wyd. Perfekta Info, Lublin, ss. 165.

Matyjaszczyk E., Dobrzański A., 2013. Weed management of bulb flowers in Poland and other European Union countries. Prog. Plant Prot. 53 (2), 282–290.

Matyjaszczyk E., Dobrzański A., 2015. Weed management in rhubarb (*Rheum raponticum* L.) in Poland and other countries Prog. Plant Prot. 55 (4), 466–471.

Matyjaszczyk E., Dobrzański A., 2016. Zachwaszczenie upraw szpinaku i problemy z jego ograniczaniem. Zagadnienia Doradztwa Rolniczego 2, 104–113.

Nowakowski M., Szymczak-Nowak J., 1999. Wpływ uprawy rzodkwi oleistej, gorczycy białej i facelii błękitnej w międzyplonie ścierniskowym na populację mątwika burakowego (*Heterodera schachtii* Schmidt). Rośl. Oleiste 20, 259–266.

Paradowski A., 2010. Czym odchwaszczać facelię? Top Agrar Polska 1, 96–97.

Radziszewski J., Rola H., 1999. Usefulness of herbicides to weeds control in Phacelia crops. Prog. Plant Prot. 39 (2), 629–632.

Ribalko J., 2005. Facielia – miedonos, sidierat ta kormova kultura. Propozicia 8/9, 40–41.

Spiridonov J., 2006. Racionalnaia sistiema poniska i otbora gierbicidov na sovriemiennom etapie. J. Spiridonov, W.G. Shiestakov (red.), Matierialy RASHN – GNU WNIIF, 10–23.

Wilczewski E., Skinder Z., Szczepanek M., 2012. Effects of weather conditions on yield of tansy phacelia and common sunflower grown as stubble catch crop. Pol. J. Environ. Stud. 21 (4), 1053–1060.

Yakimovich A., 2014. Ocienka kokurientosposobnosti liekarstviennyh i miedonosnyh kultur k sornoi rastitielnosti. W: A. Yakimovich (red.), Liekarstviennyie rastienia – bioraznoobraznie, tiehnologji, primienienje: sbornik nautzhnyh statiei po matierialam I Miezhdunarodnoi nautzshno–praktitzheskoi konf., 5–6.06.2014, Grodno, 264–266.

Yakimovich A., 2015. Wriedonosnost sornych rastienij w posiewach facielji pizshmolistnoi. W: L.I. Triepazhko (red.), Sornyie rastienia i puti ogranitzienia ih wriedonosnosti. Tiez. Dokl. Mieshdunar. Nautzh. Konf. Posviasth. Pomiati N.I. Protasova i K.P Padinova, Minsk–Priluki, 30.06–03.07.2015, 164–166.

Zagumennikov W., 2006. Optimizacija kultivirowanija liekarstviennyh rastienij w nietzhiernoziemnoi zonie Rossiji. Matierialy RASHN WILAR.

Zalecenia ochrony roślin. Część I. Wykaz środków ochrony roślin. Poznań 2014.

Streszczenie. Eksperyment polowy z zastosowaniem herbicydu Lawina 700 SC (substancja aktywna – metamitron – w różnych systemach aplikacji) prowadzono w latach 2011–2013 w Priłukach k. Mińska na Białorusi. Udowodniono, że zastosowanie herbicydów w zasiewach facelii nie zawsze jest uzasadnione. Przy intensywnym rozwoju roślina uprawna samoistnie skutecznie konkuruje z chwastami i aplikacja herbicydów nie jest potrzebna. Tylko w jednym z trzech lat badań chwasty opóźniały i zaburzały rozwój facelii, ich szkodliwość okazała się znacząca, a stosowanie herbicydów miało wymierny sens. Okazało się, że różnica w biologicznej i ekonomicznej efektywności pomiędzy jednokrotnym i dwukrotnym zastosowaniem metamitronu była nieznaczna i nie stwierdzono wzmożonego efektu fitotoksyczności. Najsłuszniejszą formułą herbicydową chroniącą facelię błękitną przed chwastami krótkotrwałymi dwuliściennymi była jednokrotna aplikacja metamitronu (1,4 $l \cdot ha^{-1}$) w fazie 1–2 par liści właściwych. Badania pokazały także, że metamitron stosowany zarówno przed wschodami, jak i po wschodach facelii może wykazać fitotoksyczne działanie w stosunku do kultury uprawnej, spowalniając wzrost roślin i powodując zniżkę plonu nasion. Efektywność zastosowania metamitronu przed wschodami – zarówno w dawce 1,4 $l \cdot ha^{-1}$, jak i większej (2,1 $l \cdot ha^{-1}$) – okazuje się bardzo niestabilna, szczególnie w aspekcie bezpośredniej fitotoksyczności herbicydu dla rośliny uprawnej, a także okresowej kumulacji substancji biologicznie czynnej w glebie.

Słowa kluczowe: facelia błękitna, metamitron, zachwaszczenie, produkcyjność