Influence of selected herbicides on weed infestation and yielding of common valerian (*Valeriana officinalis* L.)

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S u m m a r y

A field experiment on weed control in valerian canopy was carried out in 2004–2006 in Jaroszewice (central part of Lublin region). Studies involved three herbicide mixtures applied at the stage of 3–4 leaves; herbicides had no certificates to be applied for valerian in Poland. Effects of tested herbicides were compared to traditional (two-stage) chemical weed control. Experiment revealed that the strongest reduction of valerian weed infestation was ensured by mixture of pendimethalin and haloxyfop-R as well as metamitron and propachizafop. Those herbicides were characterized by great selectivity towards valerian. MCPA and chizalofop-P-ethyl caused considerable plant injuries. The yield of valerian showed considerable negative correlation with the degree of canopy weed infestation. Content of valerenic acids in valerian raw material depended mainly on weather course during experiment.

Key words: common valerian, herbicides, weed infestation, yield, valerenic acid content

INTRODUCTION

Medicines made of common valerian (*Valeriana officinalis* L.) dominate in sedatives. The raw material are underground parts of the plant (roots and rhizomes) which contain active substances. The hydrolysis products of them are valerenic acids [1-4]. In cultivation conditions, valerian provides more uniform material than that of natural stands [5, 6]. One of main problems in agrotechnology of that species is weed control. In Poland, Reglone Turbo 200 SL (before emergence or seedling setting) and Fusilade Forte 150 EC (at a stage of 3 leaves) were registered for valerian plantations control [7]. However, neither these herbicides nor mechanical control is efficient. Dicotyledonous weeds competing especially after valerian seedling setting is a great problem, because their removing is hampered by the lack of registered and certified herbicides. Results of few experiments involving herbicide control of herbs indicated that there are several active substances efficient in weed control and safe for herbal plants [8-10]. Therefore, it seems to be plausible to carry out studies upon application of some foliage herbicides for common valerian plantations and to determine their weed control abilities as well as probable phytotoxic action.

This experiment was aimed at evaluating the influence of the application date of both single herbicides and herbicide mixtures on canopy weed infestation and yield quality of common valerian cultivated under soil and climatic conditions of central part of Lublin region.

MATERIAL AND METHODS

The field experiment with common valerian ("Lubelski" cv.) cultivation was carried out in 2004–2006 in Jaroszewice (central part of Lublin region) on incomplete podzolic soil considered as III A bonitation class and good wheat complex. The experiment was set by means of split-plot method in 3 replications on 5 m^2 plots. Spring barley as well as spring vetch and pea intercrop were a forecrops for valerian. A flat (traditional) cultivation was applied. The spacing of valerian was 50 × 30 cm (65 000 seedlings per hectare). Mineral fertilization was used in spring at the following amounts recalculated onto 1 ha: N – 25 kg before planting and 25 kg at the stage of 2–3 leaves, P – 30 kg, K – 80 kg. Various combinations of foliage herbicides (with no certificates for valerian plantations) with those permitted by Plant Protection Institute Calendar [7] were compared in the study. In addition, mechanical opening (manual hoe) was made on all objects at the stage of 5–6 valerian leaves. The experimental design included:

A Reglone Turbo 200 SL (dikwat) – 1.5 l/ha – before planting the valerian as well as Fusilade Forte 150 EC (fluazifop-p-butyl) – 1 l/ha – at the stage of 3–4 leaves (control object);

B Dicoherb 750 SL (MCPA) – 0.75 l/ha and Targa Super 05 EC (chizalofop-P-ethyl) – 1 l/ha – at the stage of 3–4 leaves;

C Stomp 330 EC (pendimethalin) – 0.75 l/ha and Gallant Plus 104 EC (haloxyfop-R) – 1 l/ha – at the stage of 3–4 leaves;

D Goltix 700 SC (metamitron) – 1.2 l/ha and Agil 100 EC (propachizafop) – 1 l/ha – at the stage of 3–4 leaves.

Herbicides were applied with use of field sprayer under the pressure of 0.25 MPa.

Analysis of weed infestation of valerian canopy was performed before harvest by means of botanical-gravimetric method, determining the number, species composition and weight of weeds in the plot of 0.5×1 m^2 in 2 replications. Valerian roots and rhizomes harvested every year at the beginning of October were washed and cleaned, then dried at 35°C and weighed. Quantitative analyses of valerenic acids in roots and rhizomes were made using gas chromatograph (ITS 40) coupled with mass spectrometer (GC/MS). Results were statistically processed by determining the significance of differences by Tukey's test.

Weather conditions during the whole experiment were changeable. In 2004, a drought occurred in May and June, while in 2005, extreme rainfalls were recorded in May (147 mm); 2006 was the most advantageous and the most similar to the long-term mean of air temperatures and precipitation.

RESULTS AND DISCUSSION

The type of herbicidal mixture and its application time was of a crucial influence on air-dry weight of weeds from valerian canopy (tab. 1). In the conditions of control object (A), removal of dicotyledonous weeds before valerian emergence (dikwat) and monocotyledonous weeds (fluazifop-p-butyl) at the stage of 3–4 crop leaves, resulted in forming the largest weed weight in canopy within three-year-long period. The use of herbicides with no certificates (pendimethalin and haloxyfop-R – object C, and metamitron and propachizafop – object D) significantly reduced weed weight in comparison with control plots (by 23.8% and 18.6%, respectively). Mixture of MCPA and chizalofop-P-ethyl also reduced weed weight by about 9.6% as compared to the control, but that difference was statistically insignificant. Considering the weed-controlling effectiveness of particular herbicides during the whole experiment, a strong dependence on weather conditions can be observed (tab. 1). In 2004, when drought occurred during herbicide application, all herbicidal mixtures with no certificate (objects B, C, and D) considerably reduced air-dried weed matter in relation to control plots. The use of the pendimethalin and haloxyfop-R mixture in weed control gave a particularly positive result by reducing the weed weight in canopy by about 49.1%. In 2005, extreme rainfalls in May made efficient herbicide application more difficult. In such conditions, the lowest weed infestation was observed on plots with traditional protection (object A), where significantly lower weed weight (by 13.8%) as compared to object C (pendimethalin and haloxyfop-R) was observed. In the last study year (2006) characterized by moderate weather conditions, mixtures of herbicides again proved to be effective in weed removal; in particular pendimethalin and haloxyfop-R contributed to significant reduction of weed weight as compared to objects A (45.9%) and B (35.3%, see tab. 1).

Table 1.

Air-dry weight of weeds in common valerian canopy

objects	years of cultivation			mean
	2004	2005	2006	
g/m^2				
A dikwat and fluazifop-p-butyl (control)	38.5	41.2	30.1	36.6
B MCPA and chizalofop-P-ethyl	29.8	44.3	25.2	33.1
C pendimethalin and haloxyfop-R	19.6	47.8	16.3	27.9
D metamitron and propachizafop	23.5	46.2	19.8	29.8
mean	27.8	44.9	22.8	-
LSD (0.05) for herbicides	7.06	6.52	5.97	5.31
LSD (0.05) for years – 7.48				

Similar tendencies were also observed in reduction of number of dominating weed species (tab. 2). On control object, following weeds predominated in valerian canopy: *Stellaria media, Viola arvensis, Echinochloa crus-galli, Galinsoga parviflora*. Herbicide mixtures such as pendimethalin and haloxyfop-R (C) and metamitron + propachizafop (D) caused significant decrease of weed number in relation to control: by 52.7% and 44.6%, respectively. Mixture of MCPA and chizalofop-P-ethyl (B) showed similar as combination of dikwat and fluazifop-p-butyl (A) efficiency in reducing weeds. However, it was characterized by low efficiency in competing *Echinochloa crus-galli, Polygonum lapathifolium, Chenopodium album* and *Cirsium arvense.* The highest loss of weeds due to herbicides was recorded in object C for *Stellaria media, Viola arvensis, Echinochloa crus-galli, Euphorbia helioscopia, Galeopsis tetrahit*, and in object D for *Polygonum lapathifolium, Chamomila recutita, Elymus repens,* and *Cirsium arvense* (tab. 2).

Table 2.

Herbicidal efficiency of weeds control in common valerian canopy (mean from 2004–2006)

weeds species dominant	objects			
	(A) dikwat and fluazifop-p-butyl	(B) MCPA and chizalofop-P-ethyl	(C) pendimethalin and haloxyfop-R	(D) metamitron and propachizafop
mean number of weeds per 1 m^2				
Stellaria media (L.) Vill.	14.3	12.5	4.3	8.5
Viola arvensis Murr.	13.6	10.2	5.4	8.1
Echinochloa cruss-galli L.	10.8	12.5	6.0	9.2
Galinsoga parviflora Cav.	10.2	7.9	4.8	6.2
Polygonum lapathifolium L.	8.7	9.4	7.2	3.3
Chamomilla recutita L.	8.5	6.9	2.4	1.8
Chenopodium album L.	8.0	10.8	6.2	7.3
Elymus repens (L.) P.B.	6.7	6.9	5.3	4.6
Euphorbia helioscopia L.	5.8	4.2	0.8	2.3
Galeopsis tetrahit L.	4.4	3.5	1.2	2.7
Cirsium arvense (L.) Scop.	4.2	5.3	2.0	1.8

Myosotis arvensis (L.) Hill	3.5	2.8	0.9	1.3
Taraxacum officinale Weber	2.7	2.5	0.6	1.0
other species	16.2	6.2	8.6	7.1
total	117.6	101.6	55.7	65.2
LSD (0.05) for herbicides – 17.72				

Studied herbicidal mixtures showed varied level of phytotoxicity to common valerian (tab. 3). Regardless the vegetation season, significantly lowest percentage of damaged valerian plants (0.3%) was observed on control plots, where weeds were removed before valerian planting (dikwat) and at the stage of 3–4 leaves – only monocotyledonous weeds (fluazifop-p-butyl). Also pendimethalin and haloxyfop-R as well as metamitron and propachizafop – herbicides with no certificate for common valerian plantations – showed low phytotoxicity. Apparently higher percentage of damaged plants was observed in a case of MCPA and chizalofop-P-etyl mixture, namely during the drought (2004).

Table 3.

Phytotoxicity of herbicides to common valerian

objects	years of cultivation			Mean
	2004	2005	2006	
damaged plants (%)				
A dikwat and fluazifop-p-butyl (control)	0.5	0.1	0.3	0.3
B MCPA and chizalofop-P-ethyl	14.2	6.3	8.4	9.6
C pendimethalin and haloxyfop-R	2.6	1.9	2.0	2.2
D metamitron and propachizafop	3.5	2.2	1.9	2.5
mean	5.2	2.6	3.1	-
LSD (0.05) for herbicides	2.76	2.02	2.09	2.16
LSD (0.05) for years – 1.75				

In present study, MCPA appeared to have a phytotoxic effect on common valerian, while metamitron and pendimethalin showed negligible toxicity. High weed-controlling efficiency of metamitron along with selectivity towards the crop were confirmed by Kwiatkowski and Kołodziej [9] as well as Kucharski and Mordalski [8]. There are no literature references on studies concerning the use of pendimethalin – the least phytotoxic preparation in present study – on herbs plantations. In opinion of Michaud et al. [11] as well as Praczyk and Skrzypczak [12], weed control using herbicide spraying does not ensure an efficient weed killing, because weather conditions are often detrimental during vegetation period. Nevertheless, experiments with chemical weed control of herb plantations show the usefulness of studies on new herbicides with no certificates for herb plantations [8, 9].

The yield of common valerian (tab. 4) showed huge negative correlation with the weed infestation degree. Significantly negative correlation occurred in objects A and B (tab. 5). Therefore, the lowest yield of raw material was found in control object (A) and in object B (MCPA and chizalofop-P-ethyl) and was average for the whole experiment. Other herbicide combinations (objects C and D) had the influence on forming significantly highest yields of root and rhizome, both in relation to object A (yield increase by 14.7% and 12.2%, respectively) and in comparison to object B, in reference to which the yield on plot C was higher by 11.2%. Analysis of common valerian yielding in particular years of study revealed that both in 2004 and 2006 yields of the plant on plots C and D were considerably higher than yields on plots A and B. In 2005, differences of valerian yielding in particular objects were insignificant, and the highest yields were recorded on control plots, where weeds were controlled just before valerian seedling setting (dikwat).

Table 4.

Yield of common valerian roots and rhizomes

objects	years of cultivation			mean
	2004	2005	2006	
t/ha				
A dikwat and fluazifop-p-butyl (control)	3.38	3.31	3.47	3.38
B MCPA and chizalofop-P-ethyl	3.51	3.19	3.88	3.52
C pendimethalin and haloxyfop-R	4.28	3.25	4.35	3.96
D metamitron and propachizafop	4.24	3.21	4.11	3.85
mean	3.85	3.24	3.95	-
LSD (0.05) for herbicides	0.461	n. s.^{x}	0.417	0.392
LSD (0.05) for years – 1.75				

^{x} – non-significant

Table 5.

Simple correlation coefficient (r) between weed infestation and yield of common valerian roots and rhizomes (mean from 2004–2006)

specification	A dikwat and fluazifop-p-butyl	B MCPA and chzalofop-P-ethyl	C pendimethalin and haloxyfop-R	D metamitron and propachizafop
air dry weight of weeds	–0.81^x	–0.72^x	–0.31	–0.42
number of weeds	–0.70^x	–0.59^x	–0.37	–0.34

^{x} – significant correlation coefficient (0.05)

Contents of valerenic acids in common valerian significantly varied depending on weather conditions during the study period (tab. 6). Their highest contents were found in 2006, when air temperatures and rainfalls were the most similar to long-term mean values. The lowest levels of valerenic acids were recorded in cool and wet 2005. Herbicides applied for valerian plantation did not influence the valerenic acids concentrations. Only the tendency to increase these acids contents in dry matter of material originating from control objects (dikwat and fluazifop-p-butyl) and object C (pendimethalin and haloxyfop-R) could be observed.

Table 6.

Valerenic acids content in roots and rhizomes of common valerian

objects	years of cultivation			mean
	2004	2005	2006	
% d.m.				
A dikwat and fluazifop-p-butyl (control)	0.21	0.19	0.28	0.23
B MCPA and chizalofop-P-ethyl	0.21	0.17	0.25	0.21
C pendimethalin and haloxyfop-R	0.23	0.18	0.28	0.23
D metamitron and propachizafop	0.20	0.17	0.27	0.21
mean	0.21	0.18	0.27	-
LSD (0.05) for herbicides	n.s.[x]	n.s.	n.s.	n.s.
LSD (0.05) for years – 0.079				

[x] – non-significant

Yields of common valerian and valerenic acids content obtained through the experiment were similar to those obtained in some local [6, 13] and foreign studies [3, 14]. Any discrepancy may result from different varieties or cultivation conditions [10, 13]. Publications of other authors [6, 15] illustrate the complexity of the dependence of yielding and material quality on plant density, competitiveness in a canopy for nutrients, light, and water. Interpretation of differences in chemical composition resulting from experimental factors is difficult due to very strong effects of weather conditions and chemical composition changes in common valerian in particular periods of vegetation season [2].

CONCLUSIONS

1. Parallel dicotyledonous and monocotyledonous weed control by means of herbicidal mixtures applied at the stage of 3–4 leaves made a positive effect as compared to traditional (separate) weed control on plots before plantation setting and at the stage of 3 leaves.
2. Herbicides that are not certified for common valerian: Stomp 330 EC (pendimethalin) and Gallant Plus 104 EC (haloxyfop-R) and Goltix 700 SC (metamitron) + Agil 100 EC (propachizafop) showed great selectivity in relation to crop and high efficiency in reducing the number and weight of main weed species.
3. Herbicides Dicoherb 750 SL (MCPA) and Tagra Super (chizalofop-P-ethyl) considerably damaged the valerian plants and in consequence caused a decrease in the plant yields.
4. Traditional, two-stage application of Reglone Turbo 200 SL (dikwat) and Fusilade Forte 150 EC (fluazifop-p-butyl) herbicides showed positive weed control action in the year of unfavorable weather conditions (precipitation excess). Moreover, such herbicidal combination positively affected the valerenic acids contents in valerian roots and rhizomes.

5. The highest yields were guaranteed by application of herbicide mixture (pendimethalin and haloxyfop-R) for weed control.
6. Contents of valerenic acids in dry matter of valerian roots and rhizomes mainly depended on weather conditions during the experiment.

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WPŁYW WYBRANYCH HERBICYDÓW NA ZACHWASZCZENIE I PLONOWANIE KOZŁKA LEKARSKIEGO (*VALERIANA OFFICINALIS* L.)

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S t r e s z c z e n i e

Eksperyment polowy ze zwalczaniem chwastów w łanie kozłka lekarskiego prowadzono w latach 2004–2006 w Jaroszewicach (środkowa Lubelszczyzna). W badaniach uwzględniono trzy mieszanki herbicydów aplikowanych w fazie 3–4 liści kozłka, które nie mają atestu na stosowanie na plantacji tej rośliny w Polsce. Badane herbicydy skonfrontowano z tradycyjnym (dwufazowym) odchwaszczaniem chemicznym. Eksperyment dowiódł, że największą redukcję zachwaszczenia łanu kozłka zapewnia mieszanka herbicydów pendimetalina + haloksyfop-R oraz metamitron + propachizafop. Wymienione herbicydy wykazywały się dużą selektywnością w stosunku do rośliny uprawnej. MCPA + chizalofop-P-etyl powodowały znaczne uszkadzanie roślin kozłka. Plonowanie kozłka lekarskiego było ujemnie skorelowane ze stopniem zachwaszczenia plantacji. Zawartość kwasów walerenowych w surowcu kozłka lekarskiego zależała głównie od przebiegu pogody w latach badań.

Słowa kluczowe: kozłek lekarski, herbicydy, zachwaszczenie, plon, zawartość kwasów walerenowych