Weed control in dormant alfalfa (*Medicago sativa* L.) with active ingredients' *metribuzin*, *imazetapyr* and *pronamide*

Regulácia burín v lucerne siatej počas obdobia kľudu (*Medicago sativa* L.) účinnými látkami *metribuzin*, *imazetapyr* a *pronamide*

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Abstract

Field trials were conducted during 2008 – 2010 to evaluate weed control in dormant alfalfa (*Medicago sativa* L.) with *metribuzin*, *imazetapyr* and *pronamide*. The weed population in all experimental years was consisted mainly of annual winter and spring grass and broadleaf weeds, and some perennial weeds. The number of weed species and weed density increased with the years of alfalfa growing, from second to the fourth year. Weed density in the untreated control plots was 201.0, 217.2 and 240.5 plants per m^2 in 2008, 2009 and 2010, respectively. The most dominant weeds were *Anthemis cotula*, *Capsell bursa-pastoris* and *Taraxacum officinale* in 2008, *Alopecurus myosuroides* and *Poa pratensis* in 2009 and *Millium vernale* and *Arabidopsis thaliana* in 2010. Efficacy of herbicides in control of weeds was ranged of 91.8% (*pronamide*) to 98.4% (*metribuzin* 1.0 $kg*ha^{-1}$) in 2008, 93.1% (*imazetapyr*) to 97.3% (*metribuzin* 1.0 $kg*ha^{-1}$) in 2009 and 92.1% (*imazetapyr*) to 97.3% (*metribuzin* 1.0 $kg*ha^{-1}$) in 2010, respectively. Efficacy of herbicides in control of prevailing weeds during the 3 years field trial period was ranged of 48.5% to 100.0%. No visual alfalfa injured was determined by any rates during the experimental period, and consequently, none of the applied herbicides reduced first-harvest alfalfa yields. Alfalfa yield was markedly affected by herbicide efficacy in all experimental years, particularly in the second year, where yields of herbicide treatments were similar to that of the weed free control.

Keywords: alfalfa, alfalfa dry matter yield, herbicides, weed control

Abstrakt

Poľné pokusy prebiehali v rokoch 2008 – 2010 s cieľom vyhodnotiť reguláciu burín v trvalých porastoch lucerny siatej (*Medicago sativa* L.) prípravkami s účinnou látkou *metribuzin*, *imazetapyr* alebo *pronamide*. Populácia burín vo všetkých rokoch experimentu pozostávala hlavne z jednoklíčnolitových druhov jednoročných ozimných a jarných tiež širokolistými burinami a niektorými trvácimi druhmi burín. Početnosť a hustota burinných druhov vzrastal v porastoch lucerny siatej z roka na rok, vzostupne od druhého do štvrtého úžitkového roku. Hustota zaburinenia v neošetrených, kontrolných variantoch pokusu bola 201.0, 217.2 a 240.5 rastlín na m^2 v rokoch 2008, 2009 a 2010. Najviac zastúpeným burinnými druhmi boli *Anthemis cotula*, *Capsell bursa-pastoris* a *Taraxacum officinale* v roku 2008, *Alopecurus myosuroides* a *Poa pratensis* v roku 2009 a *Millium vernale* a *Arabidopsis thaliana* v roku 2010. Účinnosť herbicídnej regulácie burín bola v rozmedzí od 91.8% (*pronamide*) do 98.4% (*metribuzin* 1.0 kg*ha^{-1}) v roku 2008, 93.1% (*imazetapyr*) do 97.3% (*metribuzin* 1.0 kg.ha^{-1}) v roku 2009 a 92.1% (*imazetapyr*) do 97.3% (*metribuzin* 1.0 kg*ha^{-1}) v roku 2010. Účinnosť herbicídnej regulácie hlavných burinných druhov počas trojročnej periódy poľného pokusu bola v rozmedzí od 48.5% do 100.0%. Počas celej doby pokusu nebola zaznamenaná žiadna fytotoxicita na poraste lucerny siatej a nebola negatívne ovplyvnená ani prvá kosba lucerny siatej. Úroda lucerny siatej bola preukazne ovplyvnená účinnosťou herbicídov vo všetkých rokoch poľného pokusu, a to najmä v druhom úžitkovom roku. V tomto roku dosiahla úroda z variantu s herbicídnym ošetrením úrodu podobnú ako na variante bez regulácie burín.

Kľúčové slová: herbicídy, lucerna siata, regulácia burin, úroda sušiny lucerny

Detailný abstrakt

Pri pestovaní lucerny siatej je najdôležitejšie skoré zapojenie porastu tak aby bol schopný konkurovať burinám. Ak je porast lucerny siatej zapojený a v dobrej kondícií trváce druhy burín – *Cirsium arvense* (L.) Scop, *Taraxacum officinale* Weber, *Sonchus arvensis* L., *Agropyron repens* (L.) Beauv a *Crepis tectorum* L. – vstupujú do neho až v nasledujúcich úžitkových rokoch a ovplyvňujú úrodu lucerny siatej a jej schopnosť rásť na danom stanovišti ďalšie úžitkové roky. Buriny síce redukujú úrodu lucerny siatej, ale najmä zhoršujú kvalitu lucerny siatej.

Výsledky pokusov ukazujú, že mnohé herbicídy môžu byť použité na selektívnu reguláciu burín v zapojenom poraste lucerny siatej. Herbicídy na báze účinných látok imazetapyr, metribuzin a pronamide sú vo všeobecnosti najčastejšie aplikované počas obdobia dormancie porastu lucerny siatej (november – február). Tieto účinné látky pôsobia efektívne a regulujú buriny bez poškodenia porastu alebo prejavu fytotoxicity na lucerne siatej. Aplikáciou herbicídov v zapojenom poraste je zvýšená úroda a kvalita sena lucerny siatej. Poľné pokusy sme realizovali v rokoch 2008 – 2010 s cieľom vyhodnotiť reguláciu burín v trvalých porastoch lucerny siatej (*Medicago sativa* L.) prípravkami s účinnou látkou *metribuzin*, *imazetapyr* alebo *pronamide*. Populácia burín vo všetkých rokoch poľného pokusu pozostávala najmä z jednoklíčnolistových jednoročných ozimných a jarných burinných druhov, z

širokolistých burín a niektorými trvácimi druhmi burín. Početnosť a hustota burinných druhov vzrastá v porastoch lucerny siatej z roka na rok, vzostupne od druhého do štvrtého úžitkového roku. Hustota zaburinenia v neošetrených, kontrolných variantoch pokusu bola 201.0, 217.2 a 240.5 rastlín na m^2 v rokoch 2008, 2009 a 2010. Najviac zastúpeným burinnými druhmi boli *Anthemis cotula*, *Capsella bursa-pastoris* a *Taraxacum officinale* v roku 2008, *Alopecurus myosuroides* a *Poa pratensis* v roku 2009 a *Millium vernale* a *Arabidopsis thaliana* v roku 2010. Účinnosť herbicídnej regulácie burín bola v rozmedzí od 91.8% (*pronamide*) do 98.4% (*metribuzin* 1.0 kg*ha^{-1}) v roku 2008, 93.1% (*imazetapyr*) do 97.3% (*metribuzin* 1.0 kg*ha^{-1}) v roku 2009 a 92.1% (*imazetapyr*) do 97.3% (*metribuzin* 1.0 kg*ha^{-1}) v roku 2010. Účinnosť herbicídnej regulácie hlavných burinných druhov počas trojročnej periódy poľného pokusu bola v rozmedzí od 48.5% do 100.0%. Počas celej doby pokusu nebola zaznamenaná žiadna fytotoxicita na poraste lucerny siatej a nebola negatívne ovplyvnená ani prvá kosba lucerny siatej. Úroda lucerny siatej bola preukazne ovplyvnená účinnosťou herbicídov vo všetkých rokoch poľného pokusu, a to najmä v druhom úžitkovom roku, kedy úroda z variantu s herbicídnym ošetrením boli podobné ako tie, ktoré boli dosiahnuté vo variante kontrola bez burín.

Introduction

Alfalfa (*Medicago sativa* L.) is one of the most important forage legumes cultivated in the world. Unlike annual cropping systems, alfalfa management differs greatly due to its perennial habit of growth. Alfalfa is a perennial legume crop, usually grown for a three to five year period, i.e. it will remain in the field for several growing seasons and will be harvested several times each season (Gianessi et al., 2002). Therefore, specific management practices in alfalfa will affect floristic composition of the weed population (Kojić and Šinžar, 1985).

After the crop is established, alfalfa stands naturally thin over years, making the crop increasingly susceptible to weed invasion (Summers, 1998). According Peters et al., (1984), weeds are probably the single factor most responsible for stand loss in alfalfa production systems. Cool season weeds compete with alfalfa in the spring during the onset of new growth, and stand loss initiated at this time perpetuates itself through the summer months with the establishment of warm-season weed species (Smith, 1991).

Once the alfalfa is established, perennial weeds such as *Cirsium arvense* (L.) Scop, *Taraxacum officinale* Weber, *Sonchus arvensis* L., *Agropyron repens* (L.) Beauv and *Crepis tectorum* L. invade in subsequent years and affect yield and persistence adversely (Malik and Waddington, 1989). Weeds reduce alfalfa yield, but more importantly, weeds reduce the quality of alfalfa (Leroux and Harvey, 1985; Cosgrove and Barrett, 1987). Pike and Stritzke (1984) demonstrated that *Bromus secalinus* L. infestations could reduce first cutting alfalfa yields 60 to 85% when not controlled in the fall, with the total alfalfa yield for the season (3 to 5 cuttings) being reduced 25 to 35%.

Results from several experiments have shown that many herbicides can be used to control weeds selectively in established alfalfa (Wilson, 1981; Cosgrove and Barrett, 1987; Wilson, 1989; Malik et al., 1993; Wilson, 1997; Ashigh et al., 2009). Herbicides such as *imazetapyr*, *metribuzin* and *pronamide* generally are applied during alfalfa dormant period (November – February) to control weeds effectively, and, in same time, to avoid alfalfa crop injury (Waddington, 1980; Peters et al., 1984). As a result of that, yield and quality of established alfalfa increased (Harvey et al., 1976; Kapusta and Stricker, 1975; Fawcett et al., 1978; Wilson, 1981).

Taking into consideration previous mentioned facts, the objective of this study was to investigate the effectiveness of *metribuzin*, *imazetapyr* and *pronamide* for controlling weeds in dormant alfalfa, and, in same time, to estimate influence of herbicides on the alfalfa yield.

Materials and Methods

The field studies were conducted during 2008 – 2010 in established alfalfa (second, third and fourth year) in Pelagonia region on Molic vertic gleysol cumuligleyic (Filipovski, 2006) with 27.10% coarse, 47.30% fine sand, 25.60% clay+silt, 1.46% organic matter and pH 6.0. The experimental design was a randomized complete block with four replicates, and harvest plot size of 20 m^2. The field trails were carried out with alfalfa variety "Debarska" which was drill-seeded in a well-prepared seedbed at a seeding rate of 18 kg*ha^{-1} on April 16th, 2007. During the 3 years field trial period (2008-2010), established alfalfa was treated every year with follow herbicides: *metribuzin* (Sencor WG 70) applied at 0.7 and 1.0 kg*ha^{-1}, *imazethapyr* (Pivot 100 E) applied at 2.0 l*ha^{-1} and *pronamide* (Kerb W 50) applied at 1.0 l*ha^{-1} during dormant growth period (DGP), usually the beginning of March. Untreated and weed free controls were included in the studies, as well (Table 1).

Table 1. Trade names, active ingredients and rates of application of herbicides

Tabuľka 1. Obchodné názvy, aktívne látky a množstvo aplikovaných herbicídov

Treatment	Active ingredient (a.i.)	Common names	Rate (kg; l*ha^{-1})	Time of application
Untreated control	-	-	-	-
Weed free control	-	-	-	-
Metribuzin	700 g*kg^{-1}	Sencor WG 70	0.7	DGP
Metribuzin	700 g*kg^{-1}	Sencor WG 70	1.0	DGP
Imazethapyr	100 g*l^{-1}	Pivot 100 E	2.0	DGP
Pronamide	500 g*l^{-1}	Kerb W 50	3.0	DGP

DGP – dormant growth period

The herbicidal treatments were applied with a CO_2 – pressurized backpack sprayer with 400 l*ha^{-1} water. Data were recorded on the degree of weed density (by quantity method – number per m^2), herbicidal efficacy, and selectivity (by EWRS scale), and dry matter yield (kg*ha^{-1}). Weed control efficacy was estimated in spring before the first cut by the weed plants counting, and herbicide efficacy was calculated by equitation (Mani et al., 1968):

$$W_{CE} = \frac{Wcp - Wtp}{Wcp} \times 100$$

Where:

W_{CE} – weed control efficiency,

Wcp- number of weeds in the control plots,

Wtp- number of weeds in the treated plots.

Alfalfa plant injury were rated 28 days after treatment. Visible injury ratings were based on scale of EWRS (1 = 0% mortality and 9 = 100% mortality). The alfalfa at all years was harvested three times, but only yield of the first cutting is shown, because effects of applied herbicides were the most significant in this harvest. First cut forage in the both years was harvested in the middle to late of June, respectively when the alfalfa was in the early bloom stage. Alfalfa yields were determined by mechanically harvesting from 1 m^2 of each plots, and the weight of the harvested samples were recorded after drying at 50 ^oC in a forced air oven. All yields are reported on a dry weight basis. The data were subjected to statistical analysis by Statistica applying LSD – test (Steel and Torrie, 1980).

Results and discussion

Weed population (before the first cut)

The weed population before the first cut of alfalfa in all experimental years was consisted mainly of annual winter and spring grass and broadleaf weeds, and some perennial weeds. Generally, the number of weed species and weed density increased with the years of alfalfa growing, from second to the fourth year (Table 1). Concrete, in 2008, the weed population before the first cut was consisted of 13 weed species, and total number of weeds was 201.0 plants*m^{-2} (Table 2). The most prevailing among the 13 weed species were *Anthemis cotula* (45.5 plants*m^{-2}), *Capsella bursa-pastoris* (41.0 plants*m^{-2}) and *Taraxacum officinale* (30.8 plants*m^{-2}). In the 2009, the weediness was higher in compare with the previous year. Total number of weeds was 217.2 plants*m^{-2}. The most abundant among the 14 weed species were *Alopecurus myosuroides* (57.0 plants* m^{-2}) and *Poa pratensis* (39.5 plants*m^{-2}). In 2010, weed density was qualitatively and quantitatively the most expressed (16 weed species and 240.5 plants*m^{-2}, respectively). In this year, before the first cut, the most numerous weeds were *Millium vernale* (109.8 plants*m^{-2}) and *Arabidopsis thaliana* (54.0 plants*m^{-2}). An earlier weed survey of Loeppky and Thomas (1998) and Thomas et al. (2000) indicated that *Taraxacum officinale* and *Agropyron repens* are among the most abundant and difficult weed species to control in Saskatchewan alfalfa fields. Furthermore, in the study of Wilson (1989), *Taraxacum officinale*, *Capsella bursa-pastoris* and *Descurainia pinnata* were the predominant weeds in established alfalfa. Sheaffer and Wyse (1982) found that *Taraxacum officinale* is very problematic weed in stands of dormant alfalfa in Minnesota, and *Cirsium arvense* is one of the most troublesome perennial weeds in established alfalfa grown, particularly for seed production (Mesbah and Miller, 2005).

Table 2. Weed population (No*m^{-2}) in the experiment (before the first cut)

Tabuľka 2. Počet burín (ks*m^{-2}) na pokusoch (pred prvou kosbou)

Weed species	2008	2009	2010
Anthemis cotula L.	45.5	2.5	26.3
Capsell bursa-pastoris (L.) Medik.	41.0	19.8	-
Taraxacum officinale Web.	30.8	-	0.5
Alopecurus myosuroides Huds.	23.8	57.0	3.5
Stellaria media (L.) Vill	18.5	-	-
Veronica hedirifolia L.	17.0	2.5	-
Cirsium arvense (L.) Scop.	14.5	2.0	1.5
Apera spica-venti (L.) P.B.	9.5	7.8	3.5
Lactuca scariola L.	6.8	3.0	-
Vicia striata M.B.	1.0	-	-
Bromus mollis L.	1.0	16.0	1.8
Tanacetum vulgare L.	0.8	3.3	3.3
Poa trivialis L.	0.8	-	-
Poa pratensis L.	-	39.5	-
Chondrila juncea L.	-	-	10.5
Arabidopsis thaliana (L.) Heynh.	-	19.5	54.0
Milium vernale M. Bieb.	-	27.0	109.8
Thlaspi arvense L.	-	12.5	15.3
Bromus arvensis L.	-	4.8	0.3
Matricaria chamomilla L.	-	-	3.8
Crepis setosa Hall.	-	-	5.8
Lolium multiflorum Lam.	-	-	0.3
Convolvulus arvensis L.	-	-	0.3
Total weed species	13	14	16
Total weeds (No*m^{-2})	201.0	217.2	240.5

Weed control and herbicide efficacy

Criterion for herbicide efficacy was taken as the percentage of weeds that are control by any particular treatment in compare with untreated control. Data regarding herbicide efficacy presented in Table 3 show that all investigated herbicides had a highly significant (P <0.01) effect on weed density per m^2. During the 3 years field trial period, maximum weeds were recorded in untreated control plots (201.0, 217.2 and 240.5, respectively). Minimum weeds in 2008 were recorded in plots treated with *metribuzin* applied at higher rate (1.0 kg*ha^{-1}) - 3.3. Number of weeds in plots treated with *metribuzin* applied at lower rate (0.7 kg*ha^{-1}) was insignificant lower (9.5) in compare with *imazethapyr* and *pronamide* (13.0 and 16.4, respectively). In 2009, minimum weeds were observed in plots treated with *metribuzin* applied at higher rate

(1.0 kg*ha^{-1}) - 5.8, followed by *metribuzin* applied at lower rate (0.7 kg*ha^{-1}), *pronamide* and *imazethapyr* (10.5, 11.3 and 15.0, respectively). In 2010, same as in the previous years, minimum weeds were counted in plots treated with *metribuzin* applied at higher rate (1.0 kg*ha^{-1}) - 6.4, followed by *metribuzin* applied at lower rate (0.7 kg*ha^{-1}) - 11.3, while maximum weeds in herbicide treatments were observed in plots treated with *pronamide* and *imazethapyr* (16.5 and 19.0, respectively). Reduction of the weed density was in positive correlation with herbicide efficacy. Efficacy of herbicides in control of weeds was ranged of 91.8% (*pronamide*) to 98.4% (*metribuzin* 1.0 kg*ha^{-1}) in 2008, 93.1% (*imazetapyr*) to 97.3% (*metribuzin* 1.0 kg*ha^{-1}) in 2009 and 92.1% (*imazetapyr*) to 97.3% (*metribuzin* 1.0 kg*ha^{-1}) in 2010, respectively. Similar, the out of vegetation treatment of alfalfa with *imazethapyr* 100 (Speed 10 SL) resulted in 90.8% control of weeds (Dimitrova, 2001). *Metribuzin* at 1.12 kg*ha^{-1} and *pronamide* at 1.12 and 2.24 kg*ha^{-1} significantly reduced yields of weeds in established alfalfa compared with yields of the check (Peters et al., 1984).

Table 3. Effect of herbicidal treatments on weeds and herbicide efficacy (before the first cut)

Tabuľka 3. Vplyv herbicídnych ošetrení na buriny a účinnosť herbicídu (pred prvou kosbou)

Treatments	Rate kg; l*ha^{-1}	Weed density per m^2			Herbicide efficacy %		
		2008	2009	2010	2008	2009	2010
Untreated control	-	201.0	217.2	240.5	-	-	-
Metribuzin	0.7	9.5**	10.5**	11.3**	95.3	95.6	95.2
Metribuzin	1.0	3.3**	5.8**	6.4**	98.4	97.3	97.3
Imazethapyr	2.0	13.0**	15.0**	19.0**	93.5	93.1	92.1
Pronamide	3.0	16.4**	11.3**	16.5**	91.8	94.8	93.1
LSD 0.05		11.78	13.51	12.69			
LSD 0.01		16.52	18.94	17.79			

(*) Significant level P<0.05 (**) Significant level P<0.01 NS (non significant)

Efficacy of herbicides in control of prevailing weeds during the 3 years field trial period was ranged of 48.5% to 100.0% (Table 4). Particularly high efficacy showed *metirbuzin* applied at both rates (0.7 and 1.0 kg*ha^{-1}, respectively), which provided more than 96% control of predominant weeds in all experimental years. Similar results are obtained by Waddington (1985). According him, applications of 1.6 kg*ha^{-1} of *metribuzin* to established alfalfa at the start of each growing season for 4 years, excellent controlled *Taraxacum officinale* and *Bromus inermis*. *Metribuzin* at 1.1 kg*ha^{-1} reduced *Taraxacum officinale* populations at the first harvest at all locations compared to the untreated check (Sheaffer and Wyse, 1982). Wilson (1981) reported for excellent control of *Bromus tectorum*, *Kochia scoparia, Salsola kali, Descurainia pinnata* and *Lactuca serriola* with *metribuzin* at 1.1 kg*ha^{-1}. Similar, *metribuzin* was effective in controlling or suppressing the growth of *Taraxacum officinale*, *Descurainia sophia*, *Capsella bursa-pastoris*, *Bromus tectorum*, and *Poa* *pratensis* (Moyer and Acharya, 2006). Heikes (1974) obtained excellent *Taraxacum officinale* control in established alfalfa from *metribtizin* applied at 0.6 and 0.8 kg*ha^{-1}. Applied in early February, *metribuzin* and *pronamide* effectively removed weedy *Bromus* species from established alfalfa and increased yields of alfalfa forage (Peters et al., 1984). Similar results were obtained by Kapusta and Strieker (1975) who have shown that *hexazinone*, *pronamide*, *metribuzin* and *terbacil* excellent controlled *Bromus tectorum* in established alfalfa.

Table 4. Control of prevalent weeds (before the first cut)

Tabuľka 4. Regulácia vyskytujúcich sa burín (pred prvou kosbou)

Treatments	Rate kg; l*ha^{-1}	Weed control (%)					
		2008					
		ANTCO	STMED	TAROF	CIRAR	VERHE	ALOMY
Untreated control	-	-	-	-	-	-	-
Metribuzin	0.7	100.0	100.0	98.8	96.7	100.0	100.0
Metribuzin	1.0	100.0	100.0	98.8	98.0	100.0	100.0
Imazethapyr	2.0	100.0	100.0	88.8	78.5	100.0	92.4
Pronamide	3.0	51.5	100.0	69.4	61.1	100.0	100.0
		2009					
		ALOMY	POPRA	MIVER	CAPBP	BROMO	ARATH
Untreated control	-	-	-	-	-	-	-
Metribuzin	0.7	98.5	99.0	97.5	100.0	100.0	100.0
Metribuzin	1.0	100.0	100.0	100.0	100.0	100.0	100.0
Imazethapyr	2.0	88.3	88.0	91.5	100.0	92.5	100.0
Pronamide	3.0	100.0	100.0	100.0	100.0	100.0	100.0
		2010					
		MILVE	ARATH	ANTCO			
Untreated control	-	-	-	-			
Metribuzin	0.7	98.8	100.0	100.0			
Metribuzin	1.0	99.1	100.0	100.0			
Imazethapyr	2.0	82.1	100.0	100.0			
Pronamide	3.0	98.0	100.0	58.5			

ANTCO-*Anthemis cotula*; STMED-*Stellaria media*; TAROF-*Taraxacum officinale*; CIRAR-*Cirsium arvense*; ALOMY- *Alopecurus myosuroides*; VERHE-*Veronica hederifolia*; POPRA-*Poa pratensis*; MIVER- *Milium vernale*; CAPBP-*Capsella bursa-pastoris*; ARATH-*Arabidopsis thaliana*; BROMO-*Bromus mollis*

Imazethapyr at the recommended rate of 1.0 l*ha^{-1} excellent controlled many predominant broadleaf species, except C*irsium arvense* (78.5%), and showed insignificantly lower control of grass weeds in all experimental years (Table 4). Similar results were reported by Malik et al. (1993), who stated that *imazethapyr* at rate of 0.2 kg a.i.*ha^{-1} excellent control *Taraxacum officinale* in established alfalfa stand, but control of C*irsium arvense* was not satisfactory. *Imazethapyr* applied when C*irsium arvense* was 150 mm tall resulted in poor (35%) control of this weed (Mesbah and Miller, 2005). From the other side, effective decreasing of *Capsella bursa-pastoris* density in established alfalfa with *imazethapyr* applied at 0.07, 0.11 and 0.14 kg a.i.*ha^{-1} was reported by Wilson (1989).

Pronamide provided more than 98% control of predominant grass and some broadleaf weeds (*Stellaria media* and *Veronica hederifolia*) in all experimental years. But, *pronamide* showed poor control of many predominant broadleaf weeds, particularly weeds of the *Asteraceae* family, because *pronamide* is mainly active against grass weeds and *Cuscuta* spp. (Janjić, 2005; Kostov, 2006). In same directions are results of Peters et al. (1984) who stated that *pronamide* at 1.12 and 2.24 kg*ha^{-1} significantly reduced yields of weed grasses, but did not significantly reduce yields of broadleaf weeds compared with the check. Similar, *pronamide* at 1.7 kg*ha^{-1} effectively controlled *Kochia scoparia* and *Salsola kali*, but did not *Descurainia pinnata* and *Lactuca serriola* (Wilson, 1981). *Bromus tectorum* was effectively removed from established alfalfa, and alfalfa yield increased with fall applications of *hexazinone*, *metribuzin*, *pronamide*, and *terbacil* (Wilson, 1997). *Agropyron repens* control ratings one and two seasons after application of 1.1 kg*ha^{-1} *pronamide* were 100 and 90%. As a result of that, *pronamide* treatments reduced first cutting *Agropyron repens* yields, and increased first cutting alfalfa yields (Fawcett et al., 1978).

Visible alfalfa injury

Taking into consideration fact that all investigated herbicides applied in properly alfalfa growth stage (dormant growth period) possesses high selectivity to alfalfa, no visual injured were determined by any rates in all experimental years, and, consequently, none of the applied herbicides reduce first harvest alfalfa yields (Table 5). Similar results were obtained by Robison et al. (1978); Waddington (1980); Wilson (1989); Mesbah and Miller (2005). No evident alfalfa injury was detected in herbicide-treated plots with *pronamide*, *prodiamine + metribuzin*, and *metribuzin* at 0.3 kg*ha^{-1} (Wilson, 1989). Similar, no visual injury was recorded in established alfalfa when *imazethapyr* was applied on dormant stands of alfalfa (Malik et al., 1993). Opposite, *metribuzin* caused crop injury of alfalfa as a result of increased rate from 1.1 to 1.7 kg*ha^{-1} (Wilson, 1997). Earlier, Wilson (1981) reported minor visible injury of alfalfa following the application of *metribuzin* and *terbacil*. Similar, as the rate of *imazethapyr* increased from 70 to 140 g a.i.*ha^{-1} visual injury to legumes, included alfalfa, ranged from 0 to 10%, but without reducing first harvest alfalfa yields (Wilson, 1994).

Dry matter yield (kg*ha^{-1})

Weed competition caused large reductions in alfalfa yield. Comparison of untreated and weed free control indicated that weeds reduced first harvest alfalfa yield by 51%, 49% and 53% in 2008, 2009 and 2010, respectively (Table 5). However, the removal of the competitive effect of the weeds led in an increase of the participation of the yield components of the alfalfa crop and as a result the dry matter production also increased. Comparison of dry matter yields was made between weed free control and herbicidal treatments. Generally, first harvest alfalfa yield was markedly affected by herbicide efficacy in all experimental years, particularly in the second year (Table 5). During the 3 years field trial period, the lowest alfalfa dry matter yield was recorded in untreated control plots (2110, 2030 and 1950 kg*ha^{-1}, respectively). In 2008, the lowest first harvest alfalfa yield among the herbicide treatments (3420 kg*ha^{-1}) were recorded in plots treated with *pronamide*. Alfalfa yield in the *pronamide* treatment was the lowest because this herbicide showed poor control of *Asteraceae* weeds (*Anthemis cotula, Taraxcaum officinale* and *Cirsium arvense*) – the most dominant weeds in 2008. The highest first harvest alfalfa yields (4280 and 4130 kg*ha^{-1}, respectively) were recorded in weed free control plots and plots treated with higher rate of *metribuzin*. In 2009, all herbicide treatments resulted in alfalfa yields similar to that of the weed free control (Table 5). The alfalfa yield was ranged of 3600 kg*ha^{-1} (*imazethapyr*) to 4300 kg*ha^{-1} (*metribuzin* at 1.0 kg*ha^{-1}). In 2010, the lowest first-harvest alfalfa yields among the herbicide treatments (3640 kg*ha^{-1}) were recorded in plots treated with *imazethpyr*, mainly because of non-satisfactory control of *Millium vernale* – the most dominant weed in 2010. Contrary, the highest first harvest alfalfa yields (4230 and 4140 kg*ha^{-1}, respectively) were recorded in *metribuzin* (1.0 kg*ha^{-1} and 0.7 kg*ha^{-1}, respectively) treated plots.

In many studies, weed control in established alfalfa has increased its yields (Kapusta and Strieker, 1975; Wilson, 1981; Peters et al., 1984). *Metribuzin* at 1.1 and 1.7 kg*ha^{-1}, *pronamide* at 1.1 kg*ha^{-1}, and *terbacil* at 0.8 kg*ha^{-1} excellent suppressed *Bromus tectorum* biomass and increased alfalfa yield from 141% to 224% compared to the nontreated control (Wilson, 1997). In Illinois, increased alfalfa dry matter yields were obtained with an application of *metribuzin* at 0.84 kg*ha^{-1}, because the herbicide excellent controlled *Bromus tectorum* (Kapusta and Strieker, 1975). Wilson (1981) have reported a significantly increase in first cutting production of alfalfa dry matter above the weedy check by fall application of *metribuzin* at 0.6 kg*ha^{-1}, *prodiamine* + *metribuzin* at 0.6 + 0.6 kg*ha^{-1}, *pronamide* at 1.7 and 0.6 kg*ha^{-1}. According same author, increasing of *metribuzin* rate from 0.3 to 1.1 kg*ha^{-1} caused the protein content of first cutting alfalfa to increase from 17 to 20% (Wilson, 1981). In Nebraska, fall applications of *hexazinone* or *metribuzin* at 1.1 kg*ha^{-1} injured alfalfa, although first cut yields were not reduced and no damage symptoms were evident at later harvests (Wilson, 1981). In same directions are results of Dutt et al. (1979) who stated that *pronamide* treatments did not affect total forage dry matter yields; however, *pronamide* applications increased total alfalfa yields. The out of vegetation treatment of alfalfa with *imazethapyr* increased dry biomass and crude protein yield of first-cut yield for 60% and 2.4 to 2.6%, respectively (Dimitrova, 2001). Applications of 1.6 kg*ha^{-1} of *metribuzin* to established alfalfa (*Medicago sativa* L. 'Rambler') at the start of each growing season for 4 years controlled established *Taraxacum officinale* and *Bromus inermis* and increased seed yield by 68% (Waddington, 1985).

Weed management is a fundamental practice in alfalfa production (Ashigh et al., 2009). Unsuccessful weed control can result in almost the total loss of the alfalfa stand. In view of these encouraging results, application of herbicides suited for every floristic situation led to a minimization of yield losses, and, in same time, increasing quality and quantity of alfalfa hay (Cords, 1973; Cosgrove and Barrett, 1987).

Table 5. Effect of herbicide treatments on first-harvest dry matter yields and alfalfa crop injury

Tabuľka 5. Vplyv herbicídov na prvú úrodu sušiny a poškodenie lucerny

Treatments	Rate kg; l*ha^{-1}	Dry matter alfalfa yield (kg*ha^{-1})			Alfalfa injury (EWRS scale)		
		2008	2009	2010	2008	2009	2010
Untreated control	-	2110	2030	1950	-	-	-
Weed-free control	-	4280	3980	4120	-	-	-
Metribuzin	0.7	3960^{NS}	4060^{NS}	4140^{NS}	1	1	1
Metribuzin	1.0	4130^{NS}	4300^{NS}	4230^{NS}	1	1	1
Imazethapyr	2.0	3740*	3600^{NS}	3640*	1	1	1
Pronamide	3.0	3420**	4010^{NS}	3840^{NS}	1	1	1
LSD 0.05		406.77	399.65	389.63			
LSD 0.01		570.31	560.31	546.27			

(*) Significant level P<0.05 (**) Significant level P<0.01 NS (non significant)

Conclusions

Field trials were conducted during 2008 – 2010 to evaluate weed control in dormant alfalfa (*Medicago sativa* L.) with *metribuzin*, *imazetapyr* and *pronamide*.

The weed population in all experimental years was consisted mainly of annual winter and spring grass and broadleaf weeds, and some perennial weeds.

The number of weed species and weed density increased with the years of alfalfa growing, from second to the fourth year. Weed density in the untreated control plots was 201.0, 217.2 and 240.5 plants per m^2 in 2008, 2009 and 2010, respectively. The most dominant weeds were *Anthemis cotula*, *Capsell bursa-pastoris* and *Taraxacum officinale* in 2008, *Alopecurus myosuroides* and *Poa pratensis* in 2009 and *Millium vernale* and *Arabidopsis thaliana* in 2010.

Efficacy of herbicides in control of weeds was ranged of 91.8% (*pronamide*) to 98.4% (*metribuzin* 1.0 kg*ha^{-1}) in 2008, 93.1% (*imazetapyr*) to 97.3% (*metribuzin* 1.0 kg*ha^{-1}) in 2009 and 92.1% (*imazetapyr*) to 97.3% (*metribuzin* 1.0 kg*ha^{-1}) in 2010, respectively. Efficacy of herbicides in control of prevailing weeds during the 3 years field trial period was ranged of 48.5% to 100.0%. No visual alfalfa injured was determined by any rates during the experimental period, and consequently, none of the applied herbicides reduced first harvest alfalfa yields.

Alfalfa yield was markedly affected by herbicide efficacy in all experimental years, particularly in the second year, where yields of herbicide treatments were similar to that of the weed free control.

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