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Efficacy of Chemical Weed Control in Potato (*Solanum tuberosum* L.)

Zoran Jovović[1], Tatjana Popović[1], Ana Velimirović[1], Vesna Milić[2], Željko Dolijanović[3], Milana Šilj[2], Dobrivoj Poštić[4]

[1]*Biotechnical Faculty, University of Montenegro, Montenegro*
[2]*Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina*
[3]*Agricultural Faculty, University of Belgrade, Serbia*
[4]*Institute for Plant Protection and Environment, Belgrade, Serbia*

Abstract

In this paper the results of efficiency of combined application of six herbicides in weed control in potato were presented. The study was done during 2007 and 2008 in Kolašin, on acid brown soil, at an altitude of about 900 m. In the experiment the following herbicides were examined: S-metalachlor, Bentazone, Acetohlor, Flurochloridone, Metribuzin and Dimetenamid-P. The study was conducted in the Kennebec variety crop. All applied herbicides had satisfactory effect in decreasing number and biomass of weeds. As the most effective variants in two-year average, Sencor 70 WP and Genius were expressed (95 and 94% for the number and 92 and 88.8% for weed biomass) and the weakest effect had combination of Dual Gold 960 EC + Basagran (82.3; 69.4, respectively). In all investigated combinations of herbicides significantly higher tuber yield was achieved comparing to the control. The highest yield of tubers was measured in variant where Acenit 800 EC was applied - 33 t ha^{-1}, while the lowest yield had the control variant - 18.4 t ha^{-1}.

Key words: potato, weeds, herbicides, efficacy, yield

Introduction

According to the total planted area potato is a leading agricultural crop in Montenegro. In the production on arable land, potato is participating with more than 20%. Potatoes are grown in Montenegro on about 10000 hectares with a total annual production of about 0.15 million tons (Monstat, Statistical Yearbook for 2011). Despite the reduction of arable land, production of potatoes in Montenegro is constantly

growing. Low potato yields in Montenegro are caused by various factors, among which, one of the most important is lack of weed control (Jovović et al., 2013).

Weeds cause significant damage on potatoes and other crops. They cause yield losses worldwide with an average of 15 to 20% (Nouri-Ghanbalani, 2002). There are several constraints in potato production, of which weeds often pose a serious problem. They not only compete with crop plants for nutrients, soil moisture, space and sunlight but also serve as alternate host for several insect pests and diseases. These losses are reflected trough competition for nutrients, light, water, space, and the space above and below the soil surface. In addition, weeds increase the humidity in the potato crop thus creating favorable conditions for the development of the diseases (Channappagoudar et al., 2007). Weeds management includes a large number of measures with the aim to reduce or eliminate weed specimens from potato crops (Milošević, 2009). In modern agricultural practices the application of herbicides in weed control plays great importance. Herbicides provide efficient and prompt protection, much longer-term than other agricultural practices (Jovović et al, 2012).

The critical period for weed control is the period in the crop growth cycle when, in order to prevent unacceptable decrease in yield, weeds must be controlled. Weed interference before or after the critical period will not result in unacceptable yield losses (Mohammaddoust et al, 2011). High weediness can cause a visible potato crop development lags, which finally results in a significant reduction of yield. In addition to the impact on the yield, the presence of weeds in the potato crops reflects on quality of tubers. Some weeds develop a strong root system and thus reduce the potential for the development of tubers, but also hinder their harvesting. A particular problem is the presence of perennial weed species that drill tubers with underground organs and thus reduce their marketing value.

Special interest in the weed flora of a potato crop Montenegro appeared in last decade (Stešević & Jovović, 2002, 2003, 2011; Jovović et al, 2006, 2011, 2012). Chemical weed control in Montenegro is present mainly in the production of potatoes intended for the market. In the production of potatoes for home consumption and local markets, which is the dominant form of production in Montenegro (about 75% of total production), herbicides, are generally not used. Most commonly used herbicide is metribuzin with pre or post-emergence application. For these reasons, the main purpose of this research is to analyze effect of combined application of different herbicides on potato yield in agro-ecological conditions of northern Montenegro.

Materials and methods

Investigation of the influence of combined application of herbicides on weediness and potato yield was carried out in 2007 and 2008, on acid-brown soil (Table 1) in Kolašin, at an altitude of about 900 m. The study was done in the leading variety in Montenegro - Kennebec. The experiment was established in a random block design with 4 replications. The size of the elementary plot was 21 m^2. Planting of potatoes was done manually with 70 cm between row distance and 33 cm within row

plant distance respectively, achieving the density of about 43000 plants per hectare. Standard agricultural practice for the potato crop was applied.

Tab. 1. Chemical characteristics of acid-brown soil on experiment field
Hemijske karakteristike kiselo-smeđeg zemljišta na eksperimentalnom polju

Depth *Dubina* (cm)	pH		$CaCO_3$	Humus	Soluble/*Topiv* (mg/100 g)	
	H_2O	nKCl	%	%	P_2O_5	K_2O
0-40	5.67	4.79	1.68	5.07	1.9	5.5

Efficiency degree was studied for 6 herbicides in 9 combinations of application. The control variant (K) was not treated with herbicides, and the treatment consisted of one hilling. Evaluation of weed control was carried out by the method of quantitative and qualitative determination, on constant square area of 1 m^2, in the stage of the full flowering of potato plants. The efficiency of the applied methods of weed control (%) was based on a 0-to-100% scale. The basic data of the applied herbicides are shown in Table 2.

Tab. 2. Basic data for applied variants
Osnovni podaci primjenjenih varijanti

Trial variant *Probna varijanta*		Herbicide applied *Primjenjen herbicid*	Product applied *Primjenjen proizvod*	Contents of a. i. *Sadržaj a.m.*	Product rate	Application method *Metod primjene*
Herbicide/*Herbicidi*	H_1	S-metalachlor Bentazone	Dual Gold 960 EC Basagran	960 $g.l^{-1}$ 480 $g.l^{-1}$	1.2 $l.ha^{-1}$ 2 $l.ha^{-1}$	PREE POST*
	H_2	Acetohlor	Acenit 800 EC	800 $g.l^{-1}$	2.5 $l.ha^{-1}$	PREE
	H_3	Acetohlor	Genius	840 $g.l^{-1}$	2 $l.ha^{-1}$	PREE
	H_4	Acetohlor Flurochloridone	Genius Racer 25 EC	840 $g.l^{-1}$ 250 $g.l^{-1}$	2 $l.ha^{-1}$ 2 $l.ha^{-1}$	PREE PREE
	H_5	Metribuzin	Sencor 70 WP	700 $g.kg^{-1}$	0.75 $kg.ha^{-1}$	POST*
	H_6	Acetohlor Metribuzin	Genius Sencor 70 WP	840 $g.l^{-1}$ 700 $g.kg^{-1}$	2 $l.ha^{-1}$ 0.5 $kg.ha^{-1}$	PREE PREE
	H_7	Dimetenamid-P Metribuzin	Frontier super Sencor 70 WP	720 $g.l^{-1}$ 700 $g.kg^{-1}$	1 $l.ha^{-1}$ 0.5 $kg.ha^{-1}$	PREE PES
	H_8	Acetohlor Metribuzin	Genius Lord 700 WG	840 $g.l^{-1}$ 700 $g.kg^{-1}$	2 $l.ha^{-1}$ 0.5 $kg.ha^{-1}$	PREE POST*
	H_9	Metribuzin Metribuzin	Lord 700 WG Lord 700 WG	700 $g.kg^{-1}$ 700 $g.kg^{-1}$	0.5 $kg.ha^{-1}$ 0.5 $kg.ha^{-1}$	PREE POST*
K		Control variant / *kontrolna varijanta*				

PREE - Herbicide applied at the pre-emergence stage
Herbicid primjenjen u fazi prije nicanja
POST* - Herbicide applied at the post-emergence stage of crop and weeds (after hilling)
Herbicid primjenjen nakon nicanja usjeva i korova (nakon okopavanja)

Tab. 3. Meteorological conditions during the experiment
Meteorološki uslovi tokom eksperimenta

Year/*godina*	Month/*mjesec*				Average *Prosječno*
	May	Jun	July	August	
	Air temperature / *temperatura vazduha* (^{0}C)				
2007	12.8	16.7	18.3	17.5	16.3
2008	12.5	16.4	17.2	17.6	15.9
Amount of rainfall / *količina padavina* (mm)					Total
2007	136.9	101.0	44.9	16.3	299.1
2008	37.4	103.5	113.5	20.2	274.6

The tubers harvesting was done after full maturation of canopy. The yield was determined by measuring the tubers at each elementary plot, and then the yield per hectare was calculated. Meteorological conditions during the experiment are shown in Table 3. The analysis of variance was calculated according to randomize complete block design, and the significant differences among the means were evaluated according to least significant difference (lsd) test.

Results and discussion

In two-years examination of efficacy of chemical weed control in potato crop in the vicinity of Kolašin 24 weed species were recorded (23 in 2007 and 18 in 2008). According to this, the weed communities in the studied area are relatively poor in species.

Tab. 4. Structure and number of weeds in potato crop recorded in control variants over the period 2007-2008 (ind.m^{-2})
Struktura i broj korova kod krompira zabilježen u kontrolnim varijantama tokom perioda 2007- 2008 (ind.m^{-2})

Weed species *Vrsta korova*	Year / *godina*		
	2007	2008	2007-2008
Convolvulus arvensis L.	23	21	22
Chenopodium album L.	26	14	20
Polygonum persicaria L.	14	9	11.5
Sinapis arvensis L.	14	8	11
Galinsoga parviflora Cav.	13	9	11
Bilderdykia convolvulus (L.)	8	11	9.5
Amaranthus retroflexus L.	10	7	8.5
Setaria viridis (L.)	5	9	7
Other species*/ *druge vrste*	75	24	49.5
Total / *ukupno*	188	112	150

**Agropyron repens, Chenopodium hybridum, Cirsium arvense, Equisetum arvense, Euphorbia helioscopia, Geranium dissectum, Linaria vulgaris, Plantago lanceolata, Polygonum aviculare, Polygonum lapathifolium, Rumex acetossela, Stellaria media, Taraxacum officinale, Trifolium repens, Veronica agrestis* and *Viola arvensis*

The results given in Table 4 show that among the registered weed species the most common are: *Convolvulus arvensis* (23 in 2007 and 21 ind.m^{-2} in 2008), *Chenopodium album* (26 and 14), *Polygonum persicaria* (14 and 9), *Sinapis arvensis* (14 and 8), *Galinsoga parviflora* (13 and 9), *Bilderdykia convolvulus* (8 and 11), *Amaranthus retroflexus* (8 and 11) and *Setaria viridis* (5 and 9).

Tab. 5. Efficacy of investigated herbicides (Number of weed per m^2)
Efikasnost primjenjenih herbicida (broj korova po m^2)

Var.	Year *Godina*	Weed species/*vrste korova*								Other species *Druge vrste*	Total
		CON AR	CHE AL	POL PE	SIN AR	GAL PA	BIL CO	AMA RE	SET VI		
H_1	2007	12	0	2	2	2	0	1	0	12	31
	2008	7	3	0	2	0	1	0	2	7	22
	Average *Prosječno*	9.5	1.5	1	2	1	0.5	0.5	1	9.5	26.5
H_2	2007	6	2	4	1	0	0	2	3	8	26
	2008	4	0	3	0	0	2	0	2	5	16
	Average *Prosječno*	5	1	3.5	0.5	0	1	1	2.5	6.5	21
H_3	2007	4	1	1	0	0	0	0	1	4	11
	2008	2	2	0	2	0	0	0	0	1	7
	Average *Prosječno*	3	1.5	0.5	1	0	0	0	0.5	2.5	9
H_4	2007	4	0	0	2	0	0	1	1	6	14
	2008	5	0	0	0	0	0	0	1	3	9
	Average *Prosječno*	4.5	0	0	1	0	0	0.5	1	4.5	11.5
H_5	2007	3	0	0	2	0	0	2	2	1	10
	2008	3	0	0	0	0	0	0	0	2	5
	Average *Prosječno*	3	0	0	1	0	0	1	1	1.5	7.5
H_6	2007	11	8	0	1	2	0	0	0	5	27
	2008	6	4	0	2	0	1	0	2	7	22
	Average *Prosječno*	8.5	6	0	1.5	1	0.5	0	1	6	24.5
H_7	2007	9	2	0	3	3	0	2	0	6	25
	2008	6	0	4	2	0	1	2	0	1	16
	Average *Prosječno*	7.5	1	2	2.5	1.5	0.5	2	0	3.5	20.5
H_8	2007	12	3	0	2	0	0	3	0	9	29
	2008	7	0	3	1	0	0	1	1	4	17
	Average *Prosječno*	9.5	1.5	1.5	1.5	0	0	2	0.5	6.5	23
H_9	2007	10	4	2	1	1	0	2	1	6	27
	2008	6	0	2	2	0	1	0	3	4	18
	Average *Prosječno*	8	2	2	1.5	0.5	0.5	1	2	5	22.5
K	2007	23	26	14	14	13	8	10	5	75	188
	2008	21	14	9	8	9	11	7	9	24	112
	Average *Prosječno*	22	20	11.5	11	11	9.5	8.5	7	49.5	150

Tab. 6. Dry biomass of weeds (g)
Suva biomasa korova (g)

Year *Godina*	Variant/*varijanta*									
	K	H_1	H_2	H_3	H_4	H_5	H_6	H_7	H_8	H_9
2007	88.5	26.5	18.7	10.3	13.5	6.9	28.1	16.8	21.5	20.9
2008	63.1	19.8	13.8	6.8	9.8	5.2	15.9	12.2	15.4	17.2
Average *Prosječno*	75.8	23.2	16.3	8.6	11.7	6.1	22.0	14.5	18.5	19.1

The results presented in Table 5 show that the highest weediness was recorded in the control variant – 150 ind.m^{-2} (188 in 2007 and 112 in 2008). The lowest weediness had treatments with Sencor 70 WP (H_5) – 7.5 and Genius (H_3) - 9 ind.m^{-2} and the highest plots with application of Dual Gold 960 EC + Basagran (H_1) – 26.5 and Genius + Sencor 70 WP (H_6) – 24.5 ind.m^{-2}. At the same time control variant had the largest biomass of weeds – 88.5 (in 2007) and 63.1 g.m^{-2} (in 2008) (Table 6). Analysis of weediness of variants treated with herbicides demonstrated lowest weed biomass in treatments H_5 (6.1) and H_3 (8.6 g.m^{-2}), while the highest was measured in treatments H_1 (23.2) and H_5 (22 g.m^{-2}).

Tab. 7. Efficacy of investigated way of weed control for weeds number and dry biomass of weeds
Efikasnost ispitivanih načina suzbijanja korova na broj korova i suvu biomasu korova

Efficacy of investigated herbicides *Efikasnost ispitivanih herbicida*	Year/*god.*	Herbicide/*herbicidi*								
		H_1	H_2	H_3	H_4	H_5	H_6	H_7	H_8	H_9
Weeds number *Broj korova*	2007	83.5	86.2	94.1	92.6	94.7	85.6	86.7	84.6	85.6
	2008	80.4	85.7	93.8	92.0	95.5	80.4	85.7	84.8	83.9
	Average *Prosječno*	82.3	86.0	94.0	92.3	95.0	83.7	86.3	84.7	85.0
Dry biomass of weeds *Suva biomasa korova*	2007	70.1	78.9	88.4	84.7	92.2	68.2	81	75.7	76.4
	2008	68.6	78.1	89.2	84.5	91.8	74.8	80.7	75.6	72.7
	Average *Prosječno*	69.4	78.5	88.8	84.6	92.0	71.5	80.9	75.7	74.6

		2007	2008	2007/08
Weeds number *Broj korova*	LSD 0.05	3.729	3.518	3.038
	LSD 0.01	5.022	4.738	4.092
Dry biomass of weeds *Suva biomasa korova*	LSD 0.05	4.041	4.372	3.917
	LSD 0.01	5.442	5.888	5.297

All applied herbicides exhibited a very satisfactory impact on reducing the number of weed species (Table 7). Their efficiency in two-year average varied from 82.3 in combination with Dual Gold 960 EC + Basagran (H_1) to 95.0 in variant with Sencor 70 WP (H_5). Research demonstrated highest efficiency of herbicide treatments H_5, H_3 and H_4 and comparing to the other chemical weed control methods was highly significant. In some of our earlier studies we also found the effective control of weeds with metribuzin (Jovović et al., 2000, 2006, 2011 and 2012). High metribuzin efficiency in the reduction of weediness in potato crops were also reported by Hoyt and Monks (1996), Janjić et al. (2000), Mirčov et al. (2006), and others.

Along with the reduction of weeds number all applied herbicides expressed a very significant impact on reducing the biomass of weed. Coefficient of efficiency in two-year average varied from 69.4 in combination with Dual Gold 960 EC + Basagran (H1) to 92.0 Sencor 70 WP (H5). Comparison of applied combinations showed statistically significant differences between 70 WP (H5) and Genius (H3) and all others treatments. In all applied herbicide treatments efficacy in reducing the number of weed plants had significantly higher value to those achieved in reducing weed biomass. All herbicide treatments significantly reduced the weed biomass compared to control variant. These findings are in agreement with the previous work of Lal (1990), Jan et al. (2004), Janjić et al. (2006) and Jovović et al. (2011, 2012) who observed that weed dry biomass decreases due to herbicidal application in potato crop.

Tab. 8. Potato yields in experiments (t.ha^{-1})
Prinos krompira u eksperimentima (t.ha^{-1})

Year/*god*	Variant									
	K	H_1	H_2	H_3	H_4	H_5	H_6	H_7	H_8	H_9
2007	17.6	26.5	31.5	30.8	28.9	29.5	24.2	30.0	26.1	25.5
2008	19.1	28.9	34.5	33.3	31.6	32.2	29.8	34.1	30.2	31.1
Average/*Pros.*	18.4	27.7	33.0	32.1	30.3	30.9	27.0	32.1	28.2	28.3

	2007	*2008*	*2007/08*
LSD 0.05	*2.577*	*3.137*	*2.37*
LSD 0.01	*3.448*	*4.197*	*3.193*

In addition to the demonstrated effectiveness, all applied combinations of herbicides exhibited a significant effect on increasing of the potato yield (Table 8).

The highest yields of tubers, in two-year average, were measured in combinations Acenit 800 EC (H_2) - 33.0 and Genius (H3) and Frontier super + Sencor 70 WP (H_7) – both 32.1 t.ha^{-1}, while the lowest yields were obtained in the control variant - 18.4 t.ha^{-1}. In two-year average all herbicide variants gave a significantly higher yield compared to the control. Analysis within the applied herbicides showed that the difference in yield between treatments H_2, H_3 and H_7 and all other combinations were statistically justified. The higher tuber yield in herbicidal variants was attributed to lower weed dry matter, higher weed control efficiency and also meteorological conditions during the experiment. Higher average potato yield obtained in 2008 consequence of the greater amount of rainfall and also a more favorable rainfall distribution.

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Efikasnost hemijskog suzbijanja korova u krompiru (*Solanum tuberosum* L.)

Zoran Jovović[1], Tatjana Popović[1], Ana Velimirović[1], Vesna Milić[2], Željko Dolijanović[3], Milana Šilj[2], Dobrivoj Poštić[4]

[1]*Biotehnički fakultet, Univerzitet Crne Gore, Crna Gora*
[2]*Poljoprivredni fakultet, Univerzitet Istočno Sarajevo, Bosna i Hercegovina*
[3]*Poljoprivredni fakultet, Univerzitet u Beogradu, Srbija*
[4]*Institut za zaštitu bilja i životne sredine, Beograd, Srbija*

Sažetak

U radu su predstavljeni rezultati proučavanja efikasnosti kombinovane primjene šest herbicida na zakorovljenost usjeva krompira. Ogledi su izvedeni tokom 2007. i 2008. godine u Kolašinu (Drijenak), na kiselo smeđem zemljištu na nadmorskoj visini od oko 900 m. Ispitivana je efikasnost sljedećih herbicida: S-metalachlor, Bentazone, Acetohlor, Flurochloridone, Metribuzin and Dimetenamid-P. Ispitivanja su obavljena u usjevu sorte Kennebec. Svi primijenjeni herbicidi imali su zadovoljavajući efekat u redukciji broja i biomase korova. Kao najefikasnije, u dvogodišnjem prosjeku, ispoljile su se varijante Sencor 70 WP i Genius (95 i 94% za broj i 92 i 88,8% za biomasu korova), dok se najslabijom pokazala kombinacija Dual Gold 960 EC + Basagran (82,3, odnosno 69,4%) Sve proučavane kombinacije hemijskog suzbijanja korova dale su značajno veći prinos krtola u poređenju sa kontrolom. Najveći prinos izmjeren je na varijanti gdje je primijenjen Acenit 800 EC - 33 t.ha^{-1}, a najmanji na kontroli - 18.4 t ha^{-1}.

Ključne riječi: krompir, korovi, herbicidi, efikasnost, prinos

Zoran Jovović
E-mail address:
zoran.jovovic.btf@gmail.com