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Chemical control of field dodder in alfalfa

Marija Sarić-Krsmanović[1]*, Dragana Božić[2], Goran Malidža[3], Ljiljana Radivojević[1], Jelena Gajić Umiljendić[1] and Sava Vrbničanin[2]

[1]*Institute of Pesticides and Environmental Protection, Banatska 31b, 11080 Belgrade*
[2]*University of Belgrade, Faculty of Agriculture, Nemanjina 6, 11080 Belgrade*
[3]*Institute of Field and Vegetable Crops, Maksima Gorkog 30, 21000Novi Sad*
**(marijasaric.msaric@gmail.com)*

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SUMMARY

Parasitic flowering plants have recently come into focus of research interests as a result of their notable expansion and increasing damage that they are causing in agricultural fields. Damage caused by field dodder in alfalfa crops mainly includes reduced yield of fresh biomass and considerable decrease in seed production. Effective control of field dodder in alfalfa crops necessarily includes a number of preventive measures and procedures, as well as chemical control. The effectiveness of glyphosate, propyzamide, imazethapyr and diquat herbicides in controlling field dodder in alfalfa crops was tested in trials conducted in 2011. Pot and field trials were set up in an experimental field of the Institute of Field and Vegetable Crops in Novi Sad (location Rimski Šančevi) and in a private field at Popovići (vicinity of Mladenovac). In pot trials, two glyphosate application rates (288 and 360 g a.i. ha) achieved the highest effectiveness of 95% and 97.5%, respectively. Both application rates of propyzamide (1500 and 2000 g a.i. ha) had weak effectiveness (85% and 87%, respectively), while imazethapyr (150 g a.i. ha) was the weakest herbicide with 80% efficacy. In field trials at both locations, diquat (450 g a.i. ha) showed the best efficacy in controlling field dodder in alfalfa. The efficacy of all other treatments was weaker at Popovići with the following survival rates of field dodder plants: 25% (glyphosate, 288 g a.i. ha), 15% (glyphosate, 360 g a.i. ha), 79% (propyzamide, 1500 g a.i. ha), 70% (propyzamide, 2000 g a.i. ha) and 72% (imazethapyr, 150 g a.i. ha). At the location Rimski Šančevi, the same treatements resulted in around 1% remaining field dodder plants in alfalfa crop.

Keywords: Field dodder; Herbicides; Chemical control; Alfalfa

INTRODUCTION

Broad geographic distribution and spectrum of hosts make field dodder, *Cuscuta campestris*, one of the most widespread and most harmful pests among flowering parasitic plants (Parker & Riches, 1993). Field dodder may become a problem in vegetable nurseries (e.g. tomato, sweet pepper and cabbage) or in sugar beet, potato or some other crops grown in plastic greenhouses. However, the most devastating damage is caused by field dodder outbreaks in newly-established perennial legume crops (alfalfa, clover, etc.), which are generally the preferred hosts of this parasitic flowering species (Dawson et al., 1994). Damage caused to these crops mostly consists of fresh biomass yield reduction of 50% or more, and a considerable decrease in seed production (Cudney et al., 1992). Dawson (1989) reported a 57% loss of alfalfa yield after artificial infestation with *C. campestris* in Prosser, Washington (USA) over a period of two years. After the two-year period, potato was sown in the same location and was totally destroyed by field dodder (Dawson et al., 1994). Mishra (2009) also reported a 60% yield reduction in an alfalfa crop infested with *C. campestris* in Chile. In Serbia, Stojanović and Mijatović (1973) found an 80% yield decrease in alfalfa crop infested with *C. campestris*, and around 20% reduction in red clover. Stojšin et al. (1992) also reported high sugar beet yield lossess in Serbia, estimated at around 40%, as well as decreased sugar contents of between 1.3% and 2.6%. In another similar report, *C. campestris* brought about a significant decrease in sugar beet yield to around 3.5 t/ha, and sugar content in it to 1.5-1.9% (Belyaeva et al., 1978). Lanini (2004) recorded a dodder-caused downfall in tomato yield of 75%. Other studies have shown that field dodder is able to reduce carrot yields by 70-90% (Bewick et al., 1988). It is equally troublesome in onion (*Allium cepa*), but control of this parasite is difficult in that crop because no herbicide is adequately selective to prevent crop damage (Rubin, 1990). Cranberry infested with *Cuscuta gronovii* has been found to decrease yield by 50% (Bewick et al., 1988). Ornamentals and trees are frequent hosts to species of the genus *Cuscuta*, rarely causing their complete decay but weakening them by parasitism and exposing them to risks from other pests, primarily phytopathogenic fungi, bacteria and insects.

Different measures are available for controlling field dodder from preventive (pure seeding material, tolerant cultivars, etc.) to mechanical removal (mowing and hand weeding) to herbicide treatments. The present study therefore focused on testing different herbicides as a means of controlling field dodder in alfalfa crops.

MATERIAL AND METHODS

Trials testing the efficacy of different herbicides against *C. campestris* were conducted in 2011. The plants were grown in pots kept outdoors and in the field, and the herbicides shown in Table 1 were tested.

Pot trial: Alfalfa plants were grown in plastic pots (Ø 17 cm) in a mixture of commercial substrate (Flora Gard TKS1, Germany) and soil collected from a field without a history of herbicide treatments. After thinning, each pot contained 20 plants and they were watered daily. The herbicides were applied by a thin-layer chromatography sprayer under 1-2 bars pressure when alfalfa plants were 10-12 cm high and dodder plants attached to the host. The trial included two controls: alfalfa plants infested (I) and non-infested (N) with *C. campestris,* neither group treated with herbicides. Herbicide efficacy in controlling *C. campestris* was assessed in two ways, visually on a 0-100 scale (0 denoting no damage at all, and 100 denoting plant death), and by measuring fresh biomass weight. These parameters were checked: prior to herbicide treatment (0 assessment), then 1 (I assessment), 7 (II assessment), 14 (III assessment), 21 (IV assessment) and 28 (V assessment) days after treatment (DAT). All trial variants had five replicates and the trial was repeated twice. Data on fresh weight were processed by t-test in the STATISTIKA®8.0 software.

Field trial: Trials were set up in an experimental field of the Institute of Field and Vegetable Crops in Novi Sad (location Rimski Šančevi) and on a private plot at the location Popovići (vicinity of Mladenovac). Both trials were set up in a random block design with four replicates. The main trial data are shown in Table 2, and weather conditions in the areas of Novi Sad and Mladenovac in Figures 1a and 1b.

Table 1. Main information on herbicides tested

Trials		Active ingredient	Product	Application rate (l/ha; *kg/ha)	Content of active ingredient
b) Field trial	a) Pot trial	glyphosate	Glifol	0.8 and 1(H_1,H_2)	360g/l
		propyzamide	Kerb 50-WP	3 and 4*(H_3,H_4)	500g/kg
		imazethapyr	Pivot M 100-E	1.5 (H_5)	100g/l
		diquat	Reglon forte	3 (H_6)	150g/l

Table 2. Timeline and other basic information on trials at Rimski Šančevi and Popovići

Basic data	Location Rimski Šančevi	Location Popovići
Sowing date	12.04.2011.	01.04.2011.
Amount of alfalfa seed used	10 kg/ha	30 kg/ha
Amount of *C. campestris* seed sown with alfalfa	300 g	/
Sowing depth	2 cm	2 cm
Inter-row spacing	12.5 cm	10 cm
Crop year	first	first
Preceding crop	sugar beet	maize
Plot size (length x width)	5 m x 2 m	5 m x 5 m
Date of first cutting	07.07.2011.	26.07.2011.
Date of herbicide treatment	15.07.2011.	25.06.2011.
Alfalfa height at treatment	8-10 cm	around 20 cm
Date of first assessment	29.07.2011. (14 DAT)	09.07.2011.
Alfalfa height	15-20 cm (14 DAT)	around 25-30 cm
Date of second assessment	17.08.2011. (31 DAT)	25.07.2011.
Alfalfa height	25-30cm (31 DAT)	35-40 cm

DAT – days after treatment

Herbicide treatments were performed using a CO_2 backpack sprayer with 1.8 bar operating pressure, XR11003 nozzle and 300 l water/ha.

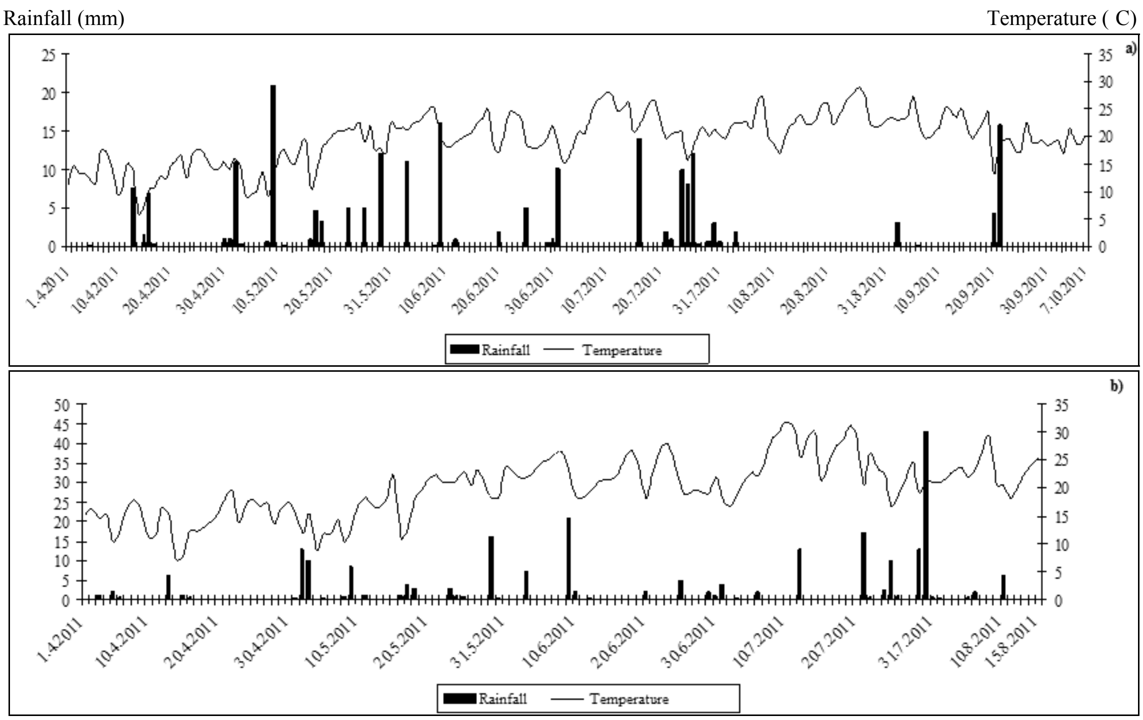

Figure 1. Mean daily temperatures and rainfall at locations Rimski Šančevi (a) and Popovići (b) during 2011 vegetation season

RESULTS AND DISCUSSION

Pot trial: Various research studies have indicated that *C. campestris* has a considerable influence on biomass weight, flower production and yield of host plants, and on their general physiological condition (Deng et al., 2003; Zan et al., 2003). Some researchers have also concluded that parasitic flowering species of the genus *Cuscuta,* especially *C. campestris*, *C. chinensis* and *C. australis,* have a significant impact on host growth (Liao et al., 2002; Zan et al., 2003; Zhang et al., 2004). The findings in our present study were consistent and *C. campestris* was found to have the strongest impact on the infested control alfalfa plants, reducing their fresh stem weight the most, which created a trend of decreasing values from assessment 0 to V (0.30-1.32 g/plant) (Figure 2). Conversely, fresh weight values in the control free of *C. campestris* (N) had a growing trend from 0 to V, ranging from 0.33 to 1.32 g/plant (Figure 2). Jeschke et al. (1994) and Jeschke and Hilpert (1997) found that *Coleus blumei* and *Lupinus albus* parazitized by *C. reflexa* had significantly smaller biomass than control plants. Similar findings were also reported by Shen et al. (2005), who monitored the stem/root (S/R) ratio of *Mikania micrantha* plants infested and non-infested with *C. campestris* over a period from 40 to 50 days after infestation, and significant differences were found. We found similar changes in stem fresh weight of the herbicide-treated plants. In H_1 and H_2 treated pots, the lowest stem weight was recorded in the first assessment (0.50 and 0.47 g/plant, respectively), and the highest in the fifth assessment (1.06 and 1.16 g/plant). These latter fresh weight values were higher than under any other herbicide treatment (Figure 2). Fresh weight (g/plant) was slightly lower in the pots treated with propyzamide (H_3 and H_4) and imazethapyr (H_5). In the fifth assessment, H_3 and H_4 fresh weights were 1.0 and 1.06 g/plant, and H_5 was also 1.06 g/plant (Figure 2).

Statistical data analysis revealed a very significant ($p<0.01$) difference in fresh weight of alfalfa plants between non-infested control (N) and infested (I) plants, as well as between N and treatments H_1, H_2 and H_4, and a significant difference ($0.01<p<0.05$) between non-infested control (N) and treatments H_3 and H_5 (Figure 2).

Besides the differences in fresh weight detected among herbicide-treated plants, differences in damage caused to *C. campestris* plants were visualized and the efficacy of different herbicide treatments against dodder plants was 80-97.5%. The two application rates of glyphosate demonstrated the best efficacy of 95% and 97.5% (H_1-288 and H_2-360 g a.i. ha, respectively) (Table 3). Both application rates of propyzamide (H_3-1500 and H_4-2000 g a.i. ha) were less effective (85% and 87%, respectively), while imazetapyr (H_5-150 g a.i. ha) had the lowest efficacy of 80% (Table 3).

Table 3. Visual assessment of herbicide efficacy (%) against field dodder plants in alfalfa

Treatment	Assessment				
	I	II	III	IV	V
I	0	0	0	0	0
H_1	3	70	87.5	93	95
H_2	5	75	90	97.5	97.5
H_3	0	60	80	82.5	85
H_4	0	65	85	85	87
H_5	0	50	77.5	80	80

I - control with *C. campestris,* H_1 and H_2 - glyphosate (288 and 360 g a.i. ha), H_3 and H_4 - propyzamide (1500 and 2000 g a.i. ha) and H_5 - imazethapyr (150 g a.i. ha)

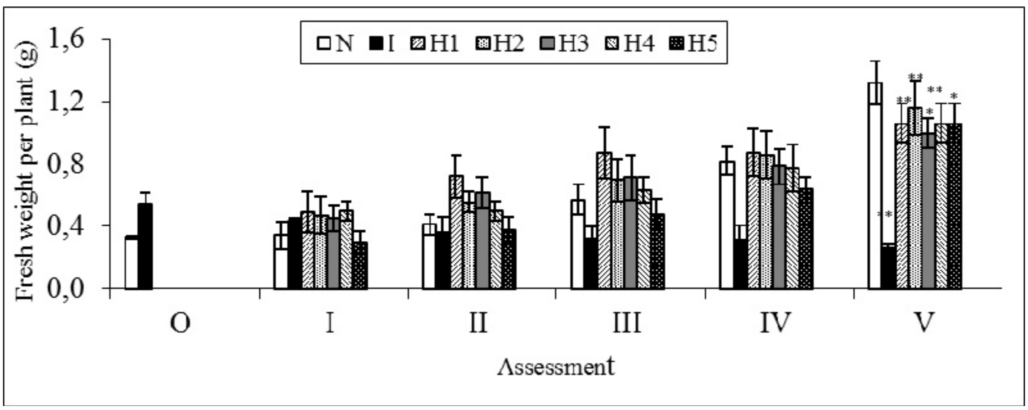

Figure 2. Effects of treatments: N - control free of *C. campestris*, I - control with *C. campestris*, H1 and H2 - glyphosate (288 and 360 g a.i. ha), H3 and H4 - propyzamide (1500 and 2000 g a.i. ha) and H5 imazethapyr (150 g a.i. ha) on fresh weight of alfalfa plants (g/plant), ($0.01<p<0.05$)*; ($p<0.01$)**; t-test

Field trials

Dodder control with herbicides in alfalfa at Popovići: Field dodder, being an obligate parasite, lives at the expense of a host plant and draws synthesized organic compounds from it which its own metabolism is unable to generate. Photosynthesis-inhibiting herbicides are therefore assumed to have little power in controlling the parasite, while herbicides that inhibit amino acid biosinthesis may affect field dodder growth (Nadler-Hassar & Rubin, 2003). A fact that supports the assumption of greater sensitivity of field dodder plants to amino acid-inhibiting herbicides is that the parasite has its own independent pathway of biosynthesis of amino acids (Wolswinkel, 1984). Herbicides inhibiting the biosynthesis of amino acids, which are predominantly used to control field dodder, belong to imidazolinones and sulfonylureas. In both our trial locations, we examined the efficacy of imazethapyr (H_5-150 g a.i. ha) in controlling field dodder in alfalfa crops, and the herbicide showed weak efficacy as dodder cover in trial plots was >70% even 30 DAT (Popovići location) (Table 4). Such weak efficacy of some herbicides was probably caused by an exceptionally dense dodder cover in trial plots of 100%. Also, herbicide application before crop cutting (the standard method of treatment after crop cutting was modified to secure the presence of field dodder plants in the crop) was considerably impeded by an unusually high crop density and high dodder infestation, which ultimately affected some of the treatments. Cudney and Lanini (2000) found that imazethapyr applied after plant emergence at the rates of 100-150 g a.i. ha significantly reduced the number of field dodder seedlings in alfalfa crop when its initial cover was low. Rimsulfuron applied at 35 g a.i. ha has also been found to reduce field dodder in tomato (Mullen et al., 1998). However, some other studies showed a low susceptibility of *C. campestris* to some sulfonylurea herbicides (Rubin, 1994) and also that *C. campestris* seeds germinated without a host in herbicide solutions and even showed a certain degree of tolerance to high concentrations of herbicides that are amino acid biosynthesis inhibitors (Nadler-Hassar & Rubin 2003).

In the first assessment 15 DAT, dodder cover in H_1- and H_2-treated plots (glyphosate 288 and 360 g a.i. ha) was 35% and 25%, respectively. The herbicide also had a phytotoxic effect on the crop, which resulted in a growth depression of 5-10% (Table 5). In contrast, dodder cover in H_3 and H_4 treatment plots (propyzamide, 1500 and 2000 g a.i. ha), and H_5 (imazethapyr, 150 g a.i. ha) ranged from 78-95% (Table 4), and there was no phytotoxic effect on the crop. Unlike these herbicides, H_6 treatment (diquat, 450 g a.i. ha) achieved 100% efficacy against field dodder. However, it also had the highest phytotoxic effect on alfalfa, although the crop started to recover after the first assessment (Table 5).

The second assessment 30 DAT revealed effects that were similar or identical to those recorded in our first assessment regarding the H_3 and H_4 treatments, while H_5 had a weaker effect compared to first assessment, showing that the dodder plants began to recover. In treatments H_1 and H_2, in which dodder cover was 10% lower than in the first assessment (25% and 15%), alfalfa also recovered from the depressive effect of that herbicide. Diquat treatment in the H_6 plot allowed no recovery of dodder plants, and its efficacy was 100%, but a significant recovery of the crop was observed.

Table 5. Assessment of phytotoxicity (%) to alfalfa plants at location Popovići

Treatment	Application rate (g a.i. ha)	15 DAT	30 DAT
Glyphosate	288	2	0
Glyphosate	360	2	1
Imazethapyr	150	1	0
Propyzamide	1500	0	0
Propyzamide	2000	0	0
Diquat	450	60	5
Control	none	0	0

DAT – days after treatment

Table 4. Field dodder cover in alfalfa crop before and after application of herbicides at location Popovići (%)

Code	Treatment	Product	Application rate (l/ha;*kg/ha) and (g a.i. ha)	0 assessment (FDCBT)	I assessment 15 DAT	II assessment 30 DAT
H_1	glyphosate	Glifol	0.8 (288)	100	35	25
H_2	glyphosate	Glifol	1 (360)	100	25	15
H_3	propyzamide	Kerb 50-WP	3* (1500)	100	80	79
H_4	propyzamide	Kerb 50-WP	4* (2000)	100	70	70
H_5	imazethapyr	Pivot M 100	1.5 (150)	100	78	72
H_6	diquat	Reglon forte	3 (450)	100	0	0
N	control	/	none	100	100	100

FDCBT – field dodder cover before treatment (%), DAT- days after treatment

Dodder control with herbicides in alfalfa at Rimski Šančevi: In contrast to our findings at the other location, field dodder cover at Rimski Šančevi before crop cutting ranged from 20-50%, and the crop had smaller density. The herbicides were applied after crop cutting at that location and their effects on the field dodder plants in alfalfa are shown in Table 6.

Herbicide effects on the field dodder plants were almost identical in both assessments (15 and 30 DAT), i.e. propyzamide and imazethapyr efficacies were very similar to glyphosate at the location Rimski Šančevi, which is consistent with our explanation regarding the timing of herbicide treatments and weather conditions during the trials. Solution transfer that occurs between the host and parasite plants as a result of different water potentials of their cell sap (Fer, 1984; Nir et al., 1996; Shlevin & Golan, 1982) makes it possible that low translocation rates of non-selective herbicides be potentially used in selective control of parasitic weeds (Nir et al., 1996). This and one other fact, that glyphosate inhibits translocation of assimilates on the host-parasite relation (Nadler-Hassar et al., 2004), have made this herbicide the most frequent choice for dodder control. Glyphosate (treatments H_1-288 and H_2-360 g a.i. ha) significantly suppressed dodder at both locations and its cover was only 25% and 15% 30 DAT where the infestation was 100% before treatment (visual assessment at Popovići location). Its cover at Rimski Šančevi was 5% in the last assessment. Dawson (1990) earlier found that glyphosate application rates of 75-100 g a.i. ha provided adequate control of *Cuscuta indecora* in a newly-grown alfalfa crop, while Mishra et al. (2004) achieved satisfactory results in controlling the species in a *Vigna mungo* crop by using 15-50 g a.i. ha glyphosate. Hock et al. (2008) reported data from a two-year study which indicated that all glyphosate application rates (140-1,120 g a.i. ha) provided high efficacy of >84% in controlling field dodder in ornamentals. Additionally, glyphosate applied at a rate of 400 g a.i. ha in a later development stage of carrot and during full bloom of *C. pentagona* has been found to suppress field dodder without causing any harm to its host plants (Bewick et al., 1988). In the plots treated with imazethapyr (H_5) and diquat (H_6), the efficacy was 100%, i.e. field dodder disappeared from the crop, while in treatments H_1 and H_2, as well as H_3 and H_4, only 1% of dodder plants remained. However, field dodder was significantly suppressed in untreated plots in both assessments as well, and infestation dropped to around 4%, probably as a result of crop cutting before herbicide application and extremely high temperatures over the period of up to 40 °C (Table 6). Due to a small number of herbicides that are available for controlling field dodder in alfalfa crops, diquat is often the choice. Applied at a rate of 450 g a.i. ha (H_6), diquat again showed the best efficacy at Rimski Šančevi. However, besides being highly efficacious it was also highly phytotoxic to alfalfa, although the crop showed a considerable recovery in the second assessment (Table 7).

Table 7. Phytotixocity assessment as % of damaged alfalfa plants at location Rimski Šančevi

Treatment	Application rate (g a.i. ha)	15 DAT	30 DAT
Glyphosate	288	1	1
Glyphosate	360	4	1
Imazethapyr	150	1	1
Propyzamid	1500	2	0
Propyzamid	2000	2	0
Diquat	450	24	12
Control	none	0	0

DAT – days after treatment

Table 6. Field dodder cover in alfalfa crop before and after application of herbicides at location Rimski Šančevi (%)

Code	Treatment	Product	Application rate (l/ha;*kg/ha) (g a.i. ha)	0 assessement (FDCBT)	I assessement 15 DAT	II assessement 30 DAT
H_1	glyphosate	Glifol	0.8 (288)	35	1	1
H_2	glyphosate	Glifol	1 (360)	20	1	1
H_3	propyzamide	Kerb 50-WP	3* (1500)	35	2	1
H_4	propyzamide	Kerb 50-WP	4* (2000)	40	1	1
H_5	imazethapyr	Pivot M 100	1.5 (150)	25	0	0
H_6	diquat	Reglon forte	3 (450)	50	1	0
N	control	/	none	50	4	4

FDCBT – field dodder cover before treatment (%), DAT- days after treatment

The most effective field dodder control should necessarily rely on a systematic approach of integrated protection from this flowering parasitic plant, starting with dodder monitoring in crops and in ruderal surfaces, and its coupling with optimal crop rotation, which should include crops that are not suitable dodder hosts, and application of a variety of preventive and mechanical removal methods, as well as herbicide treatments when other measures have failed.

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Hemijsko suzbijanje viline kosice u lucerki

REZIME

U novije vreme problematika parazitskih cvetnica postaje sve aktuelnija i dobija veći istraživački prostor upravo zbog njihovog širenja i sve većih šteta koje nanose u poljoprivredi. Štete koje vilina kosica pravi u usevu lucerke se prvenstveno odnose na smanjenje prinosa zelene biomase i značajno smanjenu produkciju semena kod semenske lucerke. Efikasno suzbijanje viline kosice u usevu luceke podrazumeva niz preventivnih mera i postupaka, kao i hemijsku kontrolu. Ispitivanje efikasnosti herbicida (glifosat, propizamid, imazetapir i dikvat) u suzbijanju viline kosice u usevu lucerke urađeno je tokom 2011. godine. Ogledi su izvedeni u saksijama i u polju, na oglednom polju Instituta za ratarstvo i povrtarstvo u Novom Sadu (Rimski Šančevi) i na privatnoj parceli na lokalitetu Popovići (okolina Mladenovca). U ogledu sa saksijama, najbolju efikasnost je ispoljio glifosat u obe primenjene količine (288 i 360 g a.s. ha), 95% odnosno 97.5%. Efikasnost koju je ispoljio propizamid u obe količine primene (1500 i 2000 g a.s. ha) je bila slabija (85% odnosno 87%), dok je najslabiju efikasnost ispoljio imazetapir (150 g a.s. ha), 80%. U poljskim ogledima, na oba lokaliteta, dikvat (450 g a.s. ha) je ispoljio najbolju efikasnost u suzbijanju viline kosice. Na lokalitetu Popovići efikasnost ostalih tretmana je bila slabija, odnosno procenat preživelih jedinki viline kosice je bio: 25% (glifosat, 288 g a.s. ha), 15% (glifosat, 360 g a.s. ha), 79% (propizamid, 1500 g a.s. ha), 70% (propizamid, 2000 g a.s. ha) i 72% (imazetapir, 150 g a.s. ha). Na lokalitetu Rimski Šančevi, pri primeni istih tretmana, vilina kosica se zadržala na usevu sa oko 1%.

Ključne reči: Vilina kosica; Herbicidi; Hemijsko suzbijanje; Lucerka