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Source / Izvornik: **Poljoprivreda, 2008, 14, 23 - 28**

Journal article, Published version
Rad u časopisu, Objavljena verzija rada (izdavačev PDF)

Permanent link / Trajna poveznica: https://urn.nsk.hr/urn:nbn:hr:151:473453

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Download date / Datum preuzimanja: **2025-02-23**

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DIGITALNI AKADEMSKI ARHIVI I REPOZITORIJI

ISSN 1330-7142
UDK = 633.34:632.094

EFFECTIVENESS OF SOME POST-EMERGENCE HERBICIDES IN SOYBEAN

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Original scientific paper
Izvorni znanstveni članak

SUMMARY

A three-year field experiment was conducted in soybean on lessive pseudogley soil at Čačinci locality (P.P. Orahovica d.d.) in North-eastern Croatia to evaluate the effectiveness of chemical weed control through single or multiple applications of post-emergence herbicides, alone or in combinations and their effects on soybean yields. Main weeds were summer annual species of Echinochloa crus-galli (140 - 269 shoots/m^2), Ambrosia artemisiifolia (8-56 plants/m^2) and Chenopodium album (3-12 plants/m^2). All herbicide treatments showed high efficacy in control of annual grass- and broad-leaved weeds, but were ineffective against perennial weeds. Multiple applications of post-em. herbicide combinations of oxasulfuron + imazamox (92%), clethodim + fomesafen (93%) and oxasulfuron + imazamox + thifensulfuron methyl (94%) at reduced rates, provided better weed control compared to a single application of oxasulfuron (91%) and imazamox (89%) at recommended rates. No significant differences were observed in yields between herbicide treatments, ranging from 3395 kg to 3496 kg /ha, on average.

Key-words: soybean, weed density, post-em. herbicides, weed control (%), crop yield

INTRODUCTION

Weed management is one of the most important aspects in soybean production and it includes different herbicide programs. Application of post-emergence weed control have increased recently, due to development of many effective post - emergence herbicides, which rapidly degrade in the soil and have a low potential to contaminate the ground water. The correct choice of post-em. herbicides, in terms of weed spectrum, weed growth stage and weed size, is of great importance for good soybean weed control (Barić et al., 1998; Ostojić, 1990; Skender et al., 1991; Barić and Ostojić, 2000; Bilandžić et al., 2003; Đurkić et al., 2004). The effect of post-emergence weed control is compatible with integrated weed management; it does not depend on precipitation and is also favourable from environmental and economic aspects (Swanton and Murphy, 1996). Long-term studies of weeds in soybean provide a way to access the influence of weed management and climatic variation on weed population dynamics.
The objective of this study was to evaluate the effectiveness of chemical weed control on individual species through single or multiple applications of some post-emergence herbicides, alone or in combinations at low rates, and their effects on soybean yields.

MATERIAL AND METHODS

The three-year field experiments (2002-2004) on soybean (cv. Aura) were conducted on lessive pseudogley soil type at Čačinci locality (P. P. Orahovica d. d.) in North-eastern Croatia. The previous crop in all three years was winter wheat. Soil tillage was conventional - ploughing with mouldboard plough at 30 - 35 cm depth with standard sowing. Pre-sowing fertilisation was 350 kg/ha NPK

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(10:20:30). Soybean was sown in the last decade of April (2003, 2004) or in the first decade of May (2002), with the interrow spacing of 45 cm, and at the depth of 4 to 6 cm. The two top dressings of crop were: at the first trifoliate growth stage (100 kg/ha of KAN) and before the beginning of the flowering (100 kg/ha of KAN). One inter-row cultivation was caried out in the first decade of June. Weather conditions during the soybean growing season (April, September) are presented in Table 1.
Weed control in soybean included five post-em. herbicide treatments, which are presented in Table 2. The herbicides were applied when the annual grass weeds were mainly at the 1-2 leaf stage, and broad-leaved weeds were at the 2-4 leaf stage. In addition to herbicide combinations, application was conducted about 7 days after the initial application. Herbicides were applied by a knapsack-sprayer Solo (Lurmark AN 1.0 nozzle type) in 300 l/ha of water volume at a pressure of 300 kPa. The effectiveness of herbicide treatments was measured by the average plants number/m^2 of weed species determined two to three times during the vegetation period, i. e. before herbicide application and 14 days after the final herbicide application. Weed samples were collected by counting plant numbers of each weed species in a 0.25 m^2, replicated 16 times within each treatment. The average percent of weed control was estimated relative to the untreated control. Weeds on untreated plots were removed by hand hoeing, 45-50 days after sowing. Phytotoxic effects of herbicides on crop plants were evaluated using a 1-9 scale. Soybean was mechanically harvested and grain yield was recorded and adjusted to 14% of the moisture content. Data were subjected to analysis of variance to determine the significant differences between weed control treatments. For analysis of variance, the year was used as the main factor and weed control treatments as the sub-factor. Means percentage of weed control and soybean yield were compared using Fisher`s Protected LSD test ($P< 0.05$).

Table 1. Weather conditions during the soybean growing season (2002-2004)
Tablica 1. Vremenske prilike u vegetacijskom periodu soje (2002.-2004.)

Month/Year	Precipitation - *Oborine* (mm)			Temperatures – *Temperature* (^oC)		
Mjesec/Godina	2002	2003	2004	2002	2003	2004
April	128	14	27	10.9	10.9	11.5
May	152	24	76	18.5	19.7	15.1
June	41	65	98	21.1	23.7	19.7
July	71	37	68	22.7	22.8	21.5
August	75	43	104	21.5	24.4	21.0
September	127	72	80	15.7	16.4	15.8
Total - *Ukupno* (mm)	594	255	453			
Mean - *Prosjek* (^oC)				18.4	21.3	17.4

RESULTS AND DISCUSSION

A total of seven weed species were recorded in the three-year study of soybean, three of which were annual broad-leaved species, three perennials and one grass species. The weed flora was dominated by summer annual weeds. The composition of weed species did not vary much between the years. However, the density of weed populations varied significantly according to the year (Table 3, 4, 5). *Echinochloa crus-galli* (L.) PB. was the most abundant weed species in all three years and gathered 74 - 91 % of the total weed density. The highest barnyard grass density of 269 shoots/m^2 was found in wet season of 2002 with high total precipitation of 280 mm in April and May (Table 1). On the other hand, the lowest density of 140 shoots/m^2, was found in exstremely dry of 2003 with total precipitation of only 38 mm in April and May. The total grass density in 2002 was by 92% and 55% higher than in 2003 and 2004, respectively.

Table 2. Treatments of post-emergence herbicides
Tablica 2. Varijante post-em. herbicida

Treatment *Varijanta*	Trade name *Trgovačko ime*	Active ingredient *Djelatna tvar* *	Rate per m^2 *Količina po* m^2 (kg or /*ili* l/ha)
1	Dynam 75 WG (Syngenta)	oxasulfuron 75%	0.10
2	Pulsar 40 (BASF)	imazamox 40%	1
3	Dynam 75 WG (Syngenta) + Pulsar 40 (BASF)	oxasulfuron 75% + imazamox 40%	0.06 + 0.8
4	Select Super (Tomen) + Flex (Syngenta)	clethodim 12.3% + fomesafen 25%	1 + 1
5	Dynam 75 WG (Syngenta) + Pulsar 40 (BASF) + Harmony 75 WG (Du Point)	oxasulfuron 75% + imazamox 40% + thifensulfuron methyl 75%	0.05 + 0.06 + 0.008

* The recommended rate of certain surfactant or crop oil (4) was used in all herbicide treatments (Maceljski, 2005)

Three annual broad-leaved species were: *Ambrosia artemisiifolia* L., *Chenopodium album* L. and *Polygonum lapathifolium* L. The highest *A. artemisiifolia* density of 56 plants/m^2 or 24% of total weed density was found out in 2004 and the lowest of 7.5 plants/m^2 or 5% in 2003. *C. album* and *P. lapathifolium* were the most abundant broad-leaved weeds in 2003, reached 11.5 plants and 2.4 plants per m^2, respectively. Perennial weeds of *Calystegia sepium* L., *Convolvulus arvensis* L. and *Equisetum arvense* L. gathered less than 1% of the total weed density, in all three years.

Post-emergence herbicide treatments provided the best total weed control in 2002 (92 - 96 %), some lower in 2004 (91 - 94%) and the lowest, but still good weed control in 2003 (84 –91%). In both wet seasons of 2002 and 2004, weed control efficacy was great because a large number of weeds emerged early in the season. The spraying was performed at the two-leaf stage of *E. crus-galli*, and 2-4 leaf stage of broad-leaved weed plants and any new weed emergence occured after that time. On the contrary, in the unfavourable 2003, which was associated with hot, dry conditions, the emerging of weeds was not uniform and it was prolonged till late in the season, until the end of June. In spite of that, weeds had a competitive advantage, due to the slowly growing soybean plants until the first trifoliate stage yet in middle of June. That was three to four weeks later than in other two years. Therefore, all herbicide treatments were less effective compared to 2002 and 2004 (Table 6). Such a high competitive ability of weeds under dry conditions concurs with other findings (Skender et al., 1989). In all years, the herbicide combinations in multiple application at reduced rates (3, 4, 5) provided consistently effective and better weed control (92 - 94%) than herbicide treatments in a single application at recommended rates (1, 2) with less weed control (89-91%). However, all herbicide combinations were ineffective against perennial weeds.

Herbicides caused no injury to soybean, with exception of oxasulfuron and imazamox (1, 2) which caused temporary soybean injury, only in 2003.

Soybean yields significantly differed between years (Table 6). The greatest yields were in 2002 (4100 kg/ha) and the lowest in 2003 (2475 kg/ha). No significant differences were observed in yields between herbicide treatments, ranging from 3395 kg to 3496 kg/ha, on average. Compared to average yields from herbicide treatments (3459 kg/ha), average percent yield depression from untreated control plots were 8%. These results showed that the weedy period of 50 days, from the sowing to the removal of weeds, significantly affected crop yields on untreated control plots. Harrison (1990) reported that the soybean crop could tolerate five weeks of interference at two *C. album* plants/m^2. Coble et al. (1981) found that when adequate moisture was available, four weeks of weed-free maintenance was required to prevent soybean loss from *A. artemisiifolia* interference. Van Acker et al. (1993) reported for Ontario condition that with an acceptable soybean yield loss of 2.5%, the beginning of the critical period of weed control was highly variable ranging from the second node growth stage to the beginning of the pod stage. However, the end of the critical period consistently occurred at the fourth node stage.

Table 3. Species composition in soybean and weed density (plants per m^2) on untreated control and with herbicide treated plots in 2002

Tablica 3. Korovne vrste i broj korova po m^2 u soji, u netretiranim i herbicidnim varijantama u 2002. godini

Weed species *Korovne vrste*	Untreated control *Kontrola*	Herbicide treatments *Herbicidne varijante*				
		1	2	3	4	5
Echinochloa crus-galli (L.) PB.	268.5	13.0	18.0	10.0	11.0	8.0
Chenopodium album L.	2.8	0.4	0	0	0	0
Ambrosia artemisiifolia L.	21.0	0.3	0.9	0	0	0.5
Polygonum lapathifolium L.	1.0	0.5	0.2	0.5	0.5	0
Calystegia sepium L.	0.8	0.3	1.2	0.6	0.8	1
Convolvulus arvensis L.	0.4	0	0.7	0.5	0.2	0
Equisetum arvense L.	1.0	0.8	1.5	1	1.0	1
Total number of weeds/m^2 *Ukupan broj korova/m^2*	295.5	15.3	22.5	12.6	13.5	10.5
Percentage of weed control (%) *Koeficijent učinkovitosti (%)*		95	92	96	95	96

Table 4. Species composition in soybean and weed density (plants per m^2) on untreated control and with herbicide treated plots in 2003

Tablica 4. Korovne vrste i broj korova po m^2 u soji, u netretiranim i herbicidnim varijantama u 2003. godini

Weed species *Korovne vrste*	Untreated control *Kontrola*	Herbicide treatments *Herbicidne varijante*				
		1	2	3	4	5
Echinochloa crus-galli (L.) PB.	140.0	18.0	21.0	16.0	9	11.0
Chenopodium album L.	11.5	1.0	1.0	0	0	0
Ambrosia artemisiifolia L.	7.5	1.8	1	1.4	2	1
Polygonum lapathifolium L.	2.4	0	1	0.4	1	1
Calystegia sepium L.	0	0	0.5	0.5	0.5	0
Convolvulus arvensis L.	0.3	1.0	0	0	2	1
Equisetum arvense L.	0.5	0.5	1	0.5	1.0	0.5
Total number of weeds/m^2 *Ukupan broj korova/m^2*	162.2	22.3	25.5	18.8	15.5	14.5
Percentage of weed control (%) *Koeficijent učinkovitosti (%)*		86	84	88	90	91

Table 5. Species composition in soybean and weed density (plants per m^2) on untreated control and with herbicide treated plots in 2004

Tablica 5. Korovne vrste i broj korova po m^2 u soji, u netretiranim i herbicidnim varijantama u 2004. godini

Weed species *Korovne vrste*	Untreated control *Kontrola*	Herbicide treatments *Herbicidne varijante*				
		1	2	3	4	5
Echinochloa crus-galli (L.) PB.	173.6	15	10	8	7	9
Chenopodium album L.	2.5	0.2	0.2	0	0	0
Ambrosia artemisiifolia L.	56.1	4	5	6	6	4
Polygonum lapathifolium L.	0.5	0	0.3	0.1	0.2	1
Calystegia sepium L.	0.7	0.2	0	1	0.2	0
Convolvulus arvensis L.	0.7	0.3	1	0	0.7	0
Equisetum arvense L.	1.0	1	1	2	1	1
Total number of weeds/m^2 *Ukupan broj korova/m^2*	235.1	20.7	17.5	17.1	15.1	15.0
Percentage of weed control (%) *Koeficijent učinkovitosti (%)*		91	92	93	94	94

Table 6. Effectiveness of post-emergence herbicides and soybean yields (2002-2004)
Tablica 6. Učinkovitost post-em herbicida na korove i prinos soje (2002. – 2004.)

Herbicide treatments *Herbicidne varijante*	Weed control (%) *Učinkovitost herbicida (%)*				Grain yield (kg/ha) *Prinos zrna (kg/ha)*			
	2002	2003	2004	Mean *Prosjek*	2002	2003	2004	Mean *Prosjek*
oxasulfuron 75%	95 ab	86 bc	91 a	91 bc	4210 a	2471 a	3733 a	3471 a
imazamox 40%	92 b	84 c	92 a	89 c	4135 a	2437 a	3613 a	3395 ab
oxasulfuron 75% + imazamox 40%	96 a	88 ab	93 a	92 ab	4172 a	2590 a	3622 a	3461 a
clethodim 24% + thifensulfuron methyl 75%	95 ab	90 ab	94 a	93 a	4147 a	2544 a	3797 a	3496 a
oxasulfuron 75% + imazamox 40% + thifensulfuron methyl 75%	96 a	91 a	94 a	94 a	4194 a	2486 a	3735 a	3472 a
Untreated control - *Kontrola*					3745 b	2317 a	3446 a	3169 b
LSD (P < 0.05)	2.64	3.30	2.86	1.53	360	525	437	237

Means of weed control (%) and soybean yield followed by the same letter are not significantly different at P < 0.05.

CONCLUSIONS

The three-year field experiments in soybean showed that all investigated post-emergence herbicides, alone or their combinations in single and multiple applications provided very good control of dominant grass weed of *Echinochloa crus-galli* and broad-leaved weeds of *Ambrosia artemisiifolia* and *Chenopodium album* when weed plants were small, at 2-4 leaf stage and soybean plants were up to the third trifoliate growth stage.
The herbicide combinations of oxasulfuron + imazamox (92%), clethodim + fomesafen (93%) and oxasulfuron + imazamox + thifensulfuron methyl (94%) in multiple application at reduced rates provide consistently effective and better weed control (92 - 94%) than herbicide treatments of oxasulfuron and imazamox in single application at the recommended rates (89 - 91%). All herbicide treatments were ineffective against perennial weeds.
Soybean yields significantly differed between years, from 2475 kg/ha in 2003 to 4100 kg/ha in 2002. No significant differences were observed in yields between herbicide treatments, ranging from 3395 kg to 3496 kg/ha, on average. Compared to yields of herbicide plots (3459 kg/ha), average percent yield depression in untreated control plots was 8%.

Acknowledgements

This work was supported by the Croatian Ministry of Science, Education and Sports ("Integrated arable crop protection from weeds"- 079-0790570-2716).

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UČINKOVITOST NEKIH POST-EMERGENCE HERBICIDA U SOJI

SAŽETAK

Trogodišnji poljski pokusi obavljeni su u usjevu soje na lesiviranome pseudogleju na lokaciji R. J. Čačinci (P.P. Orahovica d.d.), s ciljem utvđivanja učinkovitosti nekih post-emergence herbicida i njihovih kombinacija primijenjenih jednokratno u preporučenim količinama ili višekratno u smanjenim količinama te njihov utjecaj na prinos soje. Dominantni korovi bili su: Echinochloa crus-galli (140 - 269 izdanaka/m^2), Ambrosia artemisiifolia (8 - 56 izdanaka/m2) i Chenopodium album (3 - 12 izdanaka/m^2). Sve herbicidne varijante postigle su, u prosjeku, dobru do odličnu učinkovitost na jednogodišnje travne i širokolisne korove, ali neadekvatnu učinkovitost na višegodišnje korove. Prosječna učinkovitost bila je veća u višekratnoj primjeni herbicidnih kombinacija oxasulfuron + imazamox (92%), clethodim + fomesafen (93%) i oxasulfuron + imazamox + thifensulfuron methyl (94%) nego u jednokratnoj primjeni oxasulfurona (91%) ili imazamoxa (89%). Prinosi soje značajno su varirali po godinama (2475 kg/ha u 2003., 3658 kg/ha u 2004. i 4100 kg/ha u 2002.), ali se nisu statistički razlikovali po herbicidnim varijantama, s prosječnim prinosima od 3395 kg do 3496 kg /ha.

Ključne riječi: soja, broj korova, post-em. herbicidi, učinkovitost herbicida, prinosi soje

(Received on 6 November 2008; accepted on 27 November 2008 - *Primljeno 6. studenog 2008.; prihvaćeno 27. studenog 2008.*)