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EFFECTS OF NICOSULFURON APPLICATION TIMING ON WEEDS AND SWEET MAIZE CROP

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The effect of nicosulfuron application timing on weeds and sweet maize hybrid (ZPSC 504*su*) was studied. The herbicide was applied according to the recommended rate for commercial maize on four dates of applications.Weed plants abundance (the number of species, the number of plants per species and fresh biomass) was evaluated for each weed species for each herbicide application date, and at the end, the total dry weight of weeds per a variant was estimated. The herbicide application on all four dates over both years reduced the number of weed species and the number of weed plants per species. Effects of the applied herbicide differed over years due to differences in meteorological conditions. The ear length of the studied sweet maize hybrid statistically significantly differed in the herbicide application date and investigation year interaction.

Weed suppression with the aim to obtain the planned yields of sweet maize has an important role. Nevertheless, different susceptibility of sweet maize to herbicides points out to cautiousness in their application.

Key words: sweet maize; weeds, nicosulfuron, response to herbicide

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INTRODUCTION

Nicosulfuron is a herbicide of a sulphonylurea group and is used to control many annual and perennial weeds of the family *Poaceae*, (BHOWMIK *et al.*, 1992; HINZ and OWEN, 1996; WILLIAMS and HARVEY, 2000). Since it is applied after emergence of both, weeds and maize (2-6 leaves) this herbicide has been more often used in suppression of resistant weed species, such as Johnson grass (*Sorghum halepense*). However, a herbicide of this group can damage maize. Many authors point out to differences in susceptibility of maize inbreds, especially of hybrids with specific traits, such as popping maize hybrids and sweet maize hybrids to herbicides of the sulphonylurea group (ROBINSON *et al.*,1993; MONKS *et al.*, 1992; O' SULIVAN *et al.*, 1998; STEFANOVIĆ *et al.*, 2002). According to the majority of authors, the specificity of effects of herbicides of the sulphonylurea group is unpredicted and most often attributed to a genotype and meteorological conditions of the year (CAREY *et al.*, 1997; GREEN and ULRICH, 1998; STEFANOVIĆ *et al.*,1997). O'SULIVAN *et al.* (1995) state that different tolerance of maize genotypes to nicosulfuron could be explained by a different metabolism of the herbicide in the plant.

Considering that sweet maize is a type of a hybrid with specific traits, susceptible to many stress factors, the effects of nicosulfuron application timing on weeds and sweet maize hybrids were observed.

MATERIAL AND METHOD

The three- replicate trial was set up according to the split-plot design on degraded chernozem at Zemun Polje during 1997 and 1998. The hybrid ZPSC 504*su* of the FAO maturity group 500 (medium late maturity hybrid) was used in the experiment. The herbicide was applied in accordance with the rate recommended for commercial maize (500 g a.i. ha^{-1}) on four application dates (A.T.), that coincided with four developmental stages of maize. The dates of herbicide application varied in dependence on meteorological conditions of the year (tab.1).

Table 1. - Herbicide application timing in dependence on the developmental stage of maize

Herbicide application timing	Year 1997		Year 1998	
	Date	Developmental stage	Date	Developmental stage
A.T. I	19/05	4-5-leaf	14/05	4-5-leaf
A.T.II	23/05	5-6-leaf	25/05	6-7-leaf
A.T.III	27/05	6-7-leaf	29/05	7-8-leaf
A.T.IV	04/06	7-8-leaf	03/06	8-10-leaf
Control variant was not treated by the herbicide				
Weed evaluation		23/06/1997	26/06/1998	

A.T. = date of herbicide application

The herbicide was not applied in the control. The trial was not hoed. Weed sampling was done on the same day on all application dates. Hence, in 1997, weeds were evaluated after 43 days, i.e. 21 days in the first (A.T. I), i.e. the fourth application timing (A.T. IV), respectively. The evaluation was done by the one square meter area method with three replications. Abundance (the number of species, the number of plants per species and fresh biomass) of each weed species on each date of the herbicide application was determined, and at the end, the total dry weight of weeds were calculated per a variant.

Fresh biomass of the whole maize plants were measured in 1997 on the 25th, 21st, 17th and 8th day after the herbicide application (3 x 4 plants per variant). The coefficient of correlation was estimated by the comparison of dry weight of weeds and maize biomass. The ear length and weight of observed sweet maize were measured at harvest maturity in both years of investigation. Gained results were statistically processed by the analysis of variance and analysed by the LSD test.

Mean monthly air temperatures and precipitation sums of the growing period differed over years of investigation (1997 and 1998, tab.2).

Table 2. - Mean monthly air temperatures and precipitation sums in 1996 and 1997

Year	Month						Average for the growing period
	April	May	June	July	August	September	
	Air temperatures (°C)						
1997	8.2	18.6	21.8	21.4	21.4	17.7	18.2
1998	14.9	17.0	25.0	23.8	23.7	17.6	20.3
	Precipitation (mm)						
1997	87.0	51.0	31.0	131.0	113.0	31.0	444.0
1998	31.0	51.0	62.0	33.0	45.0	95.0	317.0

The mean monthly air temperature of the growing period of 1997 (18.2 °C) was lower than of 1998 (20.3 °C). At the same time, the total precipitation sum was higher in 1997 (434 mm) than in 1998 (317 mm).

RESULTS AND DISCUSSION

The total number of weed species, as well as, the number of plants per species differed over dates of the herbicide application and the year of investigation. In 1997, 10 weed species with 104.6 plants m^{-2} were observed in the control, while in 1998, the total number of weed species was greater (16), but the number of plants was smaller (14.9 m^{-2}). Unfavourable conditions for maize development (smaller amounts of precipitation) favoured the development of weeds (tab.3).

The herbicide application on all four dates affected the reduction of the number of both, species and weed plants per species in relation to the control. However, due to differences in maize development, caused by meteorological conditions of the year, the effect of the applied herbicide on weeds differed over years.

Table 3. - The effect of nocosulfuron application timing on the number of weed species and the number of weed plants per species (% in relation to the control)

Herbicide application timing	Years of investigation							
	1997				1998			
	Number of species		Number of plants		Number of species		Number of plants	
	No.	%	No.	%	No.	%	No.	%
A.T. I	11	110.0	50.6	48.4	16	100.0	8.8	59.1
A.T. II	10	100.0	25.2	24.1	13	81.3	7.2	48.3
A.T. III	7	70.0	127.9	122.3	10	62.5	5.6	37.6
A.T. IV	7	70.0	57.6	55.1	12	75.0	10.3	69.1
Untreated variant	10	100.0	104.6	100.0	16	100.0	14.9	100.0

A.T. = date of herbicide application

The lowest number of weed species in 1997 was registered on the third and fourth date of nicosulfuron application (70%), while the number of weed plants per species was the lowest on the second date of herbicide application (25.2%) in relation to the control. In 1998, the lowest number of both, species and plants per species was recorded on the third date (62.5% and 37.6%, respectively).

Table 4. - Fresh biomass of distributed weeds in dependence on nicosulfuron application timing in 1997 (g m^{-2})

Weed species	Nicosulfuron application timing				
	A.T. I	A.T. II	A.T. III	A.T. IV	Untreated variant
Sorghum halepense	480.1	28.4	-	42.8	594.4
Chenopodium hybridum	3.6	-	16.7	-	394.4
Lathyrus tuberosus	173.5	103.9	4.3	-	322.4
Chenopodium album	13.6	41.7	13.2	-	222.4
Setaria viridis	69.3	33.7	9.6	110.3	208.8
Setaria glauca	-	-	-	-	88.8
Bilderdykia convolvulus	50.3	56.7	-	-	85.2
Sonchus arvensis	12.9	-	-	-	57.6
Ambrosia artemisiifolia	12.7	-	-	-	56.4
Solanum nigrum	-	-	-	-	20.8
Convolvulus arvensis	37.6	66.1	28.7	190.0	-
Panicum crus-galli	23.5	14.4	-	76.7	-
Veronica persica	20.1	37.6	-	75.9	-
Polygonum aviculare	-	20.3	-	-	-
Amaranthus blitoides	-	9.5	-	-	-
Datura stramonium	-	-	4.8	-	-
Rubus caesius	-	-	14.4	28.9	-
Cynodon dactylon	-	-	9.5	20.9	-
Total fresh biomass	897.2	412.3	103.9	545.5	1538.4
% out of untreated variant	58.3	26.8	6.7	35.4	100.0

The species *Sorghum halepense* (594.4 g m^{-2}) and *Chenopodium hybridum* (394.4 g m^{-2}) were the most distributed weed species (on the basis of the weight of biomass) (tab.4). The biomass weight of the majority of distributed weed species, especially grass ones, was lower in the treated variants than in the control. According to results presented in Table 4, it is observable that the effect of nicosulfuron in control of the species *Sorghum halepense* was the strongest 26 days after the herbicide had been applied (V.R.III). Furthermore, the total weight of fresh biomass of other distributed weeds decreased on all dates of the herbicide application. Hence, the total weight of fresh biomass of all distributed weeds had the same trend as the total number of plants per species (the lowest was on the third date of the herbicide application - 103.9 g m^{-2} or 6.7%). In 1998, *Chenopodium album* (803.7 g m^{-2}) and *Datura stramonium* (258.9 g m^{-2}) were the most distributed weed species (tab.5). Total fresh biomass in the control was higher in 1998 (1912.5 g) than in 1997 (1538.4 g). In 1998, the effect of nicosulfuron in control of the species *Sorghum halepense* was the strongest 27 days after the herbicide application (V.R.III), although the lowest total fresh biomass of weeds was observed on the fourth date of the herbicide application (244.5 g m^{-2} or 14.5%).

Table 5. - Fresh biomass of distributed weeds in dependence on nicosulfuron application timing in 1998 (g m^{-2})

Weed species	Nicosulfuron application timing				
	A.T. I	A.T. II	A.T. III	A.T. IV	Untreated variant
Chenopodium album	20.0	326.1	67.2	114.3	803.7
Datura stramonium	-	-	-	-	258.9
Chenopodium hybridum	41.8	22.9	-	38.4	223.5
Amaranthus retroflexus	22.8	4.0	3.2	5.8	187.8
Panicum crus-galli	129.2	47.2	20.1	12.0	136.6
Sorghum halepense	38.0	95.3	2.1	5.3	108.9
Sinapis arvensis	-	-	-	-	87.6
Setaria viridis	15.2	25.5	-	0.6	67.3
Sonchus asper	-	-	-	7.8	43.5
Sonchus oleraceus	-	-	-	-	41.5
Setaria glauca	15.3	23.3	8.0	12.0	32.7
Convolvulus arvensis	93.7	36.4	69.2	17.7	25.2
Solanum nigrum	1.3	5.2	25.3	21.6	16.6
Rubus caesius	32.1	-	13.3	-	14.0
Amaranthus albus	-	-	-	-	6.1
Setaria verticillata	94.3	3.8	9.7	11.6	2.7
Amaranthus blitoides	0.6	-	-	-	-
Ambrosia artemisiifolia	60.9	-	22.0	-	-
Hibiscus trionum	0.8	-	-	-	—
Veronica persica	5.0	11.3	-	-	-
Bilderdykia convolvulus	3.6	4.0	-	1.0	-
Polygonum aviculare	-	49.6	-	-	-
Total number of weed species	16	13	10	12	16
Total fresh biomass	540.1	770.1	246.1	244.5	1912.5
% out of untreated variant	23.3	38.1	17.7	14.5	100.00

The comparison of the total fresh biomass of weeds over both years shows that this parameter was the smallest on the third, i.e. fourth date of the herbicide application in 1997 and 1998, respectively. The shifting of the maize development stages caused by meteorological conditions produced the differences in the date of the herbicide application in the years of investigation. Due to this, effects of nicosulfuron on all studied parameters of weeds were different. Other authors, studying the possibility of controlling rhizome of Johnson grass (*Sorghum halepense*) in maize crop with nicosulfuron, state that this plant is the most susceptible in the 6-8-leaf stage, and this stage is the most optimum time for its control (CAMACHO *et al.*, 1991). These authors state that precipitation is necessary for herbicides to rich the soil.

Although investigated sweet maize plants did not show any deformities during the performance of the trial, the measured fresh biomass of maize plants was smaller on all dates of the nicosulfuron application in 1997 than in the control and regularly decreased over later dates of the herbicide application (Figure 1).

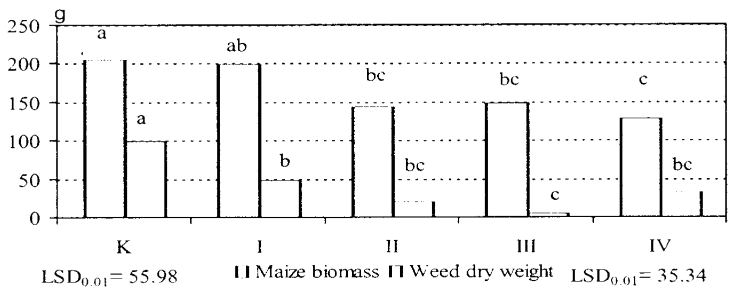

Fig. 1. - Average maize plant weight and weed dry weight in 1997

The total weed dry weight regularly reduced from the first to the fourth date of the herbicide application. The weed dry weight increased only on the fourth date of the herbicide application and adversely affected maize plants. The statistical analysis shows highly significant differences in maize biomass and weed dry weight and the coefficient of correlation of these two parameters is high (r^2=0.72). Although the dry weight of weeds reduced in relation to the control, the regular reduction of the weight of maize biomass over later dates of the nicosulfuron application indicates the possibility of phytotoxic effects of the herbicide on maize plants.

The ear length and weight of sweet maize at harvest maturity as parameters of the yield for both years of investigation are presented in tab. 6.

The ear length of the observed sweet maize did not on the average statistically significantly changed, depending on meteorological data, but it was smaller than in the control (17.9 cm). However, statistically significant changes for this parameter were determined in the herbicide application timing x investigation years interaction. The ear length was greater in all treated variants over all dates of the nicosulfuron application in 1997 than in the control, while in 1998, it was shorter on the fourth date of the nicosulfuron application (17.7 cm) than in the control. A similar regularity is observable in the sweet maize ear weight, which was on the average lower than in the control for both years (184.0 g). In 1997, ear weights of sweet maize at harvest maturity was the lowest in the control (162.0 g), and the highest on the first date of the herbicide application (203.7 g). In 1998, the average ear weight was higher than in the previous year, but with greater differences among herbicide application dates. The highest (238.6 g), i.e. lowest (205.9 g), ear weight was recorded on the second, i.e. forth date of the herbicide application, respectively. If it is considered that the total weed fresh biomass in 1998 was the lowest on the forth date of the herbicide application (14.5%), then the ear weight reduction is probably a result of unfavourable effects of the late herbicide application on the maize plant. This was also a result of unfavourable meteorological conditions (a high air temperature in the July-August period accompanied with a precipitation deficit).

Table 6. - Measured parameters of maize in 1997 and 1998

Herbicide application timing	Measured parameters of maize: Ear length (cm) 1997	1998	Mean (G.)	Ear weight (g) 1997	1998	Mean (G.)
A.T.I	$18,8^{ab}$	$18,8^{ab}$	$18,8^{ns}$	$203,7^{bc}$	$232,1^{ab}$	$217,9^{a}$
A.T.II	$18,5^{ab}$	$19,6^{a}$	$19,1^{ns}$	$192,3^{c}$	$238,6^{a}$	$215,4^{a}$
A.T.III	$18,4^{ab}$	$18,9^{ab}$	$18,7^{ns}$	$193,7^{c}$	$212,2^{abc}$	$202,9^{ab}$
A.T.IV	$18,7^{ab}$	$17,7^{ab}$	$18,2^{ns}$	$201,5^{c}$	$205,9^{bc}$	$203,7^{ab}$
Untreated variant	$17,1^{b}$	$18,8^{ab}$	$17,9^{ns}$	$162,0^{d}$	$206,1^{bc}$	$184,0^{b}$

$LSD_{0,05}$ G.xV.R. =1,88 Ns $LSD_{0,05}$ GxV.R. =28.56 $LSD_{0,05}$=20,19

The previous studies on nicosulfuron effects on morphological parameters of maize inbred lines under our conditions show that nicosulfuron affects the length and fresh biomass of the above ground part and root of maize in dependence on the applied herbicide concentration (KEREČKI, 2002). STEFANOVIĆ *et al.*, (1997) indicate a significant deviation of maize biomass in comparison with the control when the used herbicides were applied after maize emergence. Although some previous studies show that sweet maize was differently resistant to nicosulfuron (MORTON and HARVEY, 1992), subsequent studies show that this herbicide can be applied in tolerant hybrids of this type of maize (WILLIAMS and HARVEY, 1996). All this point out to the fact that weed control has an important role in obtaining planned yields of sweet maize. If the variability of meteorological conditions is considered then a due application of herbicide gains in its importance. Nevertheless, different susceptibility of sweet maize to herbicides point out to caution in their application.

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UTICAJ VREMENA PRIMENE NIKOSULFURONA NA KOROVE I USEV KUKURUZA ŠEĆERCA

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I z v o d

Ispitivan je uticaj vremenskih rokova primene nikosulfurona na korove i hibrid kukuruza šećerca (ZPSC 504*su*). Herbicid je primenjen u preporučenoj količini (500 g a.m. ha^{-1}) za merkantilni kukuruz, u četiri vremenska roka primene herbicida (V.R.).

Kod korova je ocenjivana brojna zastupljenost (broj vrsta, broj jedinki i sveža masa) svake vrste korova u svakom vremenskom roku primene herbicida, a na kraju obračunata ukupna suva masa korova po varijanti. Kod kukuruza je u 1997. godini merena sveža biomasa celih biljaka kukuruza, s dužina i težina klipova ispitivanog hibrida kukuruza šećerca u vreme tehnološke zrelosti merena je u obe godine. Dobijeni rezultati su statistički obrađeni metodom analize varijanse i analizirani LSD testom.

Primena herbicida u sva četiri vremenska roka, u obe godine, uticala je na smanjenje broja vrsta i jedinki korova. Međutim, zbog razlika u meteorološkim uslovima godina, efekat primenjenog herbicida na korove nije bio isti u obe godine. Biomasa kukuruza se u 1997. godini statistički značajno razlikovala u zavisnosti od vremena primene herbicida, pri čemu se i suva masa korova smanjivala. Dužina klipa ispitivanog hibrida šećerca se statistički značajno razlikovala u interakciji faktora vremenski rok primene herbicida i godine ispitivanja. Težina klipova kukuruza šećerca u fazi tehnološke zrelosti je u proseku za obe godine značajno manja na kontroli.

Dobijeni rezultati ukazuju na činjenicu da suzbijanje korova u postizanju planiranih prinosa kukuruza šećerca ima važnu ulogu. Ako se pri tome ima u vidu variranje klimatskih uslova, onda je pravovremena primena herbicida veoma važna. Pri svemu tome, različita osetljivost kukuruza šećeraca prema herbicidima ukazuje na opreznost pri njihovoj primeni.

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