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Efficacies of Reduced Herbicide Rates for Weed Control in Maize (*Zea mays* L.) During Critical Period

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Abstract: The sensitivities of *Amaranthus retroflexus* L., *Chenopodium album* L., *Xanthium strumarium* L. and *Portulaca oleraceae* L. at different growth stages were compared against two common herbicides used in maize (nicosulfuron and 2.4-D-amine). The sensitivities of weeds at 2-4 leaves growth stages were higher than at 5-8 leaves; they could be controlled by 90% with about 30-40% lower rates. Based on the results of pot experiments the performances of reduced rates were evaluated under naturally weed-infested conditions in the field experiments conducted in 2002 and 2003. Results from the experiment conducted in 2002 suggested that none of the herbicide alone provided acceptable weed control under practical growing conditions, even at the recommended rates, but the mixture of reduced rates was highly efficient against weeds. Therefore the efficacy of this herbicide mixture alone; in combination with ammonium-sulphate additive or with hand hoeing was evaluated in two field experiments under practical maize growing conditions in 2003. Results showed that low rate herbicide mixture provided acceptable weed control during critical period, provided highest grain yield and it's efficacy against difficult to control weeds was improved by ammonium-sulphate addition.

Key words: Maize, weed control, critical period, reduced herbicide rate, ammonium-sulphate additive

INTRODUCTION

Weed control is important in maize production and is carried out by mechanical and/or chemical measurements. Although both methods are effective in controlling weeds, intensive use of weed control is closely associated with higher production costs and/or some side effects. As the weed control systems based solely on herbicides has lost their popularity due to some problems, such as water and air contamination[1] and selection of herbicide resistant weed biotypes[2], attempt is being put on Integrated Weed Management (IWM) strategies in maize, in which the herbicide use is being reduced.

Optimization of herbicide use can be achieved at three steps: non-chemical preventive measures to reduce the initial density of weeds, assessment of the need for weed control after crop establishment and finally the choice of herbicide rates to be applied[3]. Although each step is important in developing an optimum weed control strategy, the second and third steps should be considered jointly in the case of post emergence weed control.

Critical Period for Weed Control (CPWC) is an important concept for Integrated Weed Management (IWM) in maize, which should be considered for assessing the need for and timing of weed control. Considering CPWC it is possible to develop an efficient herbicide strategy with reduced herbicide rates[4]. Since the previous CPWC studies conducted in maize suggest that in general a short term weed control is enough (2-3 weeks) to provide maximum maize grain yield[5,6], use of herbicides at reduced rates could be an integral control strategy within the frame of IWM.

In some previous studies concerning weed control with reduced herbicide rates, it was shown that the herbicide rates could be reduced by considering weed species, weed growth stages and environmental conditions and the influences of these factors on herbicide efficacy can be quantified with conducting dose-response experiments[3,7,8]. Considering these factors it is possible to provide information about the reduction rate of herbicide dose in a given field situation.

Since weed control is important in maize production, an integrated weed management strategy should be developed in Turkey. With this aim, critical period for weed control was determined as the first step in previous studies conducted in 2001 and 2002. Results of these studies suggested that the weed control should be carried out between 3- and 7-10- leaf stages of maize in order to provide an acceptable grain yield[9]. The objective of the present experiments was to develop a weed control strategy with minimum herbicide input during critical period.

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MATERIALS AND METHODS

Dose-response experiments: Dose-response experiments were conducted in 2001 to determine the effective minimum rates of two common maize herbicides nicosulfuron and 2.4-D-amine. *Amaranthus retroflexus* L. *Portulaca oleracea* L., *Chenopodium album* L. and *Xanthium strumarium* L. were used in the studies as model weed species, which are the most common broad leaved-weeds of maize fields in the region.

Weeds were collected from maize fields at cotyledon stage and transferred to pots containing a mixture of soil-sand-turf (1/1/1 ratios) two times with one-week interval in order to obtain plants in two different growth stages at application date. Weeds were then treated with different rate series of each herbicide at 2-4 and 5-8 leaf stages. Untreated weeds from each growth stage were used for the comparison. Herbicides were applied through portable plot spray equipment (Solo), with TeeJet nozzle under 2.5 bar pressure with a water volume of 300 l ha^{-1}. Nicosulfuron was applied as formulated herbicide (Sanson ™ 40 g a.i. / l) in 8 rates (5, 10, 15, 20, 25, 30, 40 and 50 g a.i ha^{-1}). 2.4-D-amine was applied as formulated herbicide (Di Amin™ 500 g a.i/l) in 9 rates (50, 100, 200, 300 , 400, 500, 600, 800 and 1000 g a.i ha^{-1}).

To asses the efficacies of different herbicide rates, as well as to describe dose-response relationships, weeds were harvested from pots 2 weeks after treatments. After determining fresh biomass per plant, dose-response curves were fitted to data and ED_{90} values were determined for each weed growth stage by the following non-linear equation[10] via Sigma Plot package:

$$Y=100/[1+9\ (x/ED_{90})^{b}] \qquad (1)$$

In this Eq. 1 Y denotes the response of weeds against rate x; ED_{90} denotes the herbicide rate providing 90% biomass reduction and b denotes slope of the dose-response curve.

Field experiments: In order to evaluate the field performance of the reduced herbicide rates determined via dose-response experiments, three experiments were carried out in 2002 and 2003 on sandy loam soil at the research station of Agricultural Faculty of Adnan Menderes University, Turkey. The experimental design was the Randomized Complete Blocks with four replications for each treatment. Each plot was 21 m^{-2} in size (4 maize rows X 10 m length).

Experiment in 2002: A standard grown variety of maize (Cv. pioneer) was planted on 29th April, 2002. Common cultural practices were applied during whole growing season except for the weed control. Main weed species on experimental plots were *A. retroflexus* and *C. album*. Based on the results of pot experiments nicosulfuron and 2.4-D-amine were applied at about 30 and 40% reduced rates, respectively (nicosulfuron: 35 g a.i ha^{-1} and 2.4-D-amine: 600 g a.i. ha^{-1}). Recommended rates of both herbicides (Nicosulfuron: 50 g a.i ha^{-1} and 2.4-D-amine: 1000 g a.i. ha^{-1}) were also applied for the efficacy comparison. Since the results from pot experiments suggested that both herbicides have complementary effects in terms of broad-spectrum weed control, a mixture of herbicides in reduced rates was also included in the experiment. A weedy plot was left on each block as control treatment. Plots were treated at 3-4-leaf stages of maize (starting times of critical period), when weeds were at 0-4-leaf stages. Corresponding weed ground cover at the application date was about 25%. Herbicide treatments were done as described for pot experiments.

Experiments in 2003: Since the low rate mixture of both herbicides (36 g a.i ha^{-1} nicosulfuron+ 600 g a.i ha^{-1} 2.4-D-amine as formulated herbicides) provided acceptable weed control efficacy in the previous field experiment, it was aimed to evaluate the performance of this mixture under practical conditions in two field experiments in 2003. The first experiment was conducted in main crop maize, which was sown on 2nd May, 2003 (Cv. Terebia) and the second experiment was conducted in second crop maize sown on 30th June, 2003 after wheat harvest (Cv. Dekalp 585). In both experiments, plots were naturally infested with *A. retroflexus*, *P. oleracea* and *X. strumarium*. In addition to these broad-leaved weed species, *Cyperus rotundus* L. was also observed homogenously on all experimental plots.

Low rate herbicide mixture was applied alone, in mixture with ammonium-sulphate additive (at 1% v/v) or in combination with hand hoeing (two weeks after treatment). For the comparison of weed control efficacy, a mixture of both herbicides in recommended rates was also included in the experiment. Whole season weedy, whole season weed free and during critical period weed free plots (achieved by hand hoeing) were included in experiments for yield comparison.

All weed control treatments were applied at 3-5 leaf stages of maize. During the treatments weeds were in 0- 6 leaf stages and average weed ground cover on the plots were about 35 and 20% in the experiments conducted in main and second crop maize, respectively.

Evaluation of field experiments: In all field experiments efficacies of herbicide treatments were visually evaluated 2 weeks after treatments (data not shown). At 10 leaf stage of maize (the end of critical period) weeds were harvested from 4 sites (each in 0.25 m^{-2} areas) of each plot to determine the weed biomass m^{-2}. Plots were harvested by hand at the end of 2003 growing season and grain yield was determined for each plot. Experimental data was subjected to analysis of variance and means were compared by Duncan test by using SPSS 10.0 package.

RESULTS

Dose-response experiments: There were differences among herbicide sensitivities of weed species. Both weeds, for which dose-response curves coud be determined, were more sensitive to herbicides at their early growth stages. From the ED_{90} values it can be seen 29 and 40% reduced rates of herbicides could be applied in the case of early growth stages of sensitive weeds (Table 1).

In the case of nicosulfuron a dose-response relationship could be described only for *A. retroflexus*, because other weeds could not be controlled satisfactorily with below labeled rates. *P. oleracea* was controlled only with the recommended rate of nicosulfuron, whereas an acceptable control of *X. strumarium* and *C. album* could not be achieved even with the recommended rate. In the case of 2.4-D amine, a dose-response relationship was determined only for *X. strumarium*, whereas the efficacy of this herbicide on other weed species was not acceptable, even at the recommended rate.

Field experiments: In the experiment conducted in 2002, it was observed that all treatments significantly reduced the biomass of *A. retroflexus*, but the reduction by nicosulfuron treatment was significantly higher than by 2.4-D-amine treatment. The efficacies of reduced rates of both herbicides were comparable with the efficacies of their recommended rates. Although none of the herbicides alone controlled *C. album* satisfactorily, the low rate herbicide mixture controlled this weed effectively, causing a biomass reduction by 95% (Table 2).

Also in the experiments conducted in 2003, biomass of all weed species was significantly reduced by all treatments (Table 3 and 4). *A. retroflexus* and *X. strumarium* were controlled by all herbicide treatments adequately (over 90% weight reduction) in both experiments. The efficacies of treatments on *P. oleracea* were variable depending on the experiment. In the first experiment, none of the treatments provided acceptable control of *P. oleracea* (over 90%). The highest efficacy on this weed was obtained with low rate mixture treatment with ammonium-sulfate addition (about 80% biomass reduction), which was significantly higher from the efficacy of low rate mixture without ammonium-sulfate

Table 1: Parameter for dose-response relationships between nicosulfuron and *A. retroflexus* and between 2,4-D amine and at different growth stages

	Amaranthus retroflexus L.		*Xanthium strumarium* L.	
	Nicosulfuron		2,4-D-amine	
Parameter	2-4 leaf	5-8 leaf	2-4 leaf	5-8 leaf
ED_{90} (g a.i ha^{-1})	32.4±3.8	45.6±7.3	350.0±53.0	580.00±112
b	1.7±0.2	2.8±0.6	3.5±0.6	2.61±0.65
Relative rate reduction (%)	29	-	40	-

± Standard errors of estimated parameters

Table 2: Efficacies of different nicosulfuron and 2.4-D-amine rates on *A. retroflexus* and *C. album* under field conditions in 2002

	Weed biomass (g/plant)			
Treatments	*A. retroflexus*	Reduc-tion (%)	*C. album*	Reduc-tion (%)
Untreated	7.6±1.9d	(0)	5.6±1.3bc	(0)
Nicosulfuron 35 g a.i ha^{-1}	0.5±0.2a	(94)	8.3±1.9d	(0)
Nicosulfuron 50 g a.i ha^{-1}	0.1±0.2a	(98)	5.8±0.6bc	(0)
2.4-D-amine 600 g a.i ha^{-1}	2.4±0.6c	(69)	4.1±0.9b	(27)
2.4-D-amine 1000 g a.i ha^{-1}	2.0±0.4bc	(74)	3.4±0.3b	(39)
Low rate mixture*	0.3±0.2a	(96)	0.2±0.2a	(95)*

Nicosulfuron 35 g a.i. ha^{-1} + 2.4-D-amine 600 g a.i. ha^{-1}; ± Standard errors of means; Means with different letters are significant at 0.05

(about 50% biomass reduction). In the second experiment, all treatments gave over 90% effects on *P. oleracea*. However recommended rate mixture treatment reduced the biomass of *P. oleracea* (by 99%) significantly higher than low rate mixture treatments (by 90%). An acceptable control of *C. rotundus* could not be achieved in both experiments, but the efficacy of treatments on this weed was higher in the second experiment than in the first. In both experiments efficacy of low rate mixture on *C. rotundus* was increased generally by AS addition to spray solution.

As far as the effect of treatments on total weeds is concerned, it was observed that the efficacies of treatments were higher in the second experiment than in the first experiment. Highest weed control efficacy was obtained with the AS addition to low rate mixture in the first and with recommended rate mixture in the second experiment, which can be attributed to the higher efficacy of treatments on *P. oleracea* and *C. rotundus*.

Yield values showed that leaving weeds on plots whole season resulted in about 65% lower yield in the main crop maize and 49% in the second crop maize, as compared with whole season weed free plots. All treatments provided significantly higher yield (2-3 fold higher yield) than the control treatment left weedy whole season (Table 5). The low rate herbicide mixture provided similar grain yield as with the whole season weed free conditions showing that recommended rate mixture and/or additional hand hoeing was not necessarry to obtain maximum yield.

Table 3: Biomass of weed species as affected by different treatments in the experiment conducted in main crop maize in 2003

Treatments	Fresh biomass ($g\ m^{-2}$)				
	A. retroflexus	*X. strumarium*	*P. oleracea*	*C. rotundus*	Total
Untreated	249±77.0b	685±149.0b	613±204.0c	239±31.2c	1786±291.0c
Low rate mixture	14±2.4a	25±3.6a	294±24.4b	223±5.2bc	555±25.2b
	(94)	(96)	(52)	(7)	(65)
Low rate mixture + AS	22±2.0a	20±6.8a	120±22.4a	180±6.6a	342±27.1a
	(91)	(97)	(80)	(25)	(81)
Recommended rate mixture	11±3.8a	15±5.4a	178±35.0ab	200±15.0ab	403±48.0ab
	(96)	(98)	(71)	(16)	(77)

± Standard error of means, Means with different letter are significant at 0.05; Values in parentheses are % biomass reduction in relation to untreated plots

Table 4: Biomass of weed species as affected by different treatments in the experiment conducted in second crop maize in 2003

Treatments	Fresh biomass ($g\ m^{-2}$)				
	A. retroflexus	*X. strumarium*	*P. oleracea*	*C. rotundus*	Total
Untreated	548±290.0b	99.0±58.0b	1061.0±197.0c	345.0±136.0b	2069.0±371.0b
Low rate mixture	1.5±0.7a	0.3±0.3a	106.0±49.0b	173.0±41.0a	283.0±76.0a
	(100)	(100)	(90)	(50)	(86)
Low rate mixture + AS	3.4±1.6a	0.1±0.1a	109.0±36.0b	129.0±24.0a	251.0±30.0a
	(99)	(100)	(90)	(62)	(88)
Recommended rate mixture	5.0±2.8a	1.0± 0.5a	10.0±2.8a	144.0±41.0a	162±40.0a
	(99)	(100)	(100)	(58)	(92)

± Standard error of means, Means with different letter are significant at 0.05; Values in parentheses are % biomass reduction in relation to untreated plots

Table 5: Influences of different weed control treatments on maize grain yield in main and second crop maize in 2003

Treatments	Yield (ton/ha)	
	Main crop maize	Second crop maize
Low rate mixture	8.54±0.51a	6.19±0.40a
Low rate mixture + hand hoeing*	8.90±0.63a	6.21±0.40a
Low rate mixture + AS	10.46±0.62a	6.29±0.47a
Recommended rate mixture	9.57±0.78a	6.23±0.44a
Hand hoeing during critical period	9.49±0.59a	6.13±0.40a
Weed free (whole season)	10.06±0.27a	6.06±0.57a
Weedy (whole season)	3.57±0.82b	3.11±0.66b

* Applied two weeks after treatments, ± Standard error of means, Means with different letter are significant at 0.05

DISCUSSION

Results from the present studies showed that a weed control strategy with reduced herbicide rates can be realized by considering the sensitivities of different common weed species of a particular field, as also stated by Mekki and Leroux[11], as well as by Kudsk and Streibig[3]. In the cases, when very sensitive weed species dominate on the field, such as *A. retroflexus* against nicosulfuron or *X. strumarium* against 2.4-D-amine, weed control can be achieved by the reduced rates of these herbicides, which serves to save the costs and reduce the possible risks of chemical weed control. However, dose-response experiments, as well as the field experiment from 2002 showed that none of these herbicides would provide acceptable broad-spectrum weed control under practical growing conditions, because at least two or more weed species occur as dominating weed flora on most of the growing areas in the region. Therefore, it is important to use herbicide mixtures to achive broad-spectrum weed control. Use of low rate herbicide mixtures to extend the weed control spectrum is an important issue in integrated weed management strategies[12]. This statement was also confirmed with the results of this study, so that the reduced rate herbicide mixture provided in most instances broad-spectrum weed control, which was not achieved by either herbicides applied alone. The ammonium-sulphate (AS) addition to low rate herbicide mixture increased the efficacy, especially on the less sensitive species, such as *P. oleracea* and *C. rotundus*, consequently on total weeds. The increased efficacy of nicosulfuron on these weed species was also demonstrated in previous studies conducted under field conditions and under controlled conditions[13,14].

Results of this study confirmed also the critical period finding obtained from previous studies, so that a weed control duration between 3-4 and 7-10-leaf stages of maize provided acceptable grain yield. This weed free period could be achieved by all weed control treatments investigated in field experiments in 2003. However, the low rate herbicide mixture treatment supplemented with ammonium-sulfate additive can be considered as the most promising method to achieve an economical feasible weed control with least side effects.

Nicosulfuron is widely used for the control of weeds in maize in Turkey, but its efficacy is limited with grass weeds and a few broad-leaved weeds. In order to achieve broad-spectrum weed control, especially of broad-leaved weeds, growers apply usually 2.4-D amine alone or in mixture with nicosulfuron. Although this mixture is effective in controlling weeds, 2.4-D cause important damages to the broad-leaved crops grown on the fields around (especially on cotton) and sulfonylurea herbicides (nicosulfuron) increase the costs of weed control. Therefore, it is important to develop an herbicide rate reduction strategy in maize to reduce the costs and risks of chemical weed control in Turkey.

Results of these studies suggest that the herbicide use in maize production can be reduced within the frame of integrated weed management strategy by considering the critical periods for weed control and by determining the appropriate herbicide rate or rate mixtures via dose-response experiments that provide acceptable weed control under any field situation.

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REFERENCES

1. Hurle, K., 1996. Weed Management impact on the abiotic environment in particular on water and air quality. In: Proc. 2nd Intl. Weed Control Cong. Cophenhagen, Denmark, pp: 1153-1158.
2. Rubin, B., 1996. Herbicide-resistant weeds-the inevitable phenomenon: Mechanisms, distribution and significance. J. Plant Dis. Protect., Sp. Issue XV: 17-32.
3. Kudsk, P. and J.C. Streibig, 2003. Herbicides-a-two-edged sword. Weed Res., 43: 90-102.
4. Knezevic, S.Z., S.P. Evans, E.E. Blankenship, R.C. Van Acker and J.L. Lindquist, 2002. Critical period for weed control: The concept and data analysis. Weed Sci., 50: 773-786.
5. Berzsenyi, Z., P. Bonis, T. Arendas and D.Q. Lap, 1995. Investigations about the effects of some factors influencing efficacy of post mergence weed control in maize (*Zea mays* L.). In: Proc. 9th EWRS (European Weed Research Society) Symp., Budapest, pp: 257-264.
6. Del Pino, A. and G. Covarelli, 1999. Critical period of weed competition in maize. In: Proc. 11th EWRS (European Weed Research Society) Symp., Basel, Switzerland, pp: 68.
7. Kudsk, P., 1989. Experiences with reduced doses in Denmark and the development of the concept of factor-adjusted doses. In: Proc. Brighton Crop Protection Conf. Weeds, pp: 545-554.
8. Christensen, S. and J.E. Olesen, 1995. Adaptive weed control in an integrated wheat management system for winter wheat. In: Proc. 9th EWRS (European Weed Research Society) Symp., Budapest, pp: 663-669.
9. Doğan, M.N., A. Ünay. Ö. Boz and F. Albay, 2004. Determination of optimum weed control timing in maize (*Zea mays* L.). Turkish J. Agric. For., 28: 349-354.
10. Hanson, D. and J. Ascard, 2002. Influence of developmental stage and time of assessment on hot water weed control. Weed Res., 42: 307-316.
11. Mekki, M. and G.D. Leroux, 1994. Activity of nicosulfuron, rimsulfuron and their mixture on field corn (*Zea mays*), Soybean (*Glycine max*) and seven weed species. Weed Sci., 8: 436-440.
12. Terry, P.J., 1996. The use of herbicides in the agriculture of developing countries. In: Proc. 2nd Intl. Weed Control Cong. Copenhagen, pp: 601-609.
13. Doğan, M.N. and Ö. Boz, 2002. Einfluss von Ammonium-Sulfat auf die Wirksamkeit von Maisherbiziden unter Feldbedingungen in der Türkei. Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz, Sonderheft XVIII, 885-892 (in German with English abstract).
14. Doğan, M.N., 2004. Ein Beitrag zur Verbesserung herbizider Wirkung durch Ammonium-Sulfat als Zusatzstoff. 7. Türk-Alman Tarımsal Araştırma Sonuçları Simpozyumu. 24-30 Mart 2003, Ankara, Cuvillier Verlag-Göttingen, pp: 121-126.