Comparing the Efficacy of Amicarbazone, a Triazolinone, with Sulfonylureas for Weed Control in Maize (*Zea mays*)

E. Zand[1 *], M. Ali Baghestani[1], S. Soufizadeh[2], A. Eskandari[3], R. Deihimfard[3], R. Pourazar[4], F. Ghezeli[5], P. Sabeti[6], H.Esfandiari[7], A. Mousavinik[8], F. Etemadi[2]

[1] Department of Weed Research, Plant Protection Research Institute, P.O. Box 19395-1454, Tehran, Iran, [2] Department of Agronomy, Faculty of Agriculture, Tarbiat Modares University, P.O. Box 14115- 336, Tehran, Iran, [3] Department of Agronomy, Faculty of Agricultre,Ferdowsi University of Mashhad, Mashhad, Iran, [4] Khuzestan Agricultural and Natural Resources Research Center, Ahvaz, Iran, [5] Fars Agricultural and Natural Resources Research Center, Shiraz, Iran, [6] Kermanshah Agricultural and Natural Resources Research Center, Kermanshah, Iran, [7] Esfehan Agricultural and Natural Resources Research Center, Esfehan Iran, [8]Department of Agronomy, Agricultural and Natural Resources Campus, University of Tehran, Karaj, Iran.

(Received 30 May 2007; returned 14 October 2007; accepted 28 January 2008)

ABSTRACT

Six field experiments were conducted in 2006 in Iran to investigate the efficacy of different herbicide options for weed control in maize. Treatments consisted of entire weed-infested control, pre-and post-emergence applications of amicarbazone at 350, 525, and 700 g ai ha^{-1}, post-emergence applications of nicosulfuron at 60 g ai ha^{-1}, foramsulfuron at 450 g ai ha^{-1}, rimsulfuron at 10, 11.25, and 12.5 g ai ha^{-1} plus non-ionic surfactant at 0.2% (v/v), nicosulfuron plus rimsulfuron at 26.25, 30 and 33.75 g ai ha^{-1} plus non-ionic surfactant at 0.5% (v/v), 2,4-D plus MCPA at 1080 g ai ha^{-1}, pre-plant applications of atrazine plus alachlor at 800+ 2400 g ai ha^{-1}, respectively, and EPTC at 4920 g ai ha^{-1}. Post-emergence herbicides were applied at three-to-six leaf stage of maize. The results indicated

Correspondence to: Eskandar Zand, E-mail: eszand@yahoo.com

that nicosulfuron, and rimsulfuron at the two highest doses were the most efficient herbicides for weed control. Foramsulfuron and EPTC also acted well in this respect. Application of these herbicides also led to high grain yield of maize. Amicarbazone when applied as pre- and post-emergence did not show a consistent response at different locations.

Key words: Agrochemicals; broadleaved weed; dual- purpose herbicide; grass weed.

چکیده

به منظور بررسی کارایی علف‌کش های جدید در کنترل علف‌های هرز مزارع ذرت، شش آزمایش در سال 1385 در مناطق مختلف کشور به اجرا در آمد. تیمارها عبارت بودند از: شاهد با علف‌هرز، کاربرد پیش و پس رویشی آمیکاربازون در غلظت‌های 350، 525 و 700 گرم ماده موثر در هکتار، کاربرد پس رویشی علف‌کش های نیکوسولفورون در غلظت 60 گرم ماده موثر در هکتار، فورام سولفورون در غلظت 450 گرم ماده موثر در هکتار، ریم سولفورون در غلظت‌های 10، 11/25 و 12/5 گرم ماده موثر در هکتار + مویان غیر یونی با غلظت 0/2%، نیکوسولفورون + ریم سولفورون در غلظت های 26/25، 30 و 33/75 گرم ماده موثر در هکتار + مویان غیر یونی با غلظت 0/5%، تو-فور-دی + ام سی پی ای در غلظت 1080 گرم ماده موثر در هکتار، کاربرد پیش کاشت آترازین + آلاکلر با غلظت 800 + 2400 گرم ماده موثره در هکتار و ای پی تی سی در غلظت 4920 گرم ماده موثر در هکتار. علف کش های پس رویشی در مرحله سه تا شش برگی ذرت مورد استفاده قرار گرفتند. نتایج نشان دادند که علف‌کش های نیکوسولفورون و نیز ریم سولفورون در غلظت‌های 11/25 و 12/5 گرم ماده موثر در هکتار بیشترین کارایی را در کنترل علف‌های هرز دارا بودند. علف‌کش های فورام سولفورون و ای پی تی سی نیز از کارایی مناسبی برخوردار بودند. همچنین، کاربرد این علف‌کش ها منجر به عملکرد بالا در ذرت گردید. علف‌کش آمیکاربازون در هر دو زمان کاربرد و در تمامی مناطق از کارایی رضایت بخش برخوردار نبود.

کلمات کلیدی: ترکیبات شیمیایی کشاورزی، علف‌هرز پهن‌برگ، علف‌هرز باریک‌برگ، علف‌کش دو منظوره.

INTRODUCTION

Herbicides consist nearly half the agrochemicals currently applied in cropping systems in Iran. Therefore, reducing herbicides in crop production programs is an important challenge to be addressed. A solution to this concern is to use an integrated weed management (IWM) system. Rotational application of herbicides, introduction of low-dose herbicides, and application of weed killers with less environmental risk are among the important components of IWM in mitigating the negative environmental impacts of current high-input agriculture.

Amicarbazone is a newly released triazolinone herbicide which is used for weed control in maize. It can be applied both as pre- and post-emergence. It selectively inhibits Acetolactate Synthase (ALS) and some enzymes involved in photo system II of plants. This herbicide could be taken up by roots and leaves of emerging weeds and is of low hazard to the environment (USEPA, 2005). Nicosulfuron plus rimsulfuron (2:1 ratio) controls several grass and broad-leaved weeds in maize (*Zea mays* L.). Mixture of these two sulfonylureas enhances the control of several broad-leaved and grass weeds and therefore provides a broader spectrum of weed control (Tomlin, 2003; Vencill, 2002). Bruce and Kells (1997) found that smooth crabgrass (*Digitaria ischaemum* Schreb. ex Muhl.) was not controlled by nicosulfuron while Reidy and Swanton (1994) reported adequate control of this species using nicosulfuron plus rimsulfuron. These findings indicate that sulfonylureas differ greatly in their ability to control grass weeds. So, mixing them with each other may enhance the spectrum of weed control.

Rimsulfuron, nicosulfuron and foramsulfuron are among the newly registered sulfonylurea herbicides in Iran to control weeds in maize (Baghestani *et al.*, 2007). These herbicides have been reported to be very effective on grasses, broadleaved weeds and rhizomatous perennial temperate weeds (Bruce & kells, 1997; Koeppe *et al.*, 2000; Lum *et al.*, 2006). Baghestani *et al.* (2007) found that nicosulfuron at 80 g ai ha^{-1} could control some broadleaved and grass weeds in maize. These researchers also reported weak control of johnsongrass (*Sorghum halepense* (L.) Pers.), yellow nutsedge (*Cyperus esculentus* L.), large crabgrass (*Digitaria sanguinalis* (L.) Scop.) and redroot pigweed (*Amaranthus retroflexus* L.) by applying this herbicide. Sikkema *et al.* (2007) found that post-emergence application of foramsulfuron can be used for wirestem muhly (*Muhlenbergia frondosa*) control in maize.

The objective of the present study was to determine the efficiency of weed control in maize with different newly released sulfonylurea herbicides compared to some current ones.

MATERIALS AND METHODS

A set of experiments was conducted at Research Fields of Plant Protection Research Institute at six locations in Iran during 2006 growing season. For climate variability, sites with different climatic conditions were selected. Soil texture and planting date of maize at each location are presented in Table 1. All experiments were established in a randomized complete block design with four replications. Maize cultivar SC 704 was planted at all locations. Plots consisted of four 10-m rows, with rows spaced 0.75m apart. Seedbed was prepared and fertilized following standard agricultural practices. Naturally occurring weed populations were used in the experiments. Weed composition at each location is presented in Table 2.

Herbicide treatments consisted of an entire weed-infested control, pre- and post-emergence applications of amicarbazone WG 70% at 350, 525, and 700 g ai ha^{-1}, post-emergence applications of nicosulfuron SC 4% at 60 g ai ha^{-1}, foramsulfuron OD 22.5% at 450 g ai ha^{-1}, rimsulfuron DF 25% at 10, 11.25, and 12.5 g ai ha^{-1} plus non-ionic surfactant (Citogate) at 0.2% (v/v), nicosulfuron plus rimsulfuron WG 75% at 26.25, 30 and 33.75 g ai ha^{-1} plus non- ionic surfactant (Citogate) at 0.5% (v/v), 2,4-D plus MCPA SL 72% at 1080 g ai ha^{-1}, and pre-plant applications of atrazine WP 80% plus alachlor EC 48% at 800 + 2400 g ai ha^{-1}, respectively, and EPTC EC 82% at 4920 g ai ha^{-1}. Post-emergence herbicides were applied at three- to six-leaf stage of maize. All herbicides were sprayed with an Elegance 18 electric knapsack sprayer equipped with flooding nozzle and calibrated to deliver 300 L ha^{-1} of spray solution at a pressure of 2.5 bar. Herbicides were applied in one-half of each plot and

Table 1. Soil texture and maize planting dates at different locations in 2006.

Location	Soil texture	Planting date
Ahvaz	Silty clay loam	16 July 2006
Karaj	Clay loam	22 May 2006
Kermanshah	Silty clay	14 May 2006
Varamin	Sandy clay	12 May 2006
Isfehan	Clay loam	31 May 2006
Shiraz	Clay loam	8 July 2006

Table 2. Weed composition of the experimental fields at each location in 2006 (+ indicates the weed species present at each location).

Weed species	Location					
	Ahvaz	Karaj	Kermanshah	Varamin	Esfehan	Shiraz
Corchorus olitorius L.	+	-	-	-	-	-
Cleome viscosa L.	+	-	-	-	-	-
Physalis alkekengi L.	+	-	-	-	-	-
Cardaria draba (L.) Desv.	+	-	-	-	-	-
Echinochloa colonum (L.) Link	+	-	-	+	+	-
Solanum nigrum L.	-	+	-	-	-	-
Hibiscus trionum L.	-	+	-	-	-	-
Datura stramonium L.	-	+	-	-	-	-
Chenopodium album L.	-	+	-	+	-	+
Setaria viridis (L.) Beauv.	-	+	+	-	-	-
Sorghum halepense (L.) Pers.	-	-	+	+	-	+
Amaranthus retroflexus L.	-	-	+	+	+	+
Glycyrrhiza glabra L.	-	-	+	-	-	-
Cyperus esculentus L.	-	-	-	+	-	+
Amaranthus blitoides S. Wats.	-	-	-	+	-	-
Convolvulus arvensis L.	-	-	-	-	-	+
Portulaca oleracea L.	-	-	-	-	-	+

the other half was kept as its control (Zand *et al.*, 2007; Baghestani *et al.*, 2007).

Since amicarbazone, atrazine plus alachlor and EPTC were applied as pre-emergence and pre-plant, counting the number of weeds was not possible prior to herbicide applications. Percent weed population reduction was measured separately for each weed species by counting the number of weeds 30 days after treatment (DAT) within two fixed 1.5m^2 quadrates that were dropped in the treated and untreated halves of each plot. Newly emerged weeds between herbicide applications and weed counting were hand weeded. Percent weed biomass reduction was measured 30 DAT using two 0.375m^2 quadrates that were dropped in the treated and untreated halves of each plot. All weeds were cut at the ground level, separated by species and oven dried at 75ºC for 48-72h. Percent weed reduction population and biomass were calculated by subtracting weed population/biomass in the treated half from weed population/biomass in the untreated half, dividing the product by weed population/biomass in the untreated half and multiplying by 100. Weed control was considered satisfactory if population or biomass of weeds were reduced by at least 85%. At maturity, grain yield was determined.

All data were analyzed statistically using PROC GLM procedure in SAS statistical software (SAS Institute, 2000). The assumptions of variance analysis were tested by insuring that the residuals were random, homogenous, with a normal distribution about a mean of zero. If the assumptions of variance were not adequately met, percent weed biomass and population reductions were subjected to an arcsine square root transformation. Maize yield data were subjected to a log(x+1) transformation when required. The Duncan multiple range test (DMRT) set at 0.05 was used to determine the significance of the difference between treatment means. Since weather conditions, soil texture, planting dates and weed species were different at each location, therefore, data for each location were analyzed separately.

RESULTS AND DISCUSSION

Weed Control

Statistical analysis showed significant differences between treatments in case of weed population in Ahvaz (Table 3). The highest reduction in jazmin de rio (*Cleome viscosa* L.) population (88.13%) was obtained by rimsulfuron at 11.25 g ai ha^{-1}. Atrazine plus alachlor, and pre-emergence applications of amicarbazone at the two highest doses failed to control this weed. Chinese lantern plant (*Physalis alkekengi* L.) was controlled well by nicosulfuron, while the lowest effect was achieved by amicarbazone at 350 g ai ha^{-1} applied pre-emergence. None of the treatments resulted in satisfactory control of hoary cress (*Cardaria draba* (L.) Desv.) and tussa jute (*Corchorus olitorius* L.). Maximum reduction of weed population was 76.78% when treated with nicosulfuron. Jungle rice (*Echinochloa colonum* (L.) Link) population was reduced remarkably by all treatments except for pre- and post-emergence applications of amicarbazone at 350 g ai ha^{-1}.

Percent biomass weed production in Ahvaz is presented in Table 3. All treatments but 1) pre-emergence applications of amicarbazone at all doses, 2) post-emergence application of amicarbazone at the two highest doses (525 and 700 g ai ha^{-1}), and 3) foramsulfuron reduced jazmin de rio biomass more than 91%. Similar results were observed in the case of Chinese lantern plant and tussa jute. The highest reductions in hoary cress biomass, 95.03% and 94.15%, were obtained in plots treated by post-emergence application of amicarbazone at 1000 g ai ha^{-1} and 2,4-D plus MCPA, respectively. Other treatments resulted in less than 85.52% reduction in biomass. Pre- and post-emergence applications of amicarbazone did not control jungle rice satisfactorily. In general, in each location, pre-emergence application of amicarbazone did not control weeds good enough even by two-fold increase in dose.

Better control of weeds was obtained in Karaj (Table 4) compared to Ahvaz, regardless of the time of application. Weed control greatly differed according to weed species. The best control by amicarbazone was observed for jimsonweed (*Datura stramonium* L.), common lambsquarters (*Chenopodium album* L.) and green foxtail (*Setaria viridis* (L.) Beauv.). Nicosulfuron completely controlled black nightshade (*Solanum nigrum* L.), venice mallow (*Hibiscus trionum* L.) and jimsonweed, but poorly controlled green foxtail. Rimsulfuron at 11.25 and 12.5 g ai ha^{-1} did not result an acceptable control of black nightshade. Rimsulfuron at the lowest dose was also inefficient in controlling venice mallow and common lambsquarters. Mixture of nicosulfuron with rimsulfuron did not show any additional advantage over nicosulfuron. This herbicide (mixture of nicosulfuron plus rimsulfuron) at all doses failed to control black nightshade. Application of atrazine plus alachlor resulted in 93.75% reduction in weed populations at this location. Efficacy of EPTC and 2,4-D plus MCPA differed with respect to weed species.

The efficacy of herbicides in reducing weed biomass in Karaj was almost similar to the pattern observed for percent weed population reduction (Table 4). Pre- and post-emergence applications of amicarbazone to control black nightshade, venice mallow, jimsonweed, common lambsquarters and green foxtail were acceptable.

Dominant weed species in Kermanshah consisted of johnsongrass, green foxtail, redroot pigweed and licorice (*Glycyrrhiza glabra* L.) (Table 5). Herbicides efficacy were poor in this location. Nicosulfuron controlled johnsongrass satisfactorily, caused 91.25% reduction in weed population. EPTC was ranked second after this. Green foxtail population was reduced 94% and 93.66% when EPTC and nicosulfuron were applied, respectively. The highest reductions (80.60, 82.48 and 81.06%) in redroot pigweed population were achieved where EPTC, 2,4-D plus MCPA, and nicosulfuron were applied, respectively. Other treatments caused about 74.43% reduction in redroot pigweed population. Population reduction of licorice ranged between 27.92% and 85% in plots sprayed with nicosulfuron plus rimsulfuron at 33.75 g ai ha^{-1} and 2,4-D plus MCPA, respectively.

Percent of weed biomass reduction in Kermanshah were almost the same as weed population (Table 5). The biomass of johnsongrass and green foxtail were reduced beyond 83% by nicosulfuron and EPTC. Percent of reduction in redroot pigweed biomass differed from 9.7 to 82.53% (atrazine plus alachlor and 2,4-D plus MCPA, respectively).

Neither amicarbazone nor nicosulfuron plus rimsulfuron could control weeds satisfactorily. Presenting nicosulfuron and rimsulfuron as one formulation resulted in significant reduction in the efficacy of nicosulfuron to control weeds, while nicosulfuron alone was among the best choices for weed control. EPTC also controlled weeds well and was better than triazolinone and sulfonylurea herbicides.

In Varamin, significant differences between treatments were observed (Table 6). Johnsongrass was completely controlled by rimsulfuron (11.25 g ai ha^{-1}) and EPTC. Nicosulfuron plus rimsulfuron at the lowest dose also reduced the population (91.67%). The control level of johnsongrass in Varamin was more than in Kermanshah, which reflects the effects of environmental conditions on herbicide efficacy. Percent of reduction in jungle rice population ranged between 93.65 and 100% where maize was treated with EPTC, nicosulfuron, rimsulfuron (10 g ai ha^{-1}), foramsulfuron, and nicosulfuron plus rimsulfuron (26.25 and 30 g ai ha^{-1}). Yellow nutsedge was completely controlled by pre- and post-emergence applications of amicarbazone (525 and 350 g ai ha^{-1}), nicosulfuron plus rimsulfuron (30 and 33.75 g ai ha^{-1}), atrazine plus alachlor and EPTC. Nicosulfuron and rimsulfuron at the lowest dose reduced yellow nutsedge population by 90.48% and 90.91%. Except for some minor treatments (pre- and post-emergence applications of amicarbazone at 525 and 350 g ai ha^{-1}, respectively, and rimsulfuron at the two highest doses), the rest reduced mat amaranth (*Amaranthus blitoides* S. Wats.) population by 91.59%. On the other hand, redroot pigweed was satisfactorily controlled by all herbicide treatments, therefore the percent of reduction in weed population varied between 90.64% and 100%. The results showed that herbicides tested at this location had a good potential to suppress weeds belonging to *Amaranthus* genus. In the case of common lambsquarters, pre-emergence application of amicarbazone (525 g ai ha^{-1}), nicosulfuron, rimsulfuron (11.25 g ai ha^{-1}) and 2,4- plus MCPA reduced common lambsquarters population by 100%. Amicarbazone at 350 and 525 g ai ha^{-1} applied pre- and post-emergence respectively, and rimsulfuron (12.5 g ai ha^{-1}) could also reduce common lambsquarters population between 96% and 90%.

Yellow nutsedge biomass was reduced (100%) when maize was sprayed with 1) pre-emergence application of amicarbazone at all doses, 2) post-emergence application of amicarbazone at the lowest dose, 3) nicosulfuron, 4) nicosulfuron plus rimsulfuron at 26.25 and 33.75 g ai ha^{-1}, and EPTC (Table 6). The results showed that nicosulfuron plus rimsulfuron (26.25 g ai ha^{-1}) and EPTC could be used for chemical weed control management. Generally, where broadleaved weeds are dominant, 2,4-D plus MCPA is still an efficient herbicide.

In Isfahan, none of the herbicide treatments controlled jungle rice and redroot pigweed well (Table 7). The highest and lowest population reductions of the grass weeds were obtained when amicarbazone (350 g ai ha^{-1}) and rimsulfuron (10 g ai ha^{-1}) were applied. Atrazine plus alachlor, EPTC and 2,4-D plus MCPA did not act efficiently. Redroot pigweed biomass was reduced when nicosulfuron plus rimsulfuron (26.25 g ai ha^{-1}) was applied, which did not follow the results of population reduction (Table 7). This shows that the herbicide stunted growth of weed, but not injured it completely. No measurement was made in the case of jungle rice.

Weed control was unsatisfactory in the case of all herbicide treatments in Shiraz (Table 8). Percent of population and biomass reductions of weed species never exceeded 89.98 and 66.93%, respectively.

Maize Grain Yield

In Ahvaz, maize yield was highest (> 5300 kg ha^{-1}) in plots treated by rimsulfuron (12.5 g ai ha^{-1}), nicosulfuron plus rimsulfuron (33.75 g ai ha^{-1}), nicosulfuron and the full season weedy check, respectively (Table 9). These results, however, did not exactly correspond with those of percent of weed population reduction. Reduction in weed biomass could be attributed to stunting growth of weeds by herbicides, although this did not lead to complete death. Nonetheless, it considerably reduced the competitive ability of weeds with maize.

In Karaj, highest grain yield was produced in plots treated with foramsulfuron; i.e. 16643 kg ha^{-1} (Table 9). Rimsulfuron (11.25 g ai ha^{-1}) was ranked second in this respect. The lowest yielding plot belonged to EPTC. Higher grain yield obtained at this location compared with Ahvaz which could be attributed to much better control of weeds in this location. In fact, the lowest yielding plot in Karaj still produced 920 kg ha^{-1} more of that in Ahvaz. This indicates again the importance of environmental effects on the efficacy of herbicides.

In Kermanshah, the results of grain yield completely agreed with those expected from weed control levels (Table 9). In other words, nicosulfuron and EPTC which caused maximum reduction in weed populations and biomass, also produced the highest grain yield (9300 and 9177.8 kg ha^{-1}, respectively) and caused significant differences with other treatments except for foramsulfuron. The full season weedy check was ranked among the lowest yielding plots. These results showed that rotational applications of nicosulfuron, foramsulfuron, and EPTC could be considered as good options for weed control in this location.

Grain yield ranged between 6300 and 14325 kg ha^{-1} in Varamin (Table 9). Foramsulfuron, and nicosulfuron plus rimsulfuron at the lowest dose, nicosulfuron and EPTC led to highest grain yield compared with other treatments (14325, 14133, 14013 and 13917 kg ha^{-1}, respectively,) while the lowest grain yield was achieved where maize was sprayed with amicarbazone (350 g ai ha^{-1}) applied post-emergence. Applications of atrazine plus alachlor and 2,4-D plus MCPA caused yield loss. This might be attributed to their lower efficacy in reducing weed biomass.

In Isfahan, grain yield of plots treated by amicarbazone (350 g ai ha^{-1}) applied pre-emergence ranked first among treatments (Table 9). 2,4-D plus MCPA and the full season weedy check had the lowest grain yields, respectively. None of the herbicide treatments in this location controlled weeds satisfactorily. So, we suggest the low yield in this location might be addressed to possible damage of herbicide treatments (except for pre-emergence application of amicarbazone at 350 g ai ha^{-1}) on maize.

Neither weed population nor weed biomass were reduced by herbicide treatments in Shiraz. The highest yield at this location was achieved in plots treated by foramsulfuron followed by rimsulfuron at the highest dose, which were significantly different from other treatments (Table 9).

In conclusion, the results obtained in this study differed according to the location of the experiments. Taking all aspects into consideration, nicosulfuron and rimsulfuron at 11.25 and 12.5 g ai ha^{-1}, respectively, could be regarded as better options for weed control in maize. Amicarbazone (applied as pre- or post-emergence) could also be supposed as a herbicide option which could be used rotationally with above mentioned herbicides. Further investigations are necessary to completely prove the efficacy of amicarbazone. Among traditionally applied herbicides, EPTC is still a reliable option for weed control in maize.

Table 3. Effect of different herbicide treatments on percent weed populations and biomass reductions 30 days after treatment (DAT) in Ahvaz in 2006.

Treatments	Dose ($g\ ai\ ha^{-1}$)	Weed species					
		Jazmin de rio		Chinese lantern plant		Hoary cress	
		Weed population reduction (%)	Weed biomass reduction (%)	Weed population reduction (%)	Weed Biomass reduction (%)	Weed population reduction (%)	Weed biomass reduction (%)
Amicarbazone (Pre-emergence)	350	18.75d*	1.01g	9.09f	12.36g	20.48gef	20.82h
Amicarbazone (Pre-emergence)	525	0.00e	2.63gf	11.82ef	6.71h	34.02de	17.39hi
Amicarbazone (Pre-emergence)	700	0.00e	8.74e	13.54ef	11.38g	54.99bc	20.00h
Amicarbazone (Post-emergence)	350	3.13de	4.62f	14.86ef	3.12i	12.50gf	12.95i
Amicarbazone (Post-emergence)	525	36.53c	84.33c	35.03de	85.24d	37.61cde	70.55d
Amicarbazone (Post-emergence)	700	76.39ab	93.53b	68.06abc	92.70b	69.41ab	95.03a
Nicosulfuron	60	76.88ab	98.45a	91.25a	97.14a	76.78a	81.35bc
Foramsulfuron	450	36.22c	71.86d	33.27def	80.79e	42.36cd	43.75f
Rimsulfuron	10	80.59ab	98.47a	84.21ab	98.14a	37.27cde	29.23g
Rimsulfuron	11.25	88.13a	98.83a	84.92ab	98.45a	43.64cd	59.80e
Rimsulfuron	12.5	75.84ab	99.24a	88.79ab	98.19a	65.12ab	85.03b
Nicosulfuron plus rimsulfuron	26.5	44.29c	91.32b	47.77cd	77.03f	30.07def	71.38d
Nicosulfuron plus rimsulfuron	30	57.75bc	92.77b	72.79abc	95.44ab	32.76de	75.74cd
Nicosulfuron plus rimsulfuron	33.75	40.63c	99.24a	89.86a	98.43a	74.85a	85.52b
Atrazine plus allachlor	1080	0.00e	93.08b	49.25cd	93.33b	9.96g	1.34j
EPTC	800+ 2400	42.98c	91.52b	63.56bc	88.63c	3.33g	16.89hi
2,4-D plus MCPA	4920	71.39ab	98.73a	52.78cd	97.49a	76.22a	94.15a

* Means within each column followed by same letter are not significantly different (Duncan 5%).

Table 3. Continued.

Treatments	Dose ($g\ ai\ ha^{-1}$)	Weed species			
		Tussa jute		Jungle rice	
		Weed population reduction (%)	Weed biomass reduction (%)	Weed population reduction (%)	Weed biomass reduction (%)
Amicarbazone (Pre-emergence)	350	20.48ef*	12.68f	57.02d	14.79g
Amicarbazone (Pre-emergence)	525	34.02de	15.10f	90.85bc	60.97e
Amicarbazone (Pre-emergence)	700	54.99bc	19.93e	95.01abc	77.83d
Amicarbazone (Post-emergence)	350	12.50gf	7.85g	54.07d	16.60f
Amicarbazone (Post-emergence)	525	37.61cde	81.70d	90.26bc	82.23c
Amicarbazone (Post-emergence)	700	69.41ab	92.94bc	93.82abc	97.70b
Nicosulfuron	60	76.78a	96.33abc	94.20abc	98.71ab
Foramsulfuron	450	42.36cd	95.32abc	98.33a	98.34ab
Rimsulfuron	10	37.27cde	98.04ab	97.21a	98.67ab
Rimsulfuron	11.25	43.64cd	98.51a	95.77ab	99.20ab
Rimsulfuron	12.5	65.12ab	97.95ab	97.39a	98.90ab
Nicosulfuron plus rimsulfuron	26.5	30.07def	80.67d	90.98bc	99.22ab
Nicosulfuron plus rimsulfuron	30	32.76de	92.71bc	97.43a	98.91ab
Nicosulfuron plus rimsulfuron	33.75	74.85a	98.43a	98.81a	99.52a
Atrazine plus alachlor	1080	9.96g	91.95c	88.92c	98.66ab
EPTC	800+ 2400	3.33g	83.46d	94.13abc	98.43ab
2,4-D plus MCPA	4920	76.22a	97.99ab	-	-

* Means within each column followed by same letter are not significantly different (Duncan 5%).

Table 4. Effect of different herbicide treatments on percent weed populations and biomass reductions 30 days after treatment DAT in Karaj in 2006.

Treatments	Dose (g ai ha^{-1})	Weed species					
		Black nightshade		Venice mallow		Jimsonweed	
		Weed population reduction (%)	Weed biomass reduction (%)	Weed population reduction (%)	Weed biomass reduction (%)	Weed population reduction (%)	Weed biomass reduction (%)
Amicarbazone (Pre-emergence)	350	69.44ab*	59.37abc	96.88a	93.03a	100a	100a
Amicarbazone (Pre-emergence)	525	92.59a	98.55a	66.67a	72.16a	90.00a	85.09a
Amicarbazone (Pre-emergence)	700	75.00ab	50.00abc	100a	100a	75.00a	92.16a
Amicarbazone (Post-emergence)	350	93.33a	94.97ab	-	95.54a	83.33a	87.73a
Amicarbazone (Post-emergence)	525	83.33ab	95.45ab	83.33a	98.18a	100a	100a
Amicarbazone (Post-emergence)	700	100a	100a	85.12a	72.19a	100a	100a
Nicosulfuron	60	100a	100a	100a	100a	100a	100a
Foramsulfuron	450	82.50ab	97.89a	100a	100a	100a	100a
Rimsulfuron	10	100a	100a	56.43a	75.00a	87.50a	75.00a
Rimsulfuron	11.25	7.14d	75.54abc	100a	100a	100a	100a
Rimsulfuron	12.5	79.17ab	98.03a	87.46a	89.16a	87.50a	97.55a
Nicosulfuron plus rimsulfuron	26.5	0.00d	44.68bc	100a	100a	75.00a	84.46a
Nicosulfuron plus rimsulfuron	30	0.00d	85.46a	100a	100a	87.57a	78.96a
Nicosulfuron plus rimsulfuron	33.75	50.00bc	33.23c	100a	100a	0.00a	66.50a
Atrazine plus alachlor	1080	100a	100a	100a	100a	96.67a	97.94a
EPTC	800+2400	100a	100a	84.09a	66.67a	61.11a	75.00a
2,4-D plus MCPA	4920	16.67cd	30.70c	80.00a	51.44a	55.00a	83.60a

*Means within each column followed by same letter are not significantly different (Duncan 5%).

Table 4. Continued.

Treatments	Dose ($g\ ai\ ha^{-1}$)	Weed species			
		Common lambsquarters		Green bristlegrass	
		Weed population reduction (%)	Weed biomass reduction (%)	Weed population reduction (%)	Weed biomass reduction (%)
Amicarbazone (Pre-emergence)	350	100a*	100a	100a	100a
Amicarbazone (Pre-emergence)	525	100a	100a	100a	100a
Amicarbazone (Pre-emergence)	700	100a	100a	100a	100a
Amicarbazone (Post-emergence)	350	75.00ab	4.00c	100a	100a
Amicarbazone (Post-emergence)	525	100a	100a	72.50ab	84.35a
Amicarbazone (Post-emergence)	700	95.83ab	99.43a	100a	100a
Nicosulfuron	60	83.33ab	20.00bc	60.00b	50.00ab
Foramsulfuron	450	100a	100a	100a	100a
Rimsulfuron	10	50.00b	75.00a	100a	100a
Rimsulfuron	11.25	100a	100a	88.89a	62.50ab
Rimsulfuron	12.5	90.00ab	66.67ab	92.59a	67.89a
Nicosulfuron plus rimsulfuron	26.5	100a	100a	0.00c	-
Nicosulfuron plus rimsulfuron	30	50.00b	98.88a	100a	100a
Nicosulfuron plus rimsulfuron	33.75	83.33ab	81.52a	100a	100a
Atrazine plus alachlor	1080	100a	100a	93.75a	85.37a
EPTC	800+ 2400	100a	100a	100a	100a
2,4-D plus MCPA	4920	100a	100a	-	-

* Means within each column followed by same letter are not significantly different (Duncan 5%).

Table 5. Effect of different herbicide treatments on percent weed populations and biomass reductions 30 DAT in Kermanshah in 2006.

Treatments	Dose (g ai ha^{-1})	Weed species							
		Johnsongrass		Green bristlegrass		Redroot pigweed		Licorice	
		Weed population reduction (%)	Weed biomass reduction (%)	Weed population reduction (%)	Weed biomass reduction (%)	Weed populatio n reduction (%)	Weed biomass reduction (%)	Weed population reduction (%)	Weed biomass reduction (%)
Amicarbazone (Pre-emergence)	350	26.77ef*	25.90d	3.76f	3.16d	24.87d	20.33ef	35.00cde	18.49de
Amicarbazone (Pre-emergence)	525	15.00ef	14.56d	9.44f	7.80d	22.70d	26.72cdef	54.17bcde	48.17bcde
Amicarbazone (Pre-emergence)	700	18.91ef	24.55d	0.00f	0.30d	25.00d	47.03bcd	51.25bcde	52.13bcd
Amicarbazone (Post-emergence)	350	8.05f	7.41d	1.31f	0.80d	30.92d	28.26cdef	41.25cde	41.53de
Amicarbazone (Post-emergence)	525	8.33f	15.63d	7.31f	4.65d	30.70d	19.83ef	39.44abc	16.85e
Amicarbazone (Post-emergence)	700	15.94ef	16.39d	4.06f	3.57d	27.94d	22.91def	69.05abc	86.41a
Nicosulfuron	60	91.25a	86.77a	93.66a	86.82ab	81.06ab	74.42a	55.00bcde	51.76bcd
Foramsulfuron	450	71.53abc	72.53ab	78.20bc	77.10bc	74.43ab	74.62a	65.95abcd	49.67bcde
Rimsulfuron	10	50.44d	50.06c	61.61d	63.09c	52.50c	45.45bcd	31.67de	34.14de
Rimsulfuron	11.25	68.75bcd	67.59abc	78.08bc	66.07c	62.64bc	60.45ab	41.67cde	24.90de
Rimsulfuron	12.5	82.50ab	77.60ab	82.50b	83.95ab	73.73ab	73.04a	75.56ab	69.94abc
Nicosulfuron plus rimsulfuron	26.5	30.47e	58.87bc	68.00cd	66.61c	53.81c	44.88bcd	28.15e	34.17de
Nicosulfuron plus rimsulfuron	30	54.46cd	74.48ab	70.33cd	67.94c	53.69c	40.44bcde	30.00e	23.13de
Nicosulfuron plus rimsulfuron	33.75	71.26abc	77.75ab	78.41bc	77.56bc	53.63c	49.25bc	27.92e	34.63de
Atrazine plus alachlor	1080	19.30ef	14.24d	22.35e	10.58d	19.69d	9.70f	58.75bcde	52.04bcd
EPTC	800+ 2400	83.55ab	83.01a	94.00a	94.36a	86.60a	75.24a	40.83cde	43.57cde
2,4-D plus MCPA	4920	-	-	-	-	82.48a	82.53a	85.00a	76.09ab

* Means within each column followed by same letter are not significantly different (Duncan 5%).

Table 6. Effect of different herbicide treatments on percent weed populations and biomass reductions 30 DAT in Varamin in 2006.

Treatments	Dose (g ai ha^{-1})	Weed species					
		Johnsongrass		Jungle rice		Yellow nutsedge	
		Weed population reduction (%)	Weed biomass reduction (%)	Weed population reduction (%)	Weed biomass reduction (%)	Weed Population reduction (%)	Weed biomass reduction (%)
Amicarbazone (Pre-emergence)	350	63.14ab*	77.65a	51.19cd	81.07a	72.34a	100a
Amicarbazone (Pre-emergence)	525	78.50ab	18.72b	15.00d	79.92a	100a	100a
Amicarbazone (Pre-emergence)	700	50.00b	60.03ab	70.00abc	91.58a	85.71a	100a
Amicarbazone (Post-emergence)	350	57.78ab	66.57ab	53.79bcd	66.67a	100a	100a
Amicarbazone (Post-emergence)	525	72.62ab	76.78a	100a	100a	51.19a	54.35ab
Amicarbazone (Post-emergence)	700	50.00b	55.76ab	86.90abc	93.75a	50.00a	67.92ab
Nicosulfuron	60	87.88ab	92.97a	94.95ab	75.00a	90.48a	100a
Foramsulfuron	450	84.21ab	82.05a	100a	100a	73.33a	34.43b
Rimsulfuron	10	79.55ab	82.42a	93.94abc	75.00a	50.00a	50.00ab
Rimsulfuron	11.25	100a	100a	73.33abc	75.00a	90.91a	87.58ab
Rimsulfuron	12.5	77.78ab	52.81ab	73.33abc	69.65a	80.00a	89.54ab
Nicosulfuron plus rimsulfuron	26.5	91.67ab	91.32a	100a	100a	60.00a	100a
Nicosulfuron plus rimsulfuron	30	66.67ab	86.62a	100a	100a	100a	66.67ab
Nicosulfuron plus rimsulfuron	33.75	85.71ab	94.42a	79.63abc	75.00a	100a	100a
Atrazine plus allachlor	1080	45.24b	61.83ab	100a	100a	100a	88.94ab
EPTC	800+ 2400	100a	100a	93.65abc	87.04a	100a	100a
2,4-D plus MCPA	4920	-	-	-	-	-	-

* Means within each column followed by same letter are not significantly different (Duncan 5%).

Table 6. Continued.

Treatments	Dose ($g\ ai\ ha^{-1}$)	Weed species					
		Mat amaranth		Redroot pigweed		Common lambsquarters	
		Weed population reduction (%)	Weed biomass reduction (%)	Weed population reduction (%)	Weed biomass reduction (%)	Weed population reduction (%)	Weed biomass reduction (%)
Amicarbazone (Pre-emergence)	350	98.58a*	75.00a	96.15ab	83.33a	96.43ab	98.52ab
Amicarbazone (Pre-emergence)	525	58.36c	72.00a	97.91ab	97.20a	100a	100a
Amicarbazone (Pre-emergence)	700	97.29a	75.00a	96.74ab	83.33a	66.67ab	50.00b
Amicarbazone (Post-emergence)	350	80.00ab	96.92a	100a	100a	83.33ab	97.79ab
Amicarbazone (Post-emergence)	525	92.75a	91.77a	97.50ab	83.33a	93.33ab	95.75ab
Amicarbazone (Post-emergence)	700	100a	100a	90.64b	78.79a	83.33ab	73.35ab
Nicosulfuron	60	93.33a	95.64a	98.76ab	75.00a	100a	100a
Foramsulfuron	450	91.59a	97.81a	100a	100a	83.33ab	77.62ab
Rimsulfuron	10	93.92a	75.00a	98.75ab	75.00a	50.00ab	50.00b
Rimsulfuron	11.25	83.33a	83.33a	100a	100a	100a	100a
Rimsulfuron	12.5	69.99bc	75.00a	96.66a	66.67a	90.00ab	50.00
Nicosulfuron plus rimsulfuron	26.5	98.89a	98.53a	100a	100a	30.00b	96.51ab
Nicosulfuron plus rimsulfuron	30	100a	100a	95.00ab	83.33a	29.17b	93.08ab
Nicosulfuron plus rimsulfuron	33.75	96.74a	95.37a	98.91a	75.00a	70.45ab	64.14ab
Atrazine plus alachlor	1080	94.93a	83.38a	94.73ab	83.33a	66.67ab	66.50ab
EPTC	800+ 2400	95.55a	75.00a	100a	100a	60.00ab	89.57ab
2,4-D plus MCPA	4920	100a	100a	97.72ab	99.82a	100a	100a

* Means within each column followed by same letter are not significantly different (Duncan 5%).

Table 7. Effect of different herbicide treatments on percent weed populations and biomass reductions 30 DAT in Isfehan in 2006.

Treatments	Dose (g ai ha^{-1})	Weed species			
		Jungle rice		Redroot pigweed	
		Weed population reduction (%)	Weed biomass reduction (%)	Weed population reduction (%)	Weed biomass reduction (%)
Amicarbazone (Pre-emergence)	350	77.29abc*	-	-	-
Amicarbazone (Pre-emergence)	525	63.46abcde	-	85.83a	59.01ab
Amicarbazone (Pre-emergence)	700	67.94abcd	-	75.95abc	70.74ab
Amicarbazone (Post-emergence)	350	87.50a	-	44.75bcde	45.64abc
Amicarbazone (Post-emergence)	525	53.33cde	-	43.40bcde	59.53ab
Amicarbazone (Post-emergence)	700	47.92de	-	18.33e	76.52ab
Nicosulfuron	60	84.52a	-	65.17abcd	84.54ab
Foramsulfuron	450	70.95abcd	-	46.35abcde	38.46bc
Rimsulfuron	10	36.90e	-	81.75ab	79.69ab
Rimsulfuron	11.25	65.28abcd	-	60.26abcde	-
Rimsulfuron	12.5	50.00cde	-	67.71abc	-
Nicosulfuron plus rimsulfuron	26.5	73.51abcd	-	21.94e	87.65a
Nicosulfuron plus rimsulfuron	30	66.67abcd	-	37.92cde	85.09ab
Nicosulfuron plus rimsulfuron	33.75	63.69abcde	-	45.45abcde	13.44cd
Atrazine plus alachlor	1080	62.18abcde	-	77.78abc	63.71ab
EPTC	800+ 2400	80.95ab	-	51.73abcde	74.87ab
2,4-D plus MCPA	4920	-	-	23.88de	38.93bc

* Means within each column followed by same letter are not significantly different (Duncan 5%).

Table 8. Effect of different herbicide treatments on percent weed populations and biomass reductions 30 DAT in Shiraz in 2006.

Treatments	Dose ($g\ ai\ ha^{-1}$)	Weed species					
		Johnsongrass		Yellow nutsedge		Field bindweed	
		Weed population reduction (%)	Weed biomass reduction (%)	Weed population reduction (%)	Weed biomass reduction (%)	Weed population reduction (%)	Weed biomass reduction (%)
Amicarbazone (Pre-emergence)	350	39.06bcd*	41.85ab	44.39cd	47.91def	50.17bc	32.36bcde
Amicarbazone (Pre-emergence)	525	28.16d	30.43b	45.60cd	43.17ef	49.84bc	44.47ab
Amicarbazone (Pre-emergence)	700	34.53cd	35.34b	45.31cd	47.35def	50.19bc	47.47a
Amicarbazone (Post-emergence)	350	25.83d	30.37b	40.16d	43.01ef	49.65bc	42.47ab
Amicarbazone (Post-emergence)	525	25.30d	29.75b	40.12d	43.17ef	47.89bc	42.70ab
Amicarbazone (Post-emergence)	700	25.56d	29.88b	40.03d	42.87ef	44.23cd	40.82ac
Nicosulfuron	60	29.29d	33.02b	46.53cd	49.17def	29.00gef	36.94acd
Foramsulfuron	450	50.79ab	43.82ab	72.58a	72.56a	65.43a	45.35ab
Rimsulfuron	10	39.71bcd	41.43ab	54.74bc	53.17cdef	22.57gf	25.11de
Rimsulfuron	11.25	39.00bcd	44.75ab	53.57bcd	55.82bcde	16.75g	27.74cde
Rimsulfuron	12.5	41.35abcd	42.67ab	54.96bc	57.28bcd	58.17ab	49.07a
Nicosulfuron plus rimsulfuron	26.5	48.75abc	50.60a	64.04ab	64.94abc	32.65def	34.64abcde
Nicosulfuron plus rimsulfuron	30	47.60abc	51.17a	64.81ab	66.55ab	38.84cde	37.35abcd
Nicosulfuron plus rimsulfuron	33.75	50.87ab	52.52a	64.85ab	66.93ab	32.62def	35.67abcde
Atrazine plus alachlor	1080	31.74d	34.87b	44.41cd	47.10def	41.96cd	43.73ab
EPTC	800+ 2400	55.78a	56.70a	44.37cd	47.33def	19.51g	27.54cde
2,4-D plus MCPA	4920	-	-	-	-	18.02g	22.20e

* Means within each column followed by same letter are not significantly different (Duncan 5%).

Table 8. Continued.

Treatments	Dose (g ai ha^{-1})	Weed species					
		Common purslane		Common lambs quarters		Redroot pigweed	
		Weed population reduction (%)	Weed biomass reduction (%)	Weed population reduction (%)	Weed biomass reduction (%)	Weed population reduction (%)	Weed biomass reduction (%)
Amicarbazone (Pre-emergence)	350	51.49c*	44.16cd	48.71de	44.51d	48.65c	44.70c
Amicarbazone (Pre-emergence)	525	48.49c	44.14cd	47.33e	44.10d	50.24c	45.27c
Amicarbazone (Pre-emergence)	700	49.18c	44.34cd	51.32de	44.52d	47.96c	43.74cd
Amicarbazone (Post-emergence)	350	48.73c	42.34cde	48.76de	44.63d	49.61c	45.11c
Amicarbazone (Post-emergence)	525	47.86c	42.95cde	47.95e	44.44d	47.31cd	44.45c
Amicarbazone (Post-emergence)	700	47.93c	42.02cde	47.95e	43.48de	45.48cd	43.01cde
Nicosulfuron	60	29.99ef	38.22efg	30.90gh	35.87fg	29.75fg	36.21fg
Foramsulfuron	450	74.27a	50.08a	89.98a	61.96a	72.30a	55.14a
Rimsulfuron	10	38.70de	43.12cde	53.98cd	44.62d	41.35cde	44.19c
Rimsulfuron	11.25	33.02de	44.83bc	56.98c	48.81c	47.94c	44.56c
Rimsulfuron	12.5	62.50b	48.96ab	72.63b	57.18b	59.19b	50.72b
Nicosulfuron plus rimsulfuron	26.5	33.59de	40.50cdef	36.09fg	38.72f	33.74ef	37.99f
Nicosulfuron plus rimsulfuron	30	33.26de	41.56cde	35.64fg	39.41f	35.44ef	39.11def
Nicosulfuron plus rimsulfuron	33.75	32.29e	39.67def	34.70g	38.44f	35.08ef	38.36ef
Atrazine plus alachlor	1080	41.89cd	42.98cde	40.01f	39.91ef	39.03de	40.45cdef
EPTC	800+ 2400	19.22g	33.98g	21.64i	29.45h	19.35h	30.33h
2,4-D plus MCPA	4920	22.73fg	36.25fg	26.35hi	34.40g	24.25gh	32.74gh

* Means within each column followed by same letter are not significantly different (Duncan 5%).

Table 9. Maize grain yield achieved under different herbicide treatments in different locations in 2006.

Treatments	Dose ($g\ ai\ ha^{-1}$)	Locations					
		Ahvaz	Karaj	Kermanshah	Varamin	Esfehan	Shiraz
Amicarbazone (Pre-emergence)	350	1772.50f*	9619.00ab	6900.00gh	11800.00ab	9333.10a	8390.00f
Amicarbazone (Pre-emergence)	525	2442.50e	8603.00ab	6710.00h	12675.00ab	7518.80abcd	6965.00j
Amicarbazone (Pre-emergence)	700	2437.50e	7786.00b	7240.00fg	11200.00ab	7860.30abcd	7260.00h
Amicarbazone (Post-emergence)	350	1965.00f	11250.00ab	6702.50h	6300.00b	6475.90cdef	6650.00l
Amicarbazone (Post-emergence)	525	4710.00b	9289.00ab	6902.50gh	12075.00ab	6001.30def	6300.00m
Amicarbazone (Post-emergence)	700	4807.50b	6664.00b	7410.00f	11250.00ab	8450.70abc	6050.00o
Nicosulfuron	60	5432.50a	8193.00ab	9300.00a	14013.00a	7539.00abcd	6140.00n
Foramsulfuron	450	4305.00c	16643.00a	9050.00ab	14325.00a	6960.40bcde	9960.00a
Rimsulfuron	10	4345.00c	7109.00b	8183.80de	10933.00ab	7925.60abcd	7150.00i
Rimsulfuron	11.25	4682.50b	12121.00ab	8700.80bc	12917.00ab	7446.60abcd	9155.00c
Rimsulfuron	12.5	5485.00a	6587.00b	8650.00bcd	8025.00ab	7755.90abcd	9620.00b
Nicosulfuron plus rimsulfuron	26.5	3827.50d	8696.00ab	8110.00e	14133.00a	6887.50bcde	8750.00d
Nicosulfuron plus rimsulfuron	30	4392.50c	8273.00b	8710.00bc	12900.00ab	7367.70abcd	8592.00e
Nicosulfuron plus rimsulfuron	33.75	5482.50a	9725.00ab	8320.00cde	13375.00ab	8494.90ab	7630.00g
Atrazine plus alachlor	1080	4670.00b	9186.00ab	7997.30e	10313.00ab	6285.60def	6800.00k
EPTC	800+ 2400	3757.50d	6365.00b	9177.80a	13917.00a	8003.50abcd	5810.00q
2,4-D plus MCPA	4920	4337.50c	8483.00b	8345.00cde	8238.00ab	4850.30f	5950.00p
The full season weedy check	-	5372.50a	8665.00ab	6741.40h	9375.00ab	5243.20f8390.00	4653.47r

- Means within each column followed by same letter are not significantly different (Duncan 5%).

REFERENCES

Baghestani M. A., Zand, E., Soufizadeh, S., Eskandari, A., PourAzar, R., Veysi, M. and Nassirzadeh, N. 2007. Efficacy evaluation of some dual purpose herbicides to control weeds in maize (*Zea mays* L.). *Crop Proectiont* **26**, 936-942.

Bruce, A. B. and Kells, J. J. 1997. Quackgrass (*Elytrigia repens*) control in corn (*Zea mays*) with nicosulfuron and primisulfuron. *Weed Technology* **11**, 373-378.

Koeppe, M. K., Hirata, C. M., Brown, H. M., Kenyon, W. H., O'Keefe, D. P., Lau, S. C., Zimmerman, W. T. and Green, J. M. 2000. Basis of selectivity of the herbicide rimsulfuron in maize. *Pesticide Biochemistry and Physiology* **66**, 170-181.

LeBaron, H. M. and McFarland, J. E. 1990. Resistance to Herbicides.*Chemical Technology* **20**, 508-511.

Lum A.F., Chikoye, D. and Adesiyan, S. O. 2005. Control of *Imperata cylindrica* (L.) Raeuschel (speargrass) with nicosulfuron and its effect on the growth, grain yield and food components of maize. *Crop Protection* **24**, 41-47.

Niekamp, J. W. and Johnson, W. G. 2001. Weed management with sulfentrazone and flumioxazin in no-till soyabean (*Glycine max*). *Crop Protection* **20**, 215-220.

Reidy, M. E. and Swanton, C. J. 1994. Response of four quackgrass biotypes to desiccation. *Canadian Journal of Plant Science* **74**, 643–646.

SAS Institute, 2000. The SAS System for Windows, Release 8.0. Statistical Analysis Systems Institute, Carry, NC.

Sikkema, P. H., Kramer, C., Vyn, J. D., Kells, J. J., Hillger, D. E. and Soltani, N. 2007. Control of *Muhlenbergia frondosa* (wirestem muhly) with post-emergence sulfonylurea herbicides in maize (*Zea mays*). *Crop Protection* **26**,1585-1588.

Sprague, C. L. and Hager, A. G. 2002. Results on herbicide resistance in Illinois: Web page: www.ag.uiuc.edu/cespubs/pest/articles. No. 7. Accessed: July 20, 2003.

Sprague, C. L., Stoller, E. W. and Wax, L. M. 1997a. Response of an acetolactate synthase (ALS)-resistant biotype of *Amaranthus rudis* to selected ALS-inhibiting and alternative herbicides. *Weed Reearch* **37**, 93–101.

Sprague, C. L., Stoller, E. W., Wax, L. M. and Horak, M. J. 1997b. Palmer amaranth (*Amaranthus palmeri*) and common waterhemp (*Amaranthus rudis*) resistance to selected ALS-inhibiting herbicides. *Weed Science* **45**, 192–197.

Tomlin, C. 2003. The Pesticide Manual. 13th ed. British Crop Protection Council, Hampshire, UK.

U.S. Environmental Protection Agency, 1998. Pesticide Fact Sheet- amicarbazone. Washington, DC.

Vencill, W. 2002. Herbicide Handbook. 8th ed. Weed Science Society of America, Lawrence, KS.

Wrubel R.P. and Gressel J. 1994. Are herbicide mixtures useful for delaying the rapid evolution of *resistance*? A case study. *Weed Technology* **8**, 635-648.

Zand, E., Baghestani, M. A., Soufizadeh, S., PourAzar, R., Veysi, M., Bagherani, N., Barjasteh, A., Khayami, M. M. and Nezamabadi, N. 2007. Broadleaved weed control in winter wheat (*Triticum aestivum* L.) with post-emergence herbicides in Iran. *Crop Protection* **26**, 746-752.