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Original Research Article

Efficacy Evaluation of Sulfosulfuron, Metsulfuron-methyl plus Sulfosulfuron, Mesosulfuron-methyl plus Iodosulfuron-methyl and Iodosulfuron plus Mesosulfuron Herbicides in Winter Wheat (*Triticum aestivum* L.)

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ABSTRACT

In order to investigate the effect of sulfosulfuron, metsulfuron-methyl plus sulfosulfuron, mesosulfuron-methyl plus iodosulfuron-methyl and iodosulfuron plus mesosulfuron on weed control and wheat biological and grain yield, a two-year field experiment was conducted in Shiraz, Iran, during 2011-2012 and 2012-2013 growing seasons. The experimental design was randomized complete blocks with four replications. Treatments were sulfosulfuron at 18, 20.25 and 22.5 g a.i. ha^{-1}, metsulfuron-methyl plus sulfosulfuron at 28, 32 and 36 g a.i. ha^{-1}, mesosulfuron-methyl plus iodosulfuron-methyl at 14.4, 18 and 21.6 g a.i. ha^{-1}, iodosulfuron plus mesosulfuron at 18, 24 and 30 g a.i. ha^{-1} and two weedy and weed free checks. Compared with the weedy check, application of herbicides in both growing seasons reduced weed biomass and increased wheat biological and grain yield. Among herbicide treatments, metsulfuron-methyl plus sulfosulfuron at 36 g a.i. ha^{-1} reduced weed dry matter by 98. 6% and 97.55% in 2011-2012 and 2012-2013, respectively, and the lowest weed dry matter was observed with this treatment. In both years, maximum wheat biological yield was obtained in weed free check that was not significantly different from metsulfuron-methyl plus sulfosulfuron at 36 g a.i. ha^{-1}. The highest wheat grain yield was obtained with metsulfuron-methyl plus sulfosulfuron at 36 g a.i. ha^{-1}.

Key Words: Herbicide, sulfonylurea, weed, wheat grain yield

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important crops among cereals. Many factors could be responsible for low yield in wheat, but one of the major causes is weed infestation. Weeds are the omnipresent types of pests that interfere with crops through competition and allelopathy, resulting in yield loss (Zaremohazabieh and Ghadiri 2011; Gupta 2006). Since mechanical method of weed control is not common in wheat fields, chemical method is used to control weeds (Montazeri et al. 2005). The efficacy of any herbicide predominantly depends on the application dose and selectivity (Steckel et al. 1997). Use of herbicides is an effective and efficient means of weed management. Contrary to popular perception, it is also very safe and, in many cases, there are no practical alternatives to chemical weed control methods (Motooka et al. 2002). However, all kinds of weeds are not controlled by one type of herbicide and continuous use of that, over the time leads to increase of weed resistance to herbicides (Hall et al. 1999). Of the many weeds that infest wheat fields of southern Iran, wild barley (*Hordeum spontaneum* L.), foxtail (*Setaria viridis* L.) and wild oat (*Avena fatua* L.) are the major weed problems (Zand et al. 2007). Several studies have been conducted on the efficacy of sulfonylurea herbicides in wheat fields. These herbicides act through inhibition of acetolactate synthase affecting meristematic tissues. Growth ceases soon after spraying and chlorosis and the necrosis of these tissues soon follow (Rao 2000). Baghestani et al. (2006) reported that sulfosulfuron at 19.95 and 24.90 g a.i. ha^{-1} was suitable for broadleaf and grass weed control in wheat. Sij et al. (2007) reported that sulfonylurea herbicides were more efficient in terms of weed control. Lair and Redente (2004) reported that sulfonylurea herbicide application increased stability and biomass of crop as much as 43% over auxin herbicide and grass weeds were reduced up to 71% by application of sulfonylurea herbicide. The present study was initiated to investigate the effect of some sulfonylurea herbicides on weed control and grain and biological yield of winter wheat.

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MATERIALS AND METHODS

Field experiments were conducted in 2011-2012 and 2012-2013 growing seasons at the research station of the College of Agriculture of Shiraz University (1810 asl, longitude 52˚, 35΄, and latitude 29˚, 40΄). The meteorological data for this location during the growing seasons for two years are shown in Table 1. Soil texture was silt-loam with pH= 7.83, EC= 0.971 dS m^{-1}, N= 0.133 mg kg^{-1}, P= 22.3 mg kg^{-1} and K= 300 mg kg^{-1}. Experiments were laid out in a randomized complete block design (RCBD) with four replicates. Seedbed preparation consisted of moldboard plowing, disking and leveling. The wheat cultivar was Shiraz and was planted on 5 November by Pneumatic planter at the rate of 200 kg ha^{-1} and maintaining 20 cm distance between crop rows. The net plot size was 5m × 3m. A basal fertilizer dose of 130 kg N, 100 kg P_2O_5, and 60 kg ha^{-1} K_2O was applied in the form of urea (46% N), diammonium phosphate (18% N; 46% P_2O_5) and sulfate of potash (50% K_2O). The whole P and K and half of N fertilizers were applied at sowing time.

Table 1. Meteorological data during the growing season.

Month	Average temperature (°C)		Precipitation (mm)	
	2011-2012	**2012-2013**	**2011-2012**	**2012-2013**
November	10.25	11.5	92	120
December	4.5	5.55	0	96
January	4.32	3.58	52	53.5
February	3.98	6.33	154	10.5
March	5.96	9.6	36	14
April	11.75	11	0	83.5
May	17.8	14.8	0	38.5
June	22.1	21.5	0	0
July	24.5	24	0	0
August	24.35	25.1	0	0
Total	**-**	**-**	**289**	**416.5**

In this study, the treatments were post-emergence sulfonylurea herbicides by 3 different doses including sulfosulfuron at 18, 20.25 and 22.5 g a.i. ha^{-1}, sulfosulfuron plus metsulfuron-methyl at 28, 32 and 36 g a.i. ha^{-1}, mesosulfuron-methyl plus iodosulfuron-methyl at 14.4, 18 and 21.6 g a.i. ha^{-1} and iodosulfuron plus mesosulfuron at 18, 24 and 30 g a.i. ha^{-1} and two control treatments including weedy (without applying herbicides) and weed free (weeding by hand). The herbicides were applied broadcast in 400 L ha^{-1} water with a 20-L knapsack hand sprayer equipped with one flat-fan nozzle 110-02 at 3 kPa at 3-4 leaf stages of weeds in mid-March in both years. Wheat was hand harvested from the central $1m^2$ of the middle rows in each plot after maturity to measure grain and biological yield. To evaluate weed growth, four weeks after herbicide application (150 days after sowing), weeds were harvested from 1 m^2 of each plot. Weed samples were oven dried at 70°C for 48 h and their dry weight measured. At the end of the growing season, grain and biological yields of wheat were measured. The collected data were subjected to the analysis of variance using Minitab and SAS statistical software and treatment means were compared by Duncan multiple range test (DMRT) at the 0.05 level of significance.

RESULTS AND DISCUSSION

Weed dry matter

Weed biomass varied with year and herbicide treatments. In both years, herbicides reduced weed biomass compared with the weedy check. Metsulfuron-methyl plus sulfosulfuron at 36 g a.i. ha^{-1} (12.5% more than recommended dose), decreased weed biomass by 98. 6% in 2011-2012 and 97.55% in 2012-2013, compared with weedy check (Table 2). Ahmadi and Nazari (2013) reported that metsulfuron-methyl plus sulfosulfuron reduced weed dry matter by 98 %. In terms of the effect on weeds dry matter, there was no significant difference between 28 g a.i. ha^{-1} and 36 g a.i. ha^{-1} doses of metsulfuron-methyl plus sulfosulfuron herbicide. However, in some cases, use of reduced doses of herbicide may give us whole dose results (Kim et al. 2006). The highest weed dry mater was observed with weedy check. Sheibani and Ghadiri (2011) also reported that the highest weed biomass was obtained from weedy check plots. Application of sulfosulfuron herbicide at 22.5 g a.i. ha^{-1} decreased weed dry matter by 75.85% in 2011-2012 and 79.23% in 2012-2013 growing seasons. Moreover, sulfosulfuron at 18 g a.i. ha^{-1} decreased weed biomass by 67.79% and 71.59% in two growing seasons which was an acceptable control compared with other doses of this herbicide. Several authors (Boström and Fogelfors 2002; Walker et al. 2002; Auskalnis and Kadzys 2006; Barros et al. 2007) reported similar results, providing acceptable weed control at limited doses.

Table 2. Total weed dry weight as affected by herbicide treatments at 150 Days after sowing.

Treatment	Dose (g a.i. ha^{-1})	Weed dry weight (g m^{-2})	
		2011-2012	2012-2013
Sulfosulfuron	18	65.5 e	55.4 ef
Sulfosulfuron	20.25	52.5 f	47.5 f
Sulfosulfuron	22.5	49.4 f	40.5 f
Metsulfuron-methyl + Sulfosulfuron	28	8.33 g	9.5 g
Metsulfuron-methyl + Sulfosulfuron	32	6.67 g	5.5 g
Metsulfuron-methyl + Sulfosulfuron	36	3.4 g	2.2 g
Mesosulfuron-methyl + Iodosulfuron-methyl	14.4	96.5 d	88.7 d
Mesosulfuron-methyl + Iodosulfuron-methyl	18	71.4 e	59.3 e
Mesosulfuron-methyl + Iodosulfuron-methyl	21.6	67.2 e	55.8 ef
Iodosulfuron + Mesosulfuron	18	184.5 b	162 b
Iodosulfuron + Mesosulfuron	24	120.5 c	106.4 c
Iodosulfuron + Mesosulfuron	30	97.2 d	80.5 d
Weedy	-	203.4 e	195 a
Weed free	-	0 g	0 g

The means with similar letters are not significantly different at 5% level (Duncan multiple range test).

Wheat biological yield

The effect of treatments on wheat biological yield was considerable. Relative to the weed free check, biological yield in the weedy check was reduced by approximately 87 and 94% during 2011-2012 and 2012-2013 growing season, respectively. All herbicide treatments improved wheat biological yields compared to the weedy check. However, in both years, metsulfuron-methyl plus sulfosulfuron consistently provided the highest biological yield (Table 3). Minimum biological yield of wheat was achieved with iodosulfuron plus mesosulfuron at 18 g a.i. ha^{-1} during 2011-2012 and 2012-2013 (Table 3). Also, metsulfuron-methyl plus sulfosulfuron at 28 g a.i. ha^{-1} increased wheat biological yield by 80.27% and 86.43% during 2011-2012 and 2012-2013, respectively, which was not significantly different from higher doses of this herbicide. Present study confirms the results of other experiments which show that one can reduce application dose of some herbicides by 25 – 40%, while still effectively controlling the weeds without a significant decrease in crop yield (Talgre et al. 2004; Domaradzki and Rola 2003).

Grain yield

In 2011-2012 and 2012-2013, wheat grain yield in metsulfuron-methyl plus sulfosulfuron at 28 g a.i. ha^{-1} was 5845 and 6420.5.2 kg ha^{-1}, respectively, without significant difference with higher doses of the herbicide and weed free check in terms of grain yield (Table 3). Golparvar et al. (2012) reported that limited doses of herbicides provided the same yield as weed free plots, therefore, this could be recommended to farmers. Maximum and minimum grain yield of wheat in this study were obtained from weed free and weedy checks. Izquierdo et al. (2003) reported that yield losses in some cereal crops due to competition with weeds can reach up to 80% depending on the infestation level. With application of sulfosulfuron and metsulfuron-methyl plus sulfosulfuron and mesosulfuron -methyl plus iodosulfuron methyl herbicides, wheat grain yield increased (Table 3). Baghestani et al. (2006) reported that the wheat yield was increased with increasing application dose of herbicide without any crop injury. Application of iodosulfuron plus mesosulfuron at 18 g a.i. ha^{-1} decreased grain yield by 42.81 and 51.62% as compared to the weed free check during 2011-2012 and 2012-2013 growing seasons, respectively. This could be due to poor weed control of the herbicide at this dose. Other researchers have concluded that the risk associated with reduced herbicide doses increased in the absence of other weed management practices like higher seed rates and competitive cultivars (Kirkland et al. 2000; O'Donovan et al. 2003a,b).

CONCLUSION

It is concluded that the most effective herbicide treatment was metsulfuron-methyl plus sulfosulfuron at 36 and 32 g a.i. ha^{-1} which provided maximum reduction in total weed dry matter. All herbicide treatments increased wheat biological and grain yield as compared with the weedy check. Maximum grain yield among herbicide treatments was observed with metsulfuron-methyl plus sulfosulfuron at 36 g a.i. ha^{-1}. Iodosulfuron plus mesosulfuron at 18, 24 and 30 g a.i. ha^{-1} (especially at 18 g a.i. ha^{-1}) did not provide acceptable full season weed control in wheat. Although sulfosulfuron and mesosulfuron-methyl plus iodosulfuron-methyl herbicides reduced weed biomass as compared to weedy check, grain and biological yields were less than metsulfuron-methyl plus sulfosulfuron treatments. Wheat herbicides such as metsulfuron-methyl plus sulfosulfuron are relatively inexpensive and available to farmers in many countries. However, because of the environmental concerns, lower application dose of these new herbicides is recommended for improving weed control in wheat fields.

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Table 3. Wheat grain and biological yields as affected by herbicide application.

Treatment	Dose (g a.i ha^{-1})	2011-2012		2012-2013	
		Grain Yield (kg ha^{-1})	**Biological yield (kg ha^{-1})**	**Grain Yield (kg ha^{-1})**	**Biological yield (kg ha^{-1})**
Sulfosulfuron	18	4798 b	12210 b	5302.5 d	13955.3 b
Sulfosulfuron	20.25	4875.5 b	12492 b	5722.5 c	14099.5 b
Sulfosulfuron	22.5	4926.8 b	12532.5 b	5792.2 c	14112.8 b
Metsulfuron-methyl + Sulfosulfuron	28	5845 a	13651 a	6420.5 b	15707 a
Metsulfuron-methyl + Sulfosulfuron	32	5902 a	13700 a	6661 ab	15877 a
Metsulfuron-methyl + Sulfosulfuron	36	5989 a	13921.3 a	6796.2 a	16047 a
Meso sulfuron methyl + Iodosulfuron methyl	14.4	4064 d	10820 c	4152 f	12755 c
Meso sulfuron methyl + Iodosulfuron methyl	18	4325 c	11022 c	4652 e	12850 c
Meso sulfuron methyl + Iodosulfuron methyl	21.6	4405 c	11722 c	4788 e	13050 c
Iodosulfuron + Meso-sulfuron	18	3437 f	9168.3 e	3423 g	8690 e
Iodosulfuron + Meso-sulfuron	24	3801.8 e	10056 d	4125 f	11731 d
Iodosulfuron + Meso-sulfuron	30	3585.3 f	9386.3 e	3650 g	11005.5 d
Weedy	-	2809 g	7556 f	2852 h	8171.5 f
Weed free	-	6010.3 a	13957.8 a	6877 a	16167.3 a

The means with similar letters are not significantly different at 5% level (Duncan multiple range test).

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