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COMPARATIVE OF THE EFFICACY OF TRIFLOXYSULFURON SODIUM WITH COTTON SELECTIVE HERBICIDES REGISTERED IN IRAN

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ABSTRACT

To evaluate the efficacy of recently introduced herbicide trifloxysulfuron sodium in weed control in cotton fields, three experiments were carried out in 2003 in three cotton growing areas of Iran, including Varamin, Khorasan and Fars. In these experiments, the effects of trifloxysulfuron sodium at 7.5, 11.25 & 15 g ha^{-1}, alone or tank mixed with cytogate at 2% (v/v), was compared with trifluralin at 0.96 & 1.2 kg ha^{-1}, ethalfluralin at 0.99 & 1.16 kg ha^{-1} and diuron at 2.4 kg ha^{-1}. Application time for trifluxysulfuron sodium was at 7-leaf stage of cotton, for diuron was pre-emergence and for trifluralin ethalfluralin was pre-planting soil incorporation. In all experiments, the effect of herbicides were compared with hand weeding (weed free) and weedy check. All herbicides, compared to weedy check, significantly reduced the number of plant and dry weight of Amaranthus retroflexus, A. blitoides, Chenopodium album, Portulaca oleracea, Acropliton repense, Alhagi camelorum, Eragrostis poaeoides, Echinocloa crus-galli, E. colonum, Sorghum halepense and Cyperus rotundus. Trifloxysulfuron at 11.25 or 15 g ha^{-1} was in most cases, more effective than its application at 7.5 g ha^{-1}. In most cases, addition of cytogate enhanced the efficacy of trifloxysulfuron. Cotton injury was observed 1-2 weeks after application of trifluxysulfuron but did not adversely affect the crop productivity. All herbicides, compared to weedy check, increased the yields.

Key words: Cotton, trifluxysulfuron sodium, trifluralin, ethalfluralin, diuron, cytogate, weed control.

INTRODUCTION

Cotton is one of the important crops in Iran, which is cultivated on around 200 thousand hectares annually, and the cotton lint production in 2001 was evaluated about 11580 tons (Anonymous, 2001). Weeds are one of the important factors in cotton yield loss. The most dominant weeds in cotton fields of Iran are *Amaranthus retroflexus* L., *Chenopodium album* L., *Abutilon theophrasti* Medic., *Solanum nigrum* L., and *Echinochloa crus-galli* (L.) Beauv. (Mirkamali and Maddah, 1974). Salimi *et al.* (2002) showed that the critical period of weed control in cotton begins from the 5th leaf stage to production of brown flower on cotton. Yield was not significantly affected by weeds when hand-weeding was carried out three times in the critical period viz. 20, 35 and 50 days after planting (Salimi and Moosavi, 1996). Trifluralin, ethalfluralin and diuron have been

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registered in Iran as cotton selective soil-applied herbicides. In Iran, no post-emergence herbicide for use in cotton was registered up to recent years.

Trifloxysulfuron (Envoke75 WG, Syngenta Crop Protection, Inc.) is a new sulfonylurea herbicide being developed for post-emergence weed control in cotton sugarcane and turf (Brecke and Unruh 2000; Hudetz *et al.*, 2000; Porterfield *et al.*, 2002a; Wells *et al.*, 2000). This herbicide is an over-the-top cotton selective herbicide with highly active compound and low use rates (Wells *et al.*, 2000). The effect of Trifloxysulfuron, at low rate of application, in control of numerous broad-leaved weeds, grasses and sedge has been reported (Hudetz *et al.*, 2000; Teuton *et al*, 2001; Brecke and Unruh, 2002; Porterfield *et al.*, 2002a; Troxler *et al.*, 2003; McElroy *et al.*, 2003).

The purpose of this investigation was evaluating the efficacy of trifloxysulfuron, alone or mixed with cytogate, in control of weeds and its selectivity with cotton varieties growing in Iran. So, in three field experiments, trifloxysulfuron was compared with trifluralin, ethalfluralin and diuron as cotton selective herbicides which have been registered in Iran.

MATERIALS AND METHODS

In this research, three field experiments were carried out in randomized complete block design with four replications in three cotton growing areas in 2003. Cotton varieties Varamin (in Varamin and Khorasan experiments) and Bakhtegan (in Fars experiment) were planted with 80 cm row space during the end of April to mid May. Plot size was 6×3.2 m^2, consisting four crop rows. Experiments were conducted under conventional tillage practice and furrow irrigation was programmed based on technical schedules (Iran Cotton Research Institute). In each experiment, the following thirteen treatments were carried out: 1 & 2) application of trifluralin at 0.96 and 1.2 kg ha^{-1} as pre-planting soil incorporation; 3 & 4) application of ethalfluralin at 0.99 and 1.16 kg ha^{-1} as pre-planting soil incorporation; 5) application of diuron at 2.4 kg ha^{-1} as pre emergence; 6, 7 & 8) application of trifloxysulfuron sodium at 7.5, 11.25 and 15 g ha^{-1} when cotton was at 7-leaf stage; 9 & 10 & 11) application of trifloxysulfuron sodium at 7.5, 11.25 and 15 g ha^{-1} tank mixed with cytogate (an adjuvant) at 2% (v/v) of herbicide solution, when cotton was at 7-leaf stage; 12) weed free check (hand weeding three times); 13) weedy check.

Herbicides were applied using knapsack sprayer with a flood-fan nozzle and a constant pressure of 2 bar (kg cm^{-2}). The sprayer was calibrated to deliver 300 L ha^{-1}.

To evaluate the effect of treatments on weeds, four weeks after the last spraying, number of plants of each weed species was separately counted in two 0.5×0.5 m^2 sites in each plot. Then, the counted weeds were cut from soil surface, transferred into an oven at 75°C for 72 h to dry and weighed.

All plots were surveyed weekly up to four weeks after the last spraying to record any abnormality such as chlorosis, necrosis, stunting etc. on the crop. For evaluation the effect of treatments on cotton, in each plot 8 plants were randomly selected then number of bolls per plant, height of plants and the number of branches on the main stem was determined. In each plot, lint yield of two central rows was picked, ginned, weighed and recorded for each treatment.

Statistical analysis

In all experiment, data obtained for each parameter were subjected to analysis of variance using SAS release 6.12 software program (SAS Institute Inc., 1989). Treatment means were compared for significant differences using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Khorasan Experiment: All chemical treatments reduced the number and dry weight of *A. blitoides* S.Watson, *E. crus-galli*, and *Alhagi camelorum* Fisch. from the weedy check (Table-1). But there were non significant differences between trifloxysulfuron at the mentioned application rate and diuron at 2.4 kg ha^{-1} or trifluralin at 0.96 and 1.20 kg ha^{-1}. Cytogate had no positive effect on the efficacy of trifloxysulfuron in control of *A. blitoides*. Trifloxysulfuron at 11.25 g ha^{-1} mixed with cytogate, diuron at 2.4 kg ha^{-1} and ethalfluralin at 1.16 kg ha^{-1} could completely control *C. album*. Trifloxysulfuron at 15 g ha^{-1} mixed with cytogate and trifluralin at 1.2 kg ha^{-1} gave good result in reducing the number of plants and dry weight of *E. crus-galli*. Application of ethalfluralin at 1.16 kg ha^{-1} and trifloxysulfuron at 11.25 or 15 g ha^{-1} (alone or mixed with cytogate) resulted in complete control of *A. camelorum* (Table-1). The best results in control of *Acroptilon repense* (L.) DC were obtained by application of trifluralin at 1.2 kg ha^{-1}. *Eragrostis poaeoides* was completely controlled in treatments ethalfluralin at 1.16 kg ha^{-1}, diuron at 2.4 kg ha^{-1} and trifloxysulfuron at 11.25 g ha^{-1} mixed with cytogate (Table-1).

Varamin Experiment: Diuron showed the lowest density of *A. blitoides*, but its effect on this weed was not significantly different from ethalfluralin at 1.16 kg ha^{-1} or trifloxysulfuron at 15 g ha^{-1} mixed with cytogate (Table-2). The dry weight of *A. blitoides* in treatments diuron and trfloxysulfuron at 15 g ha^{-1} mixed with cytogate or 11.25 g ha^{-1} (with or without cytogate) was lower than the other chemical treatments. Application of trifluralin at 1.2 kg ha^{-1} resulted in lowest number of *E. crus-galli* plants, but there was no significant difference between this treatment and trifluralin at 960 g ha^{-1}, ethalfluralin at both application rates, trifloxysulfuron at 15 g ha^{-1}+cytogate, trifloxysulfuron at 11.25 g ha^{-1} (with or without cytogate) or weedy check (Table-2). Whereas, application of diuron resulted in lowest dry weight of *E. crus-galli*, but had no significant difference with that of trifloxysulfuron at 15 g ha^{-1} with or without cytogate (Table-2). Diuron completely controlled *Portulaca oleracea* L. Cytogate enhanced the effect of trifloxysulforon in reducing the dry weight of *P. oleracea* (Table 2). In addition, this adjuvant enhanced the efficacy of trifloxysulfuron in reducing the number of plants and dry weight of *Sorghum halipense* (L.) Pers. [Table 2]. Among the chemical treatments, application of trifloxysulfuron *at al.*, rates, alone or mixed with cytogate, resulted in lowest number and dry weight of *Cyperous rotundus* L.

Fars Experiment: In this experiment, all treatments, compared to weedy check, significantly reduced the number and dry weight of *A. retroflexus* and *P. oleracea*, but there were only few significant differences among herbicide treatments (Table-3). In reducing the number of *E. crus-galli* plants, trifluralin, ethalfluralin and diuron were more effective than trifloxysulfuron *at al.*, rates of application. Trifloxysulfuron at 11.25 or 15 g ha^{-1}, especially when was mixed with cytogate, was more effective in the control of *A. retroflexus* than other chemical treatments. Application of trifluxysulfuron at 7.5 or 11.25 g ha^{-1} was more effective in reducing the number of *P. oleracea* when mixed with cytogate. Mixing the cytogate with trifluxysulfuron at 7.5 or 11.25 g ha^{-1} had significant positive effect on reducing dry weight of *P. oleracea* plants. In reducing the number and dry

weight of *E. colonum* (L.) Link, the effect of trifluralin, ethalfluralin and diuron was higher than trifloxysulfuron *at al.*, rates of application (Table-3).

Effect of treatments on cotton crop

Chlorosis and slightly stunting were observed on cotton 1-2 weeks after application of trifluxysulfuron at each rate (data not given). The symptoms were gradually recovered 3 to 4 weeks after application of this herbicide. Other herbicides showed no detectable symptoms on cotton.

In Varamin and Fars experiments, the highest number of bolls and branches per cotton plant, and lint yield were obtained from weed free treatment, whereas, in Khorasan experiment, there were non-significant differences between weed free treatment and trifloxysulfuron at some rates of application (Table-4). Among chemical treatments, in all experiments, the application of trifloxysulfuron mixed with cytogate resulted in the highest number of bolls per plant. In Varamin, trifloxysulfuron at 11.25 g ha^{-1} plus cytogate showed higher number of bolls per plant than other chemical treatments, but it was not significantly different from trifloxysulfuron at 15 or 7.5 g ha^{-1} plus cytogate, diuron at 2.4 kg, ethalfluralin at 1.16 kg ha^{-1} and trifluralin at both rates of application (Table-4). In this experiment, similar results were obtained for number of branches per plant, except ethalfluralin which was significantly lower than trifloxysulfuron at 11.25 g ha^{-1} plus cytogate. In Fars experiment, application of trifloxysulfuron at 15 g ha^{-1} plus cytogate, which resulted in the highest number of bolls, had no significant different with trifloxysulfuron at 11.25 g ha^{-1} plus cytogate and diuron. In this experiment, the number of branches in trifloxysulfuron at 7.5 g ha^{-1}, trifloxysulfuron at 11.25 or 15 g ha^{-1} plus cytogate was higher than and significantly different from the other chemical treatments (Table-4). In Khorasan experiment, trifloxysulfuron at 11.25 g ha^{-1} plus cytogate, which showed the highest number of boll, was not significantly different from trifloxysulfuron at 7.5 g ha^{-1} plus cytogate or at 11.25 g ha^{-1} alone. In this experiment, in trifloxysulfuron at 11.25 g ha^{-1} plus cytogate, number of branches was higher than other chemical treatments, but had no significant difference from trifloxysulfuron at 15 g ha^{-1} plus cytogate (Table-4).

The highest lint yield was obtained from application of trifloxysulfuron at 15 g ha^{-1} plus cytogate in Varamin and Fars experiments, and trifloxysulfuron at 11.25 g ha^{-1} plus cytogate in Khorasan experiment (Table-4). In Fars, the effect of trifloxysulfuron at 11.25 g ha^{-1} plus cytogate on lint yield was significantly higher than the other chemical treatments. Whereas, in Varamin, this treatment was significantly different only from trifloxysulfuron at 7.5 or 11.25 g ha^{-1} alone. In Khorasan, the effect of trifloxysulfuron at 11.25 g ha^{-1} plus cytogate having the highest lint yield was not significantly different from trifloxysulfuron at 11.25 g ha^{-1} alone or ethalfluralin at 1160 g ha^{-1}.

The results of this research indicated that hand weeding (weed free) was more effective than application of chemical herbicides in controlling the weeds and increasing the cotton yield. This method is very safe to environment, but is very expensive. In the previous research (Montazeri *et al.*, 1995) have also shown that chemical control of weeds, compared to hand weeding, reduced the labor cost by 80%. So, in Iran, cotton growing farmers tend to control the weeds chemically.

Trifluralin, ethalfluralin and diuron, which have been registered in Iran (Mosslanejad *et al.*, 2000), are commonly used as soil-applied herbicides in cotton fields. Soil-applied herbicides seldom provide season-long control but allow sufficient time to

gain a high differential between weeds and cotton, allowing application of post-emergence directed herbicides (Frans and Chandler, 1989; Wilcut *et al.*, 1995). A post-emergence cotton selective herbicide can be an alternative tool for chemical control in this crop. Trifloxysulfuron is a post-emergence cotton selective herbicide developed by Syngenta Crop Protection Inc. for bread-leaf weed control (Wells, *et al.*, 2000). The results of this research indicated that trifloxysulfuron is effective, in addition to broad-leaf, in control of *C. rotundus*, *E. crus-galli*, *E. colonum* and *S. halepense*. Wells *et al.* (2000) reported the efficacy of trifloxysulfuron on broadleaf weeds, *C. rotundus*, *C. esculentus* and seedlings of *S. halepense*. Good activity of trifloxysulfuron on sedge species, including *C. rotundus* and *C. esculentus* has been reported by Porterfield *et al.* (2002a), Troxler *et al.* (2003) and McElroy *et al.* (2003).

In the current research, trifloxysulfuron, especially when cytogate was mixed with the herbicide solution at 0.2% (v/v), had advantage over trifluralin, ethalfluralin and diuron in control of *C. rotundus*, *S. halepense* and *A. retroflexus*. But, on the other weed species, in most cases, the effect of this herbicide was similar to that of the registered herbicides. Complete control of *A. camelorum*, as a perennial weed, may be attributed to its translocation into the root-shoot system. Troxler *et al.* (2003) observed that less than 4% of foliar applied ^{14}C -trifloxysulfuron (^{14}C-CGA-362622) was translocated to purple and yellow nutsedge roots and tubers. It has been reported that trifloxysulfuron controls some perennial weeds (Teuton *et al.*, 2001).

Previous researches indicated that the addition of non-ionic surfactant 0.25% (v/v) to trifloxysulfuron, increased the control of *Desmodium tortuosum* (Sw.) DC., *Ipomoea lacunose* L. and *Senna obtusifolia* L. (Kendig, 2004). The results of current investigation indicated that the effect of cytogate at 0.2% (v/v) on the efficacy of trifloxysulfuron at different application rates, in different experiments and on different weed species were varying. Taken together, in most cases, cytogate enhanced the efficacy of this herbicide. This means that more investigation on the concentration of cytogate and working on the effect of other surfactants are required to improve the effect of trifloxysulfuron in weed control and its selectivity with cotton.

In this research, cotton injury by trifloxysulfuron at 7.5 to 15 g ha^{-1} was transient and did not negatively affect yields. Similar results were communicated by Holloway (2000) Porterfield *et al.* (2002a and 2002b) on cotton cultivars. Addition of cytogate at 0.2% (v/v) to trifloxysulfuron increased the lint yield. This was more pronounced for trifloxysulfuron at 11.25 and 15 g ha^{-1} in Fars and Varamin experiments. However, in most cases, there was no significant difference among chemical treatments. Consideration of trifloxysulfuron in weed control programs is dependent upon the weed spectrum and application time.

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Table-1. Mean density and dry weight (DW) of weed species in Khorasan experiment as affected by the treatments.

Treatment	Application rate g ha^{-1}	*Amaranthus blitoides*		*Chenopodium album*		*Echinocloa Crus-galli*		*Alhagi camelorum*		*Acroptilon repens*		*Eragrostis poaeoides*	
		No. m^{-2}	DW g m^{-2}	No. m^{-2}	DW g m^{-2}	No. m^{-2}	DW g m^{-2}	No. m^{-2}	DW g m^{-2}	No. m^{-2}	DW g m^{-2}	No. m^{-2}	DW g m^{-2}
Trifluralin	960	5.5 ef	13.8 fg	22 cd	21.5 c	24.3 bc	8.8 d	55 b	62.5 b	11.5de	10.8 d	42 b	11.2 bc
Trifluralin	1200	11de	14.2 fg	21.5 cd	18 cd	7.5 ef	2.4 f	37 cd	40.3 c	0 e	0 f	47ab	10.8bcd
Ethalfluralin	990	16.5 d	23.2 e	12.6 de	8.75 e	28.5 b	11.3ef	41.2 c	45 c	14.3d	11.2 d	14.6de	3.2 f
Ethalfluralin	1160	32.9 b	56.2 b	0 e	0 g	12.5 cde	3.5 c	0 e	0 d	15 d	15.3 c	0 e	0 g
Diuron	2400	7.2 e	25.6 e	0 e	0 g	14 cd	18.7 b	33.5 d	41.2 c	26.5 c	25.7ab	0 e	0 g
Trifloxysulfuron	7.5	23.6 c	43.8 c	25.9 c	30.5 b	13.7 cd	18.5 b	41.7 c	43.5 c	32.5bc	24.8ab	23.6cd	6.9 ef
Trifloxysulfuron	7.5 +cytog.	21.9 c	34.2 d	14.4 d	5.3 ef	19.1c	8.3 de	40 c	21.5 b	25 c	10.2de	15.1de	2 f
Trifloxysulfuron	11.25	17 d	27.8 de	41.5 b	25.6bc	10.2 de	14.7bc	0 e	0 d	24.3cd	17.5bc	22.5cd	8 de
Trifloxysulfuron	11.25 +cytog.	6.4 e	22.2 ef	0 e	0 g	13.6 cd	8.2 de	0 e	0 d	14.6 d	13.8cd	0 e	0 g
Trifloxysulfuron	15	12 de	13.2 g	22.5 cd	11 de	19 c	7.8def	0 e	0 d	35.5 b	12.8cd	28.2c	16.2 b
Trifloxysulfuron	15 +cytog.	7.3 e	11.2 gh	13.6 d	8.5 e	8.5 ef	2.2 f	0 e	0 d	28.6 b	7.4 e	17.6d	11.3 bc
Weed free	-	0 f	0 i	0 e	0 g	0 g	0 g	0 e	0 d	0 e	0 f	0 e	0 g
Weedy check	-	53 a	111a	58.5 a	106.5a	46.7 a	33.2 a	91a	145.3a	47a	27.8a	55 a	37.8 a

+cytog. = Tank mix of the herbicide with cytogate at 0.2% (V/V).

In each column, means with the same letter have non significant difference by DMRT at P≤0.05.

Table-2. Mean density and dry weight (DW) of weed species presented in Varamin experiment as affected by the treatments.

Treatment	Application rate g ha^{-1}	*Amaranthus blitoides*		*Echinocloa Crus-galli*		*Portulaca oleracea*		*Cyperous rotundus*		*Sorghum halepense*	
		No. m^{-2}	DW g m^{-2}	No. m^{-2}	DW g m^{-2}	No. m^{-2}	DW g m^{-2}	No. m^{-2}	DW g m^{-2}	No. m^{-2}	DW G m^{-2}
Trifluralin	960	5.8 c	17.5 b	8.3 de	43.2 a	3.8 c	30.4 bc	19.8c	5.8 d	2.75 de	67.9 ef
Trifluralin	1200	6 c	19.3 a	3.8 ef	18.6 cd	5.8 bc	48.8 a	38.3a	9.8 cd	2 def	88.3 de
Ethalfluralin	990	6 c	3.2 d	7.5 de	12.3 de	4 c	29.9 bc	11 de	7.3 cd	5.5 cd	105.4 cd
Ethalfluralin	1160	5 cde	3.17d	2.8 efg	11.5 de	6 b	23.8 c	31ab	32.95 a	6.5 bc	121.7 b
Diuron	2400	2.5 e	1.6 e	10.3 cd	3.97 f	0 d	0.0 g	25 b	12.2 bc	7 bc	118.3 bc
Trifloxysulfuron	7.5	8.8 b	4.4 cd	30 a	25.9 bc	4 c	13.5de	1 gh	0.5 e	3.25 de	31.5 fg
Trifloxysulfuron	7.5 +cytog.	9.8 b	5.31c	22.5 b	39.9 ab	3.3 c	16.8d	1.8f	0.47 e	0.25 fg	16.6 gh
Trifloxysulfuron	11.25	14 a	1.5 e	7.5 de	29.3 b	5 b	6.4ef	8.5 e	3.85 de	4.3 cde	107.2 cd
Trifloxysulfuron	11.25 +cytog.	5.5 cd	1.9 e	4.8 e	14.7 cde	8.5 a	8.7e	1.8 f	0.82 e	1. 5 ef	83.4 de
Trifloxysulfuron	15	9.8 b	4.95 c	13.5 c	10.4 def	6.5 b	8.5 e	8.5 e	4.2 de	7b c	115.3 bc
Trifloxysulfuron	15 +cytog.	4.8 de	1.1 e	8 de	4.4 ef	3 cd	4.3 f	1.8 f	0.50 e	1.3 efg	28.2 fg
Weed free	-	0 f	0 f	0 g	0 g	0 d	0 g	0 h	0 e	0 fg	0 i
Weedy check	-	5 cde	23.2a	4.5 e	44.9 a	3.3 c	33.5 b	14 d	29.5 ab	18.3 a	148.5a

+cytog. = Tank mix of the herbicide with cytogate at 0.2% (v/v).

In each column, means with the same letter have non significant difference by DMRT at P≤0.05.

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