Original Article

SELECTIVITY OF PREEMERGENCE HERBICIDE TREATMENTS FOR COTTON CROP

SELETIVIDADE DE HERBICIDAS APLICADOS EM PRE-EMERGENCIA NA CULTURA DO ALGODOEIRO

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ABSTRACT: The use of preemergence herbicides in cotton crop is one of the main tools in weed control. However, little is known about the effects of different herbicide tank mixtures on this crop. Therefore, this work was aimed at evaluating the selectivity of herbicides applied isolated or in mixtures to cotton at preemergence. Herbicide treatments included alachlor, s-metolachlor, diuron, prometryn, trifluralin, oxyfluorfen, alachlor+diuron, alachlor+prometryn, s-metolachlor+diuron, s-metolachlor+prometryn, oxyfluorfen+diuron, oxyfluorfen+prometryn, trifluralin+diuron, trifluralin+prometryn, trifluralin+oxyfluorfen. Herbicide treatments did not affect cotton stand. Oxyfluorfen, isolated or in mixture with diuron, prometryn, and trifluralin caused more significant crop injuries than all the other herbicide treatments. However, only oxyfluorfen+diuron, and trifluralin+oxyfluorfen decreased crop yield, and are regarded as presenting lower selectivity to cotton, cv. Delta-Opal.

KEYWORDS: Gossypium hirsutum. Residual herbicides. Tank mixture.

INTRODUCTION

Cotton (*Gossypium hirsutum* L. *latifolium* (Hutch.)) is a physiologically complex crop, and its yield results depend on the interaction of several biotic and abiotic variables (BELTRÃO et al., 2001). Among biotic factors, weeds have great importance on cotton management due to both the impacts on control methods and decreases imposed to crop yield and quality fiber, which may reach up to 60% when they are not controlled (WEBSTER et al., 2009).

Due to the extensive critical period of weed interference, which is usually considered to be between 15 and 60 days after crop emergence (SALGADO et al., 2002), the use of herbicides has become an indispensable tool, and it is considered essential among cotton growers. However, an aggravate factor is the extensive reliance on ALS and glycines herbicides in crop systems. It has led to selection for glyphosate and ALS-resistant biotypes of weeds in cotton (WHITAKER et al., 2011).

Failure to adopt a strategy that effectively controls can result in total crop failure. A key component of an effective management strategy will be integration of herbicides with different modes of action and residual activity. Herbicides applied preemergence (PRE) reduce early season weed interference and often improve season-long weed control (DAN et al., 2011). Although, the use of sub rates is frequently, either when products are applied isolated or in tank mixtures of herbicides with different mechanism of action aiming at higher control spectrum. On the other hand, little is known about the effects under selectivity in cotton crop.

Among herbicides applied at preemergence in cotton stand out alachlor, S-metolachlor, diuron, prometryn, and oxyfluorfen, which are used isolated or in mixtures. Although these herbicides are registered for use in cotton crop in Brazil (RODRIGUES; ALMEIDA, 2005), they may promote high levels of crop injury under certain soil and climate conditions. Guimarães et al. (2007) observed that alachlor caused crop injury to cotton plants. Although, this occurred in conditions of high rainfall after application. Duarte et al. (2008) verified that mixtures of metolachlor+pendimethalin (1.92+0.88 kg ha^{-1}), metolachlor+oxadiazon (1.92+0.44 kg ha^{-1}), and metolachlor+diuron+pendimethalin (1.92+1.33+0.77 kg ha^{-1}) provided high levels of intoxication resulting in cotton yield reductions in herbaceous cotton cultivar BRS 187 8H.

Tank mixtures are frequently used with the purpose of increasing control spectrum and/or improving effectiveness in hard-to-control species, hence increasing management efficiency (CARDOSO et al., 2004; DUARTE et al., 2008).

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Hence, it is very important to study the selectivity of herbicides isolated or in mixtures not only taking phytointoxication effects into account, but mainly the effect in crop yield, once there are reports on the recovery of visual phytotoxic effects caused by ones.

In order to fulfill the lack of recent research focused on selectivity of preemergence herbicides in cotton, either applied alone or in tank mixtures, the aim of this work was to evaluate herbicide selectivity to cotton in Brazilian savanna.

METERIAL AND METHODS

The experiment was conducted during the 2008/2009 crop season in Rio Verde-GO, Brazil (17º47'24" S, 50°56'31" W, altitude=698 m). The soil was identified as Rhodic Hapludox with 390 g kg^{-1} clay, 85 g kg^{-1} silt, 525 g kg^{-1} sand, with base saturation of 50% and 1.98% organic matter, and pH H_2O 5.45. Prior to experiment conduction, soil was prepared and the sowing realized in convectional system.

The sowing of cotton cultivar Delta Opal was carried out mechanically on 01/12/2009. Seeds were treated with Maxin XL (0.25 L 100 kg $seed^{-1}$), Cruiser (0.4 L 100 kg $seed^{-1}$) and Permit (0.6 kg 100 kg $seed^{-1}$). Lines were spaced 0.8 m apart and sowing density was 8 seeds per linear meter. Simultaneously, soil was fertilized with 400 kg ha^{-1} of the 02-20-18 N-P-K formula. Additional fertilization with 70 kg ha^{-1} of K_2O (potassium chloride), and 100 kg ha^{-1} of N (urea and ammonium sulphate) was applied in three operations carried out mechanically with a disk fertilizer spreader.

The experimental design was completely randomized in split-plot scheme with two checks (19.2 m^2), and four replicates. The herbicides were the main factor studied in the plots, and herbicide presence or absence was studied in the subplots. For each applied rate, a no spray check was left side by side the applied plot, with the intent of providing a site-specific correction when data were submitted to covariance analysis. Similar technique was previously used by Fagliari et al. (2001) for the evaluation of herbicide selectivity in sugarcane. More recently, it has also been used to study herbicide selectivity in soybeans (ALONSO et al., 2011; CONSTANTIN et al., 2007; JAREMTCHUK et al., 2008; DAN et al., 2011. According to Alonso et al. (2011), this type of experiment brings more efficient local control, especially when compared to the traditional randomized blocks design with a single check per block.

Treatments were all applied at preemergence, and were composed by the following herbicides and rates (g a.i. ha^{-1}): alachlor (1440), S-metolachlor (768), diuron (1500), prometryn (1500), trifluralin (1800), and oxyfluorfen (192) applied isolated, and by tank mixtures of alachlor+diuron (1440+1500), alachlor+prometryn (1440+1500), S-metolachlor+diuron (768+1500), S-metolachlor+prometryn (768+1500), oxyfluorfen+diuron (192+1500), oxyfluorfen+prometryn (192+1500), trifluralin+diuron (1800+1500), trifluralin+prometryn (1800+1500), and trifluralin+oxyfluorfen (1800+192). To prevent weed interference on soybeans, all subplots were kept free of weeds by manual hoeing throughout crop cycle.

Herbicides application was accomplished just after cotton sowing, and it was carried out with a backpack sprayer operating under CO_2 pressure with a 2.5 bar and six TT-110.02 spray tips (0.5 m between tips), delivering a volume of 200 L ha^{-1}. With regards to climate during application, average temperature was 24.5ºC, and relative humidity was 83% with wet soil, and wind speed of 2.1 km h^{-1}. The control of insects and diseases management was conducted according to crop needs. The crop was continuously kept free of weed interference by manual hoeing.

For the visual phytointoxication evaluations, percentage marks were attributed to each experimental unit with herbicides (visual scale, 0 - 100%) considering, in this case, visual symptoms on plants according to its development (SBCPD, 1995). Crop injury evaluations were carried out at 7, 15, and 28 days after application (DAA).

At 45 days after plant emergence, the final plant stand was determined by counting plants in 5 linear meters in both central lines. At 70 days after crop emergence, plant height was measured from the ground to the extreme monopodial branch using a graduated tape. Also, at 130 days after plant emergence, the number of fruits per plant was determined by counting 10 plants per plot. At the end of crop cycle, cotton yield was determined by manual harvest and weight of bolls from both central lines (10 m^2).

Plant height, average number of fruits, and seed cotton yield were analyzed comparing the plots treated with herbicides to adjacent twofold checks. Data were subjected to analysis of variance by the F test. When significant, differences between means were compared by the Tukey test at $P<0.05$.

RESULTS AND DISCUSSION

All treatments caused injuries to cotton plants leading to the appearance of visual phytotoxicity symptoms of variable intensity for each treatment. The results of visual crop injury evaluations at 7, 15, and 28 days after emergence (DAE) are displayed in Table 1. At 7 DAE, oxyfluorfen isolated or in mixture with diuron, prometryn, and trifluralin caused the highest levels of crop injury and injuries to others herbicides. The injuries characterized by these herbicides were necrosis on the cotyledons of some plants, what is usually described as one of the most typical symptoms of diphenyl ether herbicides PROTOX inhibitors such as oxyfluorfen (YAMASHITA et al., 2008).

At 15 DAE, treatments with alachlor, s-metolachlor, diuron, prometryn, trifluralin, and with the associations between alachlor+diuron, alachlor+prometryn, s-metolachlor+diuron, s-metolachlor+prometryn, trifluralin+diuron, and trifluralin+prometryn caused low levels of crop injury (>10%), and were the most selective among those tested (Table 1). Siqueri (2002) found light symptoms of crop injury (>20%) up to 15 DAA after the application of diuron (0.93 kg ha^{-1}), and alachlor (2.5 kg ha^{-1}), either isolated or combined, which is higher than the results presented in this research. Treatments with s-metolachlor, alone or in mixture, also did not significantly affect the over cotton plants. Toxicity and few symptom recovery from herbicide treatments containing S-metolachlor has been reported by Freitas et al. (2006).

In all treatments with oxyfluorfen isolated or associated with diuron, prometryn, and trifluralin caused high levels of crop injury (<38%) at 15 DAE (Table 1). For these treatments, symptoms of necrosis on cotyledons and yellowing followed by distortion on young leaves were noticed during this period. Although cotton plants have demonstrated slight recovery capability of injuries caused by the referred herbicides (oxyfluorfen isolated or associated with diuron, prometryn, and trifluralin), at 28 DAE crop injuries were still observed. Nevertheless, values were not higher than 25%. Cotton plants did not show symptoms for the other treatments.

Table 1. Grade averages of visual evaluations of crop injury shown by cultivar Delta Opal due to the different preemergence herbicides. Rio Verde, GO – Brazil. 2009.

Treatment		Rate (g a.i. ha^{-1})	Crop injury (%)		
			7 DAE	15 DAE	28 DAE
1	Alachlor	1440	4.3	6.3	0.0
2	S-metolachlor	768	3.7	6.5	0.0
3	Diuron	1500	4.9	7.5	0.0
4	Prometryn	1500	3.2	5.6	0.0
5	Trifluralin	1800	3.5	7.3	0.0
6	Oxyfluorfen	192	9.6	39.5	14.3
7	Alachlor+diuron	1440 + 1500	3.8	8.8	0.0
8	Alachlor + prometryn	1440 + 1500	4.9	9.3	0.0
9	S-metolachlor + diuron	768 + 1500	4.3	6.4	0.0
10	S-metolachlor + prometryn	768+ 1500	3.9	7.5	0.0
11	Oxyfluorfen + diuron	192 + 1500	10.4	46.4	21.3
12	Oxyfluorfen + prometryn	192 + 1500	9.4	42.3	15.6
13	Trifluralin + diuron	1800 + 1500	5.4	7.4	0.0
14	Trifluralin + prometryn	1800 + 1500	4.6	8.4	3.2
15	Trifluralin + oxyfluorfen	1800 + 192	12.4	48.3	24.3

DAE: Days after crop emergence.

No treatment caused significant reduction in plant population. This is a highly important factor once it represents one of the major components in order to obtain high levels of yield. Corroborating these results, Duarte et al. (2008) verified that the crop injury caused by the mixtures of metolachlor + pendimethalin (1.92 + 0.88 kg ha^{-1}), metolachlor + oxadiazon (1.92 + 0.44 kg ha^{-1}), and metolachlor + diuron + pendimethalin (1.92 + 1.33 + 0.77 kg ha^{-1}) were not enough to cause significant stand reduction on herbaceous cotton BRS 187 8H.

As a result of the different levels of crop injuries previously observed, residual activity of oxyfluorfen isolated or combined with diuron, prometryn, and trifluralin caused a slight reduction in growth of cotton plants when compared to their respective adjacent control (Table 2). The other herbicides did not affect this variable. Growth reduction reached 10% for oxyfluorfen isolated or in mixture with trifluralin. According to Melo et al. (2010), oxyfluorfen has low mobility remaining concentrated and active on soil superficial layers. It is clear that this relation between low mobility and high concentration surely favors the greater herbicide contact with plants providing an increased chance of injury by this herbicide, even though cotton is relatively tolerant to it.

Although some herbicide treatments impacted plant height, negative effects on crop cover were not observed. Such important fact shows that cotton plants resumed development indicating great recovery capacity, also observed by Beltrão et al. (2001) and Dan et al. (2011).

Table 2. Cotton plant height (cm), cv. Delta-Opal, at 70 days after treatment with preemergence herbicides. Rio Verde, GO – Brazil. 2009.

Treatment		Rate (g a.i. ha^{-1})	Height (cm)			
			Treat[1]		TC[2]	
1	Alachlor	1440	66.7	a	66.9	a
2	S-metolachlor	768	61.0	a	63.2	a
3	Diuron	1500	64.1	a	65.3	a
4	Prometryn	1500	65.4	a	66.7	a
5	Trifluralin	1800	63.1	a	64.4	a
6	Oxyfluorfen	192	58.5	b	65.4	a
7	Alachlor+diuron	1440 + 1500	64.3	a	65.2	a
8	Alachlor + prometryn	1440 + 1500	65.4	a	66.4	a
9	S-metolachlor + diuron	768 + 1500	62.6	a	63.2	a
10	S-metolachlor + prometryn	768+ 1500	64.1	a	65.3	a
11	Oxyfluorfen + diuron	192 + 1500	58.2	b	64.6	a
12	Oxyfluorfen + prometryn	192 + 1500	59.2	b	63.5	a
13	Trifluralin + diuron	1800 + 1500	65.4	a	65.1	a
14	Trifluralin + prometryn	1800 + 1500	64.1	a	65.4	a
15	Trifluralin + oxyfluorfen	1800 + 192	58.3	b	65.8	a
CV (%)			6.61			
DMS (Tukey, P<0.05)			3.27			

Means followed by the same letters in the same line do not differ from each other by F and Tukey test at 5% of probability (P<0.05). [1]Treatment (Herbicide applied); [2]TC (non applied, twofold checks);

The average values obtained for the number of fruits per plant are represented in (Table 3). The use of oxyfluorfen isolated or associated with diuron, prometryn, and trifluralin also caused negative effects to the number of fruits per plant of cultivar Delta-Opal.

Table 3. Number of fruits (fruits per plants) at 130 DAA, cv. Delta-Opal, after treatment with preemergence herbicides. Rio Verde, GO – Brazil. 2009.

Treatment		Rate (g a.i. ha^{-1})	Fruits per plants			
			Treat[1]		TC[2]	
1	Alachlor	1440	7.78	a	7.83	a
2	S-metolachlor	768	7.87	a	7.89	a
3	Diuron	1500	8.35	a	8.21	a
4	Prometryn	1500	8.18	a	7.98	a
5	Trifluralin	1800	8.01	a	7.94	a
6	Oxyfluorfen	192	6.71	b	7.97	a
7	Alachlor+diuron	1440 + 1500	8.31	a	8.40	a

8	Alachlor + prometryn	1440 + 1500	7.99	a	8.20	a
9	S-metolachlor + diuron	768 + 1500	7.84	a	8.11	a
10	S-metolachlor + prometryn	768+ 1500	8.20	a	8.14	a
11	Oxyfluorfen + diuron	192 + 1500	6.74	b	8.03	a
12	Oxyfluorfen + prometryn	192 + 1500	6.58	b	7.80	a
13	Trifluralin + diuron	1800 + 1500	8.17	a	8.15	a
14	Trifluralin + prometryn	1800 + 1500	8.04	a	8.19	a
15	Trifluralin + oxyfluorfen	1800 + 192	6.76	b	8.21	a
CV (%)			9.28			
DMS (Tukey, P<0.05)			1.05			

Means followed by the same letters in the same line do not differ from each other by F and Tukey test at 5% of probability (P<0.05). [1]Treatment (Herbicide applied); [2]TC (non applied, twofold checks).

In general, only treatments which received oxyfluorfen had this variable reduced. Oxyfluorfen applied isolated and its mixture with diuron, prometryn and trifluralin provided significant lower number of fruits when compared to their checks, which makes selectivity questionable. The Oxyfluorfen's treatments promoted significant reduction in the number of fruits showing that initial effects of phytotoxicity, leaf área and heigth plant reduction affected the accumulation of photoassimilates and, consequently, fruit formation. This is certainly worrying as this herbicide is constantly used in weed management in cotton. The other treatments did not affect the crop, and no significant differences in the number of fruits per plant were verified.

With regards to effects on yield, oxyfluorfen+diuron, and trifluralin+oxyfluorfen were the only treatments which promoted significantly lower yield in relation to their respective control without herbicides (Table 4). For these treatments, cotton yield reductions were 12.8% and 13.5%, respectively. Differences of the selectivity with consequent reduction of yield by tank mixtures clomazone+oxyfluorfen (1,00 + 0,19 kg ha^{-1}) were reported by Dan et al. (2011). Those authors explain that selectivity should to be relation with different genotypes.

One of the factors which might have contributed to yield losses in the treatments with oxyfluorfen+diuron, and trifluralin+oxyfluorfen is crop injuries observed after herbicides application, since these mixtures caused the highest levels of injuries at 15 DAE. It is possible to infer that high levels of injuries in the beginning of crop cycle might cause yield reduction, even though these plants have visually recovered with crop development. Negative effects were also noticed with respect to the number of fruits per plant.

Although oxyfluorfen applied isolated or in mixture with prometryn have also caused high levels of visual injury with consequent decrease in plant height and number of fruits, both treatments did not present significant effects on yield reduction of cotton in relation to the check without herbicide demonstrating that such effects were not sufficiently harmful to the crop as to reduce its yield. All other treatments did not show significant reduction in yield. Therefore they are selective to cotton crop.

Table 4. Cotton yield (kg ha^{-1}) from cv. Delta-Opal after treatments with preemergence herbicides. Rio Verde, GO – Brazil. 2009.

Treatment		Rate (g a.i. ha^{-1})	Cotton yield (kg per ha)			
			Treat[1]		TC[2]	
1	Alachlor	1440	3108.5	a	3161.3	a
2	S-metolachlor	768	3229.5	a	3210.0	a
3	Diuron	1500	3233.2	a	3274.1	a
4	Prometryn	1500	3229.2	a	3179.3	a
5	Trifluralin	1800	3110.9	a	3139.1	a
6	Oxyfluorfen	192	2897.3	a	3153.2	a
7	Alachlor+diuron	1440 + 1500	3092.1	a	3175.4	a
8	Alachlor + prometryn	1440 + 1500	3199.2	a	3272.1	a
9	S-metolachlor + diuron	768 + 1500	3042.7	a	3116.5	a
10	S-metolachlor + prometryn	768+ 1500	3178.0	a	3241.9	a

11	Oxyfluorfen + diuron	192 + 1500	2924.3	b	3357.5	a
12	Oxyfluorfen + prometryn	192 + 1500	3105.1	a	3398.4	a
13	Trifluralin + diuron	1800 + 1500	3178.2	a	3197.3	a
14	Trifluralin + prometryn	1800 + 1500	3172.1	a	3303.9	a
15	Trifluralin + oxyfluorfen	1800 + 192	2771.5	b	3207.2	a
CV (%)		9.16				
DMS		317.74				

Means followed by the same letters in the same line do not differ from each other by F and Tukey test at 5% of probability (P<0.05). [1]Treatment (Herbicide applied); [2]TC (non applied, twofold checks);

It is relevant to mention that toxicity to crop is constantly related to herbicides applied at preemergence, since a few products are totally selective to cotton and few are the studies which directed the selectivity of tank mixtures. Thus such study should be carried out continuously as several factors might be involved in the selectivity of a certain herbicide or its mixtures.

CONCLUSION

Treatments with oxyfluorfen isolated or in mixture with diuron, prometryn, and trifluralin caused more significant crop injuries than all the other herbicide treatments. However, all the herbicides isolated were selectivity to the culture. Between the tank mixtures, only oxyfluorfen+diuron, and trifluralin+oxyfluorfen caused lower yield than their control, and hence are regarded as presenting low selectivity to the cultivar Delta-Opal.

RESUMO: O uso de herbicidas em pré-emergência da cultura do algodoeiro é uma das principais ferramentas no controle de plantas daninhas. Entretanto, pouco se conhece sobre os efeitos de misturas em tanque de diferentes produtos nessa cultura. Dessa forma, este trabalho teve por objetivo avaliar a seletividade de herbicidas aplicados em pré-emergência, isolados ou em misturas, na cultura do algodão. Os tratamentos testados foram compostos dos seguintes herbicidas e suas respectivas doses (g a.i. ha^{-1}): alachlor (1440), S-metolachlor (768), diuron (1500), prometryn (1500), trifluralin (1800), and oxyfluorfen (192) aplicados isoladamente, e em mistura formando os seguintes tratamentos: alachlor+diuron (1440+1500), alachlor+prometryn (1440+1500), S-metolachlor+diuron (768+1500), S-metolachlor+prometryn (768+1500), oxyfluorfen+diuron (192+1500), oxyfluorfen+prometryn (192+1500), trifluralin+diuron (1800+1500), trifluralin+prometryn (1800+1500), e trifluralin+oxyfluorfen (1800+192). O experimento foi conduzido por meio de testemunhas duplas. Foram realizadas avaliações relacionadas à fitointoxicação visual, altura de planta, número de maçãs e produção de algodão em caroço. Os tratamentos herbicidas não influenciaram o estande da cultura do algodoeiro. O herbicida oxyfluorfen isolado ou em mistura com diuron, prometryn e trifluralin proporcionaram maior fitointoxicação à cultura em relação aos demais tratamentos. Entretanto, somente oxyfluorfen + diuron e trifluralin + oxyfluorfen apresentaram rendimento inferior à testemunha, sendo considerados, portanto, de baixa seletividade para o cultivar Delta-Opal.

PALAVRAS-CHAVE: *Gossypium hirsutum* L. *latifolium* (Hutch.). Herbicidas residuais. Mistura em tanque.

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