S-METOLACHLOR EFFICACY ON THE CONTROL OF *Brachiaria decumbens*, *Digitaria horizontalis*, AND *Panicum maximum* IN MECHANICALLY GREEN HARVESTED SUGARCANE[1]

Eficácia do S-Metolachlor no Controle de ***Brachiaria decumbens, Digitaria horizontalis*** *e* ***Panicum maximum*** *em Área de Cana-de-Açúcar Colhida Mecanicamente Crua*

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ABSTRACT - The aim of this study was to assess the efficacy of S-metolachlor applied in pre-emergence conditions for the control of *Brachiaria decumbens*, *Digitaria horizontalis*, and *Panicum maximum* in sugar cane mechanically harvested without previous burning of the crop (green harvest) with the crop residue either left or not on the soil surface. The experiments were established in the field according to a randomized complete block design with four repetitions in a 7 x 2 split-plot scheme. In the plots, five herbicide treatments were studied (S-metolachlor at 1.44, 1.92, and 2.40 kg ha^{-1}, clomazone at 1.20 kg ha^{-1}, and isoxaflutole at 0.188 kg ha^{-1}), and two control treatments with no herbicide application. In the subplots, the presence or absence of sugar cane crop residue on the soil surface was evaluated. S-metolachlor efficacy was not hampered by either 14 or 20 t ha^{-1} of sugar cane crop residue on the soil surface. When sugar cane crop residue was covering the soil surface, S-metolachlor at a rate of 1.44 kg ha^{-1} resulted in weed control similar at their larger rates, where as without the presence of crop residue, S-metolachlor controlled *B. decumbens*, *D. horizontalis*, and *P. maximum* at the rates of 1.92, 1.44, and 1.92 kg ha^{-1}, respectively. The herbicides clomazone and isoxaflutole were effective for the studied species, independently of the crop residue covering the soil surface. S-metolachlor caused no visible injury symptoms to the sugar cane plant. Clomazone and isoxaflutole caused visible injuries to the sugar cane plant. None of the herbicides negatively affected the number of viable culms m^2 or the culm height and diameter.

Keywords: signal grass, crabgrass, guinea grass, crop residue.

RESUMO - Objetivou-se com este trabalho avaliar o controle em pré-emergência de ***Brachiaria decumbens, Digitaria horizontalis*** *e* ***Panicum maximum*** *pelo herbicida S-metolachlor aplicado em pré-emergência em área de cana-de-açúcar colhida mecanicamente sem queima prévia das plantas, com e sem palha sobre o solo. O delineamento experimental foi o de blocos ao acaso, com quatro repetições, em esquema de parcela subdividida 7 x 2. Nas parcelas, foram estudados cinco tratamentos de herbicidas (S-metolachlor a 1,44, 1,92 e 2,40 kg* ha^{-1}*; clomazone a 1,20 kg* ha^{-1}*; e isoxaflutole a 0,188 kg* ha^{-1}*) e duas testemunhas sem aplicação. Nas subparcelas, foi avaliada a manutenção ou não da palha de cana na superfície do solo. A eficácia do herbicida S-metolachlor não foi prejudicada pela presença de 14 ou 20 t* ha^{-1} *de palha de cana sobre o solo. Com a manutenção da palha, a dosagem de S-metolachlor para o controle adequado das plantas daninhas foi de 1,44 kg* ha^{-1}*. No ambiente sem palha, o S-metolachlor controlou* ***B. decumbens, D. horizontalis*** *e* ***P. maximum*** *nas dosagens de 1.92, 1.44 e 1.92 kg* ha^{-1}*, respectivamente. Nas duas condições de palha, os herbicidas clomazone e isoxaflutole foram eficazes para as espécies estudadas. O S-metolachlor não causou nenhum sintoma visível de intoxicação à cana-de-açúcar. O clomazone e o isoxaflutole ocasionaram injúrias visuais às plantas de cana. Os herbicidas estudados não afetaram o número de colmos viáveis por* m^2*, a altura e o diâmetro de colmos.*

Palavras-chave: capim-braquiária, capim-colchão, capim-colonião, resíduos vegetais.

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INTRODUCTION

When sugar cane plants are mechanically harvested without previously burning, the crop residue left on the soil surface may reduce the ability of herbicides to reach the soil surface. This capacity is dependent on the physical and chemical characteristics of the herbicide, such as its water solubility, vapor pressure, and molecule polarity (Rodrigues, 1993). After herbicide application, the amount and period when rainfall or irrigation occurs, as well as modifications occurring in the decomposing plant residues, are also important factors regarding the retention of the herbicide by the crop residue (Correia et al., 2007). When retained by the crop residue, herbicide losses are likely to occur due to photo degradation, volatilization, and its adsorption by plant residues. The adsorption by plant residues is dependent on their degree of decomposition and age (Mersie et al., 2006).

Studies with metolachlor have reported its possible retention by plant residues and thus reduced efficacy (Oliveira et al., 2001; Teasdale et al., 2003; Fontes et al., 2004). The time interval between herbicide application and the first rains is another important factor: depending on how long that period is, the chances of herbicide loss by physical (such as volatilization) or chemical (such as photo degradation and adsorption) processes will be higher or lower. However, more detailed information about S-metolachlor is lacking. This herbicide is a metolachlor stereoisomer (Blaser, 2002) that presents higher biological activity (Munoz et al., 2011). In Brazil, S-metolachlor is recommended for pre-emergence control of monocots and some dicots species in soybean, corn, beans, cotton, and sugar cane crops. The herbicide is soluble in water (solubility = 480 mg L^{-1} at 25 ^{o}C), has low volatility (vapor pressure = 1.73 x 10^{-3} Pa at 20 ^{o}C), is nonionic (pk = zero), and is hydrophilic (K_{ow} = 3.05) (Rodrigues & Almeida, 2011). These characteristics indicate the stability of the molecule against losses to the environment and its affinity with water.

Brachiaria decumbens, *Digitaria horizontalis*, and *Panicum maximum* are important weed species that infest sugar cane fields in Brazil. *B. decumbens* originated from Africa and was introduced in Brazil in 1950 as a forage crop. It is a perennial plant that is decumbent and stoloniferous, with roots arising from low nodes coming into contact with the soil surface. *D. horizontalis* originated from the tropical regions of South America and Africa. It is an annual species that is reproduced by seeds, spreading by rooting from nodes that are in contact with the soil. *P.maximum* originated from Africa and India and was introduced in Brazil during the slavery years. It is a perennial species that is robust and rhizomatous, with glaucous culms (Kissmann, 1997).

The present study was conducted to test the hypothesis that the efficacy of S-metolachlor is not affected by sugar cane crop residue remaining on the soil surface after mechanical harvest. The aim of this study was to assess the efficacy of the herbicide S-metolachlor applied in pre-emergence conditions for the control of *Brachiaria decumbens*, *Digitaria horizontalis,* and *Panicum maximum* in areas where sugar cane was mechanically harvested without previously burning the plants with the crop harvest residue either left or not on the soil surface.

MATERIAL AND METHODS

Two experiments were conducted in a commercial sugar cane producing area from November 2010 to July 2011. The areas were chosen on the basis of the levels of sugar cane plant residue left covering the soil surface: 14 t ha^{-1}, in the first experiment, and 20 t ha^{-1}, in the second.

The first experiment was conducted at the "São José" farm located in Guariba, a municipality of the state of São Paulo, in a first cut area, where 'CTC 9' was the sugar cane variety grown. The second experiment was conducted at the "Fronteira" farm, also in the municipality of Guariba, in a fourth cut area, where the variety was 'SP 903723'.

The experiments were conducted utilizing a randomized complete block design with four repetitions in a 7 x 2 split-plot scheme. In these plots, five herbicide treatments were studied (S-metolachlor at 1.44, 1.92, and 2.40 kg ha^{-1}, clomazone at 1.20 kg ha^{-1}, and isoxaflutole at 0.188 kg ha^{-1}) along with two control treatments, one in which no herbicide was applied and the infesting weeds were left alone and one in which the weeds were manually pulled out. In the split-plots, the presence or absence of crop residue on the soil surface was evaluated.

Clomazone and isoxaflutole were included in the experiment as standard commercial herbicides to control the target species under conditions of crop residue left covering the soil surface (Rodrigues & Almeida, 2011).

The plots (herbicide/control treatments) were 6.0 m wide (four sugar cane lines) by 12.0 m long, comprising a total area of 72.0 m^2. Sub-plots (crop residue left or not) were demarcated within the plots, each one 6.0 m wide by 6.0 m long, totaling 18.0 m^2 (4.5 x 4.0 m) for the area in which the observations were actually made.

After cutting the sugar cane plants and before applying the herbicides, the areas were artificially infested with *B. decumbens* (1.0 g of seeds m^{-2} - 0.65 g of seeds for emergence 25 plants), *D. horizontalis* (0.122 g of seeds m^{-2}, 0.15 g of seeds for emergence 25 plants), and *P. maximum* (0.156 g of seeds m^{-2}, 0.17 g of seeds for emergence 25 plants). Before sowing the seeds, the crop residue accumulated between the lines was removed and piled onto the lines using a garden rake. Then, a superficial straight furrow (up to 3 cm deep), where the seeds were placed, was opened between the rows with a garden hoe. Next, the crop residue in the indicated treatments was replaced so that the space between the rows was fully covered. In the other treatments (no crop residue covering the soil surface), the crop residue was, before sowing, completely removed both from the lines and the spaces between lines.

The herbicides were applied before the emergence of the weeds and at the beginning of the sugar cane sprouting. The application of the herbicides was made with a backpack sprayer operating at a constant pressure (maintained by compressed CO_2) of 2.0 kgf cm^{-2}. The edaphic and climatic conditions of the field at the moment that the herbicides were applied are presented in Table 1.

In the first experiment, the sugar cane plants sprouted in almost 90% of the area, and each showed 2 to 3 leaves. In the second experiment, the sugar cane plants sprouted in 50% of the area, and each showed 2 to 3 leaves. A scale ranging from 0 to 100 was used to grade the sugar cane plants that sprouted, where 0 indicated the absence of plants sprouted and 100 all the plants sprouted.

Possible visual injuries in the sugar cane plants were evaluated at 13 and 11, 32 and 30, 66 and 64 days after the application of the herbicides (DAA) for the first and second experiments, respectively. A scale ranging from 0 to 100 was used to grade the visible injury level in the plants, where 0 meant the absence of any visual injury and 100 indicated a dead plant.

The control of weeds was visually assessed at 32 and 94 DAA in the first experiment and at 30 and 92 DAA in the second experiment. A scale, expressed in percentage, ranging from 0 to 100, was used to grade the level of control achieved by the herbicides, where 0 meant no control and 100 was total control. For this, all treatments were compared with the control treatment (infested, no herbicide, and no crop residue on the soil surface).

Weed density in the control treatment (infested, no herbicide, and no crop residue

Table 1 - Air and soil temperature, air relative humidity and wind speed at the beginning and end of the application of the herbicides along with the date and time of the sprayings and soil moisture

Experiment	Date	Time	Temperature (ºC)		Air relative humidity (%)	Wind speed (km h^{-1})	Nebulosity (%)	Soil moisture
			Air	Soil				
First	02/11/2010	10:30 - 11:45	27.2 - 30.1	23.1 - 23.5	60 – 49	7.1 - 12.9	0 - 10	Dry at the surface but with good moisture at 5 cm of depth.
Second	04/11/2010	9:50 - 11:00	27.9 - 30.3	22.5 - 22.7	58 – 47	13.5 - 7.8	0 - 10	Dry at the surface but with good moisture at 5 cm of depth.

on the soil surface) was evaluated at 45 and 43 DAA, respectively, for the first and second experiments. This evaluation was accomplished by counting the number of weed plants of each of the three species in a 1.0-m^2 area.

At 248 DAA in the first experiment and 266 DAA in the second experiment, the number of visible viable culms along an 8-m-long line was counted, and the height and diameter of 10 sugar cane culms randomly taken from each subplot were measured.

The results were submitted to the analysis of variance of the F test. The effects of the treatments, when significant, were compared by means of Tukey's test at the 5% level of probability. The interactions, when significant, were partitioned, and the means were compared by Tukey's test at the 5% level of probability.

RESULTS AND DISCUSSION

In the first experiment (0 and 14 t ha^{-1} of crop residue allowed to remain on the soil surface), the only species that had less than 10 plants m^{-2} in the absolute control treatment (no herbicide and no crop residue) was *D. horizontalis*. The values were 29.88, 8.88, and 11.00 plants m^{-2}, respectively for *B. decumbens*, *D. horizontalis*, and *P. maximum*. In the second experiment (0 and 20 t ha^{-1} of crop residue allowed to remain on the soil surface), *D. horizontalis* and *P. maximum* had less than 10 plants m^{-2} in the absolute control treatment, and the densities were 31.25, 5.75, and 8.25 plants m^{-2} for *B. decumbens*, *D. horizontalis*, and *P. maximum*, respectively.

The treatments influenced the results both in isolation and by interactions.

For *B. decumbens*, with both 14 and 20 t ha^{-1} of crop residue left covering the soil surface, the herbicide treatments had no significant difference in the control of that weed, which varied between 88 and 99% when the amount of crop residue was 14 t ha^{-1} and between 79 and 93% when the crop residue was 20 t ha^{-1} (Tables 2 and 3). However, when there was no crop residue covering the soil surface, S-metolachlor at 1.44 kg ha^{-1} was not effective in controlling that species while isoxaflutole showed the highest levels of control. Thus, under the situation of no crop residue present on the soil surface, the amount of S-metolachlor necessary for the control of *B. decumbens* at the level of 80 and 62% up to 94 and 92 DAA was 1.92 kg ha^{-1}.

The control of weeds in the second experiment, especially with *B. decumbens*, was directly affected by the poor development of the sugar cane crop after 30 DAA. Because of errors during the mechanical harvest, which damaged part of the ratoon plants, the sprouting of the sugar cane culms was hindered, bringing about stand failures and jeopardizing the development of the plants' canopy and, therefore, the shading of the soil surface. Thus, the weed plants at 30 DAA that did not have their growth hampered by the canopy shade grew quickly in the plots. The negative effects of the control by the herbicides at 92 DAA, therefore, did not result from the new weed plants' emergence fluxes but actually resulted from the absence of cultural management, which is essential to complement the action of herbicides.

When the crop residue conditions are compared in each herbicide treatment, in the first experiment (0 and 14 t ha^{-1}) at 32 DAA, for S-metolachlor at 1.44 and 2.40 kg ha^{-1}, for clomazone and for the control treatment, *B. decumbens* was more efficiently controlled when the crop residue was covering the soil surface. When the other treatments are analyzed, the presence or absence of crop residue was not statistically significant. At 94 DAA, S-metolachlor at 1.44 kg ha^{-1}, clomazone, and the control treatment were more effective when the crop residue was covering the soil surface. In the second experiment (0 and 20 t ha^{-1}), it was verified, as a general result, that the presence of crop residue covering the soil surface enhanced the effects of S-metolachlor at the three doses, clomazone and the control treatments on their capacity for controlling *B. decumbens* with gains in yield of up to 68%.

Crop residue alone, left on the soil surface at the levels of 14 and 20 t ha^{-1}, was sufficient for *B. decumbens* control efficiencies of 58 and 74% at 94 and 92 DAA, respectively. The inhibiting effect of sugar cane crop residue

Table 2 - Control of *Brachiaria decumbens* at 32 and 94 days after the application (DAA) of herbicides with and without sugar cane crop residue on the soil surface

Herbicides/ control treatment	Doses (kg ha^{-1})	32 DAA		94 DAA	
		Crop residue (t ha^{-1})			
		0	14	0	14
S-metolachlor	1.44	84.4 b B[1/]	92.1 a A	61.9 b B	88.1 a A
S-metolachlor	1.92	90.0 b A	92.5 a A	79.5 ab A	87.5 a A
S-metolachlor	2.40	89.4 b B	96.9 a A	81.9 a A	90.6 a A
Clomazone	1.20	90.0 b B	100.0 a A	76.2 ab B	93.8 a A
Isoxaflutole	0.188	99.8 a A	100.0 a A	93.1 a A	98.8 a A
Control treatment	-	0.0 c B	82.5 b A	0.0 c B	57.5 b A
LSD (line)		6.1		13.9	
LSD (column)		9.0		19.4	

[1/] In each column, means followed by small case letters compare the herbicide treatments in each amount of crop residue, and in the lines, means followed by capital letters compare the two amounts of crop residue in each herbicide treatment.

Table 3 - Control of *Brachiaria decumbens* at 30 and 92 days after application (DAA) of herbicides with and without sugar cane crop residue on the soil surface

Herbicides/ control treatment	Doses (kg ha^{-1})	30 DAA		92 DAA	
		Crop residue (t ha^{-1})			
		0	14	0	14
S-metolachlor	1.44	81.8 b B[1/]	95.6 a A	35.0 c B	79.4 a A
S-metolachlor	1.92	91.2 a A	96.9 a A	62.5 abc B	82.5 a A
S-metolachlor	2.40	92.5 a A	98.1 a A	67.5 ab B	86.9 a A
Clomazone	1.20	90.0 ab B	98.8 a A	53.8 bc B	89.5 a A
Isoxaflutole	0.188	98.1 a A	99.8 a A	90.0 a A	93.1 a A
Control treatment	-	0.0 c B	93.1 a A	0.0 d B	74.4 a A
LSD (line)		5.8		18.6	
LSD (column)		9.0		29.8	

[1/] In each column, means followed by small case letters compare the herbicide treatments in each amount of crop residue, and in the lines, means followed by capital letters compare the two amounts of crop residue in each herbicide treatment.

on the emergence of that species was also reported by Correia & Durigan (2004). According to these authors, the covering of the soil with raw sugar cane crop residue led to the loss of *B. decumbens* seed viability, as the ungerminated seeds, after crop residue removal, were incapable of germinating even under favorable environmental conditions. The authors attributed the loss of *B. decumbens* seed viability to physical, chemical, and/or biological factors inherent to the crop residue. It is, therefore, valid to conclude that sugar cane crop residue maintained as such on the soil surface interferes with *B. decumbens* seed germination and, consequently, in the soil seed bank composition.

When the soil surface was covered with the crop residue, the herbicides did not differ regarding the control level of *D. horizontalis* (Tables 4 and 5). When the crop residue was not covering the soil surface, in both evaluation times of the first experiment and at 30 DAA of the second one, no significant differences between the herbicides were detected. However, at 92 DAA of the second experiment, isoxaflutole was found to be the least efficient, with statistically significant differences with S-metolachlor at 1.92 and 2.4 kg ha^{-1} and with the infested control treatment.

In the first experiment, the conditions with and without crop residue did not differ within each herbicide treatment. These results are an indication that the efficacy of the herbicides in controlling *D. horizontalis* was not affected by the presence of 14 t ha^{-1} of crop residue on the soil surface. In the other experiment, a significant difference was observed only for isoxaflutole at 92 DAA between the presence and absence of crop residue, where the presence of crop residue resulted in a more efficient control of the weeds. For the other herbicides, independently of the evaluation time, the crop residue conditions did not differ statistically. In other words, keeping the soil covered with crop residue did not interfere with the performance of the herbicides. Indeed, the herbicide effects were complemented by the inhibitory effect of the crop residue on *D. horizontalis* seed germination.

At 94 and 92 DAA, *D. horizontalis* was controlled to 82% when the crop residue covering the soil was 14 t ha and to 88% at 20 t ha compared with no crop residue covering the soil surface. However, if an area highly infested with *D. horizontalis* is considered, these levels of control would not be satisfactory. At the same time, if low to median infestation levels such as those considered in this experiment (less than 10 plants m^2) are the case, the control level permitted by crop residue would be sufficient, and the use of herbicides solely for the control of *D. horizontalis* would not be justifiable. Correia & Durigan (2004) also observed that crop residue, at the amounts of 10 and 15 t ha^{-1} covering the soil surface, was capable of inhibiting *D. horizontalis* seedling emergence. However, when the amount of

Table 4 - Control of *Digitaria horizontalis* at 32 and 94 days after application (DAA) of herbicides with and without sugar cane crop residue on the soil surface

Herbicides/ control treatment	Doses (kg ha^{-1})	32 DAA		94 DAA	
		Crop residue (t ha^{-1})			
		0	14	0	14
S-metolachlor	1.44	100.0 a A[1/]	100.0 a A	99.4 a A	97.5 a A
S-metolachlor	1.92	100.0 a A	100.0 a A	100.0 a A	98.2 a A
S-metolachlor	2.40	100.0 a A	100.0 a A	100.0 a A	99.2 a A
Clomazone	1.20	100.0 a A	100.0 a A	100.0 a A	99.4 a A
Isoxaflutole	0.188	99.8 a A	100.0 a A	94.4 a A	100.0 a A
Control treatment	-	0.0 b B	96.2 b A	0.0 b B	81.9 b A
LSD (line)		1.9		7.7	
LSD (column)		2.790		11.0	

[1/] In each column, means followed by small case letters compare the herbicide treatments in each amount of crop residue, and in the lines, means followed by capital letters compare the two amounts of crop residue in each herbicide treatment.

Table 5 - Control of *Digitaria horizontalis* at 30 and 92 days after application (DAA) of herbicides with and without sugar cane crop residue on the soil surface

Herbicides/ control treatment	Doses (kg ha^{-1})	30 DAA		92 DAA	
		Crop residue (t ha^{-1})			
		0	14	0	14
S-metolachlor	1.44	100.0 a A[1/]	100.0 a A	93.1 ab A	93.8 a A
S-metolachlor	1.92	100.0 a A	100.0 a A	97.9 a A	95.6 a A
S-metolachlor	2.40	100.0 a A	100.0 a A	99.5 a A	95.0 a A
Clomazone	1.20	98.8 a A	100.0 a A	93.1 ab A	99.4 a A
Isoxaflutole	0.188	99.2 a A	100.0 a A	82.5 b B	98.1 a A
Control treatment	-	0.0 b B	98.8 a A	0.0 c B	87.5 a A
LSD (line)		1.6		12.0	
LSD (column)		2.1		13.9	

[1/] In each column, means followed by small case letters compare the herbicide treatments in each amount of crop residue, and in the lines, means followed by capital letters compare the two amounts of crop residue in each herbicide treatment.

crop residue was 5 t ha^{-1}, that is, lower than the previously mentioned values, the seedling emergence inhibiting effect was not observed.

In the first experiment, the control exerted by the herbicides of *P. maximum* was not statistically different when the amount of crop residue on the soil surface was 14 t ha^{-1} (Table 6). When no crop residue was present, the herbicides at 32 DAA showed no significant difference in their ability to control *P. maximum*. However, at 94 DAA, clomazone had the best performance in controlling *P. maximum*, differing significantly only from the lowest dose of S-metolachlor (1.44 = kg ha^{-1}) and from the infested control treatment. In the second experiment, at both crop residue conditions, the herbicide treatments did not differ significantly among themselves, resulting in control levels of 94 to 100% and of 83 to 100%, respectively, for the conditions of the presence and absence of crop residue at 92 DAA (Table 7).

When the crop residue conditions were compared for each of the herbicide treatments, it was observed in both experiments that the efficacy of the herbicides in controlling *P. maximum* was not affected by whether the crop residue was present. It was also observed that in the control treatment with crop residue, the presence of *P. maximum* plants in the plots was lower than in the plots of the control treatment without crop residue. That is, the control of the weed when the crop residue amount was 14 t ha^{-1} was 58% and at 10 t ha^{-1} was 85% at 94 and 92 DAA.

Table 6 - Control of *Panicum maximum* at 32 and 94 days after the application (DAA) of herbicides with and without sugar cane crop residue on the soil surface

Herbicides/ control treatment	Doses (kg ha^{-1})	32 DAA		94 DAA	
		Crop residue (t ha^{-1})			
		0	14	0	14
S-metolachlor	1.44	96.6 a A[1/]	98.1 a A	78.1 b A	86.9 a A
S-metolachlor	1.92	99.8 a A	100.0 a A	86.9 ab A	95.6 a A
S-metolachlor	2.40	98.2 a A	99.4 a A	93.8 ab A	95.6 a A
Clomazone	1.20	100.0 a A	100.0 a A	100.0 a A	100.0 a A
Isoxaflutole	0.188	100.0 a A	100.0 a A	93.1 ab A	98.5 a A
Control treatment	-	0.0 b B	93.1 b A	0.0 c B	57.5 b A
LSD (line)		3.3		15.4	
LSD (column)		4.6		19.5	

[1/] In each column, means followed by small case letters compare the herbicide treatments in each amount of crop residue, and in the lines, means followed by capital letters compare the two amounts of crop residue in each herbicide treatment.

Table 7 - Control of *Panicum maximum* at 30 and 92 days after application (DAA) of herbicides with and without sugar cane crop residue on the soil surface

Herbicides/ control treatment	Doses (kg ha^{-1})	30 DAA		92 DAA	
		Crop residue (t ha^{-1})			
		0	14	0	14
S-metolachlor	1.44	98.1 a A[1/]	98.8 a A	83.1 a A	93.8 a A
S-metolachlor	1.92	100.0 a A	100.0 a A	90.8 a A	93.8 a A
S-metolachlor	2.40	100.0 a A	100.0 a A	83.8 a A	93.8 a A
Clomazone	1.20	100.0 a A	100.0 a A	100.0 a A	100.0 a A
Isoxaflutole	0.188	100.0 a A	100.0 a A	100.0 a A	100.0 a A
Control treatment	-	0.0 b B	96.9 a A	0.0 b B	85.0 a A
LSD (line)		2.7		14.8	
LSD (column)		3.6		20.4	

[1/] In each column, means followed by small case letters compare the herbicide treatments in each amount of crop residue, and in the lines, means followed by capital letters compare the two amounts of crop residue in each herbicide treatment.

Contrary to the observations made in this experiment, when bean was directly sown under corn crop residue, the herbicide metolachlor was not detected 15 days after its application in any of the soil layers (0-5, 5-10, and 10-15 cm) submitted to analysis (Fontes et al., 2004). Teasdale et al. (2003) also verified metolachlor to be present in lower initial concentrations in the soil solution when the herbicide had been sprayed over the residue of *Vicia villosa*, which resulted in the poor control of *Panicum dichotomiflorum*. In both works, the authors ascribed the results to the retention of the herbicide by the plant residues covering the soil surface and to increased losses of the herbicides to the surrounding environment. It is worth noting that S-metolachlor is a stereoisomer of metolachlor (Blaser, 2002) with a higher biological activity (Munoz et al., 2011) and that the amount of rain and the period during which the rainfall occurred after the herbicide was applied may have had an important effect on the retention of the herbicide.

Oliveira et al. (2001) observed that the low precipitation during the first days after the mixture of atrazine and metolachlor was applied may explain the low removal of the metolachlor from the plant residues to the soil. Correspondingly, Cavenaghi et al. (2007) reported that in amounts of crop residue equal to or higher than 5 t ha^{-1}, the herbicide amicarbazone was almost completely intercepted so that the amount of the product capable of reaching the soil when it was being applied was practically zero. However, a 20 mm rain that fell over the area was important for the removal of a large part of the herbicide. When the applied mixture was clomazone and hexazinone, 2.5 mm of rain was sufficient to wash it away from sugar cane crop residue at a rate of 5.0 t ha^{-1} (Negrisoli et al., 2011).

The rain volume up to 28 days after the herbicides were applied is shown in Figure 1. The amount of rain that fell during that period, although sufficient to remove S-metolachlor from the sugar cane crop residue to the soil, was not capable of checking its capacity to control the weeds. In the first 20 days after the herbicides were applied in both experimental areas, it rained approximately 70 mm.

The herbicides had significant effects on the phytointoxication grades at 13 or 12 DAA and at 32 or 30 DAA (Table 8). Clomazone and isoxaflutole caused visible injuries to the plants, and these injuries were classified as moderate (from 9 to 18% in the first experiment and from 8 to 17% in the second). These injuries disappeared up to 66 or 64 DAA. The symptoms were confined to the leaves, which were directly exposed to the spray jet. These symptoms were characterized by chlorosis, a whitening of the leaves (clomazone was the only application capable of causing this

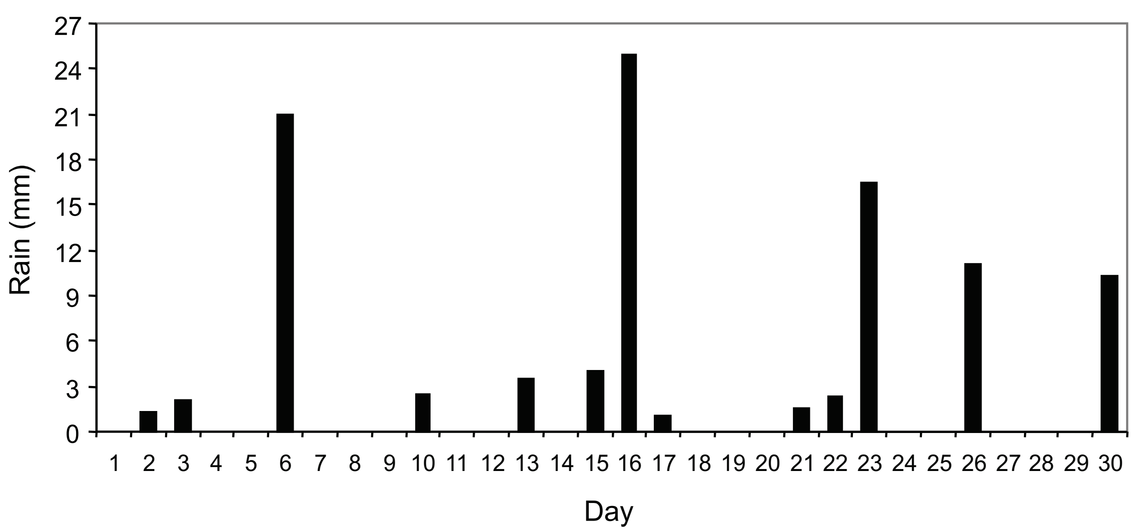

Figure 1 - Daily precipitation during the period from 01 to 30 of November 2010 registered by the Agroclimatological Station situated 5 km from the two experimental areas.

Table 8 - Phytointoxication grades in the sugar cane crop at 13 or 11 days after application (DAA) of herbicides and at 32 or 30 DAA in the first (0 and 14 t ha^{-1} of crop residue) and the second (0 and 20 t ha^{-1} of crop residue) experiments

Herbicides/ check treatment	Doses (kg ha^{-1})	First experiment		Second experiment	
		Evaluation moment - DAA			
		13	32	11	30
S-metolachlor	1.44	0.0 a[1/]	0.0 a	0.0 a	0.0 a
S-metolachlor	1.92	0.0 a	0.0 a	0.0 a	0.0 a
S-metolachlor	2.40	0.0 a	0.0 a	0.0 a	0.0 a
Clomazone	1.20	17.6 c	3.8 b	17.5 c	3.8 a
Isoxaflutole	0.188	9.4 b	8.1 a	8.8 b	0.0 a
Check treatment	-	0.0 a	0.0 a	0.0 a	0.0 a
LSD		4.2	3.7	5.6	4.5

[1/] Means followed by the same letter are not statistically different at the 5% level of probability according to Tukey's test.

reaction) and necrosis of the leaf margins. None of these injurious effects were observed when the herbicide was S-metolachlor, independently of dose.

However, although variations were observed in the degrees of phytointoxication and in the control of weeds, the herbicide treatments and the interaction of herbicides x crop residue had no significant detrimental effect on the number of viable sugar cane culms m^2 or on the height and the diameter of the culms in both experiments. It is nonetheless important to emphasize that the presence of crop residue covering the soil surface – although it was observed only in the second experiment – may affect the development of the culms: when there was no crop residue, the sugar cane culms were taller and had a lower diameter (Table 9).

From the results, the following conclusions were drawn: the efficacy of the herbicide S-metolachlor to control *Brachiaria decumbens*, *Digitaria horizontalis*, and *Panicum maximum* was not reduced by the presence of either 14 or 20 t ha^{-1} of sugar cane crop residue covering the soil surface. When the sugar cane crop residue was covering the soil surface, S-metolachlor at a rate of 1.44 kg ha^{-1} resulted in weed control similar at their larger rates, whereas without the presence of crop residue, S-metolachlor controlled *B. decumbens*, *D. horizontalis*, and *P. maximum* at the rates of 1.92, 1.44, and 1.92 kg ha^{-1}, respectively. The herbicides clomazone and isoxaflutole were effective for the studied species, independently of the crop residue covering the soil surface. S-Metolachlor caused no visible injury symptoms to the sugar cane plant. Clomazone and isoxaflutole caused visible injuries to the sugar cane plant. None of the herbicides negatively affected the number of viable culms m^2 or the culm height and diameter.

Table 9 - Height and diameter of sugar cane culms at 266 days after the application of herbicides as functions of the presence or absence of the crop residue on the soil surface

Crop residue (t ha^{-1})	Culm height (m)	Culm diameter (cm)
0	1.7 a[1/]	2.3 b
20	1.6 b	2.4 a
LSD	0.1	0.1

[1/] Means followed by the same letter are not statistically different at the 5% level of probability according to Tukey's test.

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