PLANTA DANINHA

SBCPD
SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS
<http://www.sbcpd.org>

ISSN 0100-8358 (print)
1806-9681 (online)

Article

Selectivity of Herbicide Associations with Chemical Protector in the Treatment of Sweet Sorghum Hybrid Seeds

Seletividade de Associações de Herbicidas com Uso de Protetor Químico no Tratamento de Sementes de Híbridos de Sorgo Sacarino

MACIEL, C.D.G.[1]*
OLIVEIRA NETO, A.M.[2]
GUERRA, N.[3]
LEAL, G.B.[4]
SILVA, A.A.P.[1]
SOARES, C.R.B.[1]
KARPINSKI, R.A.K.[1]

*** Corresponding author:**
<cmaciel@unicentro.br>

Received: July 25, 2016
Approved: August 5, 2016

Planta Daninha 2017; v35:e017167026

ABSTRACT - Sweet sorghum culture is an alternative to sugar and ethanol production. With the aim of evaluating herbicide tank-mix selectivity associated or not to sweet sorghum seed treatment with naphthalic anhydride, two experiments with ESX5200 and EJX7C5110 hybrids were performed in red oxisol (clayey) field conditions, in the municipality of Campo Mourão, Paraná state. A randomized block design was used, with 4 x 2 factorial scheme, with four replications. The first factor represented three herbicide associations and a control sample without herbicide, and the second factor was constituted by the absence or presence of seed treatment with naphthalic anhydride (5.0 g kg^{-1}). Herbicide treatments were tank-mixes of atrazine + S-metolachor (2,640 + 480 g ha^{-1}) (pre-emergence); atrazine + S-metolachlor + isoxaflutole (2,640 + 480 + 11.25 g ha^{-1}) (pre-emergence) and atrazine + S-metolachlor (1,500 + 384 g ha^{-1}) (post-emergence). The following characteristics were evaluated: intoxication, plant height, stalk diameter, number of internodes per stalk and plant density, performed 60 days after emergence (DAE); stalk yield and Brix, were evaluated on day 85 DAE. Atrazine + S-metolachlor tank-mix applied in pre or post-emergence did not affect growth, development, yield and stalk quality of the ESX5200 and EJX7C5110 sweet sorghum hybrids. Sweet sorghum seed treatment with naphthalic anhydride provided partial protection against the action of atrazine + s-metolachlor + isoxaflutole tank-mixes, being more evident for the ESX5200 hybrid.

Keywords: naphthalic anhydrid, *Sorghum bicolor*, tank-mix, *safener*.

RESUMO - A cultura do sorgo sacarino tem sido uma alternativa para produção de açúcar e álcool. Com o objetivo de avaliar a seletividade de misturas em tanque de herbicidas associadas ou não ao tratamento de sementes de sorgo sacarino, como o protetor químico anidrido naftálico, um experimento com os híbridos ESX5200 e EJX7C5110 foi instalado em área de Latossolo Vermelho distroférrico (textura muito argilosa), em Campo Mourão-PR. O delineamento utilizado foi o de blocos casualizados, em esquema fatorial 4 x 2, com quatro repetições. O primeiro fator representou três associações de herbicidas e uma testemunha sem aplicação, e o segundo, a ausência ou presença do tratamento de sementes com anidrido naftálico (5,0 g kg^{-1}). Os tratamentos herbicidas foram as misturas em tanque de atrazine + S-metolachlor (2.640 + 480 g ha^{-1}) (pré-emergência); atrazine + S-metolachlor + isoxaflutole (2.640 + 480 + 11,25 g ha^{-1}) (pré-emergência); e atrazine + S-metolachlor (1.500 + 384 g ha^{-1}) (pós-emergência). As avaliações foram: intoxicação, altura de plantas, diâmetro do colmo, número de entrenós no colmo e estande, realizadas aos 60 dias após emergência (DAE); produtividade

[1] Universidade Estadual do Centro-Oeste, PPGA/UNICENTRO, Guarapuava-PR, Brasil; [2] Instituto Federal Catarinense, IFC, Rio do Sul-SC, Brasil; [3] Universidade Federal de Santa Catarina, UFSC, Curitibanos-SC, Brasil; [4] Faculdade Integrado de Campo Mourão, Campo Mourão-PR, Brasil.

Doi: 10.1590/S0100-83582017350100021

de colmos e teor de sólidos solúveis (ºBrix), realizadas aos 85 DAE. A mistura em tanque de atrazine + S-metolachlor, aplicados em pré ou pós-emergência, não alterou o crescimento, desenvolvimento, produtividade e qualidade de colmo dos híbridos de sorgo sacarino ESX5200 e EJX7C5110. O tratamento de sementes de sorgo sacarino com anidrido naftálico proporcionou proteção parcial contra a ação das misturas de atrazine + S-metolachlor e atrazine + S-metolachlor + isoxaflutole, sendo mais evidente para o híbrido ESX5200.

Palavras-chave: anidrido naftálico, *Sorghum bicolor*, mistura em tanque, *safener*.

INTRODUCTION

Sorghum can be classified as sweet, grain or fodder; the former, as well as producing a grain amount similar to the one produced by grain sorghum, presents stalks that are rich in sugar, with ºBrix oscillating from 14 to 22% (Almodares and Hadi, 2009). Some characteristics make sweet sorghum an excellent culture option, among which it is possible to highlight: short cycle, good yield with stalks rich in sugar, grains for animal feeding, tolerance to dry periods and possibility of being cultivated in all Southeastern Brazil (Teixeira et al.,1997, 1999). However, one of the obstacles to sweet sorghum production is weed management (May, 2011), due to the reduced number of herbicides registered for this culture (Correia and Gomes, 2015; AGROFIT, 2016). Normally, recommendations are only based on atrazine use both for Dicotyledons and some Monocotyledons weeds, applied during pre- or post-initial emergence.

An alternative to increase the number of herbicide treatments that are selective to sweet sorghum would be the use of chemical protectors, also known as safeners, which may be applied via seed treatment or mixed with herbicides as a formulation component (Galon et al., 2011). Safeners protect cultivated species from the herbicide action, avoiding injuries that may harm emergence or stand, as well as culture development itself (Alterman and Jones, 2003), since they normally present high specificity level (Cataneo et al., 2013).

Research results showed the protective effect of naphthalic anhydride safener for grain sorghum (Maciel, 2004), as well as for maize (Maciel et al., 2012) and white oats cultures (Rizzardi and Serafini, 2001). As for sweet sorghum, Correia and Gomes (2015) demonstrated that Na-bentazon acted as an effective protector to reduce the effects of saflufenacil herbicide, applied on CVSW 800007 hybrid during post-emergence.

Thus, the hypothesis of this work was that treating sweet sorghum seeds with naphthalic anhydride (acting as a protector), would be an effective alternative to improve the selectivity of treatments that involve the association among atrazine, S-metolachor and isoxaflutole herbicides, increasing the quantity of selective treatments for the culture. Therefore, the goal of this study was to evaluate the selectivity of atrazine, S-metolachlor and isoxaflutole herbicide tank-mixes, associated or not to treating two sweet sorghum hybrids seeds with naphthalic anhydride chemical protector.

MATERIAL AND METHODS

The work was composed of two experiments, performed in the city of Campo Mourão - Paraná state, located at the following coordinates: 23º59'31" S latitude, 52º21'31" O longitude and 538 m altitude. Soil in the experiment area is classified as Distroferric Red Latosol, with clay texture (Embrapa, 2013). The chemical analysis of soil was composed of: 6.31 water pH; 3.77 $cmol_c\ dm^{-3}$ H+Al; 0.54 $cmol_c\ dm^{-3}$ K; 5.13 $cmol_c\ dm^{-3}$ Ca; 2.18 $cmol_c\ dm^{-3}$ Mg; 28.61 $mg\ dm^{-3}$ P; 2.85% MO; 67.56% base saturation; 760 $g\ kg^{-1}$ clay; 110 $g\ kg^{-1}$ silt; e 130 $g\ kg^{-1}$ sand. The predominant climate in the region is subtropical humid, classified as Cfa by Köppen, characterized by hot summer, infrequent frosts and rain concentrations in summer, but with undefined dry season (Iapar, 2000).

The experimental design used in the two experiments was the randomized block one, in 4 x 2 factor scheme, with four replications. The first factor represented three herbicide associations, applied during culture pre- or post-emergence, and one control sample with no application; the second one was the absence or presence of seed treatment with naphthalic anhydride chemical protector, in the 5.0 g kg^{-1} dose. The used herbicide associations were tank-mixes of atrazine + S-metolachlor (2,640 + 480 g ha^{-1}) in pre-emergence, atrazine + S-metolachlor + isoxaflutole (2,640 + 480 + 11.25 g ha^{-1}) in pre-emergence and atrazine + S-metolachlor (2,640 + 384 g ha^{-1}) in post-emergence, when the culture was in plant development stage, represented by four to five totally expanded leaves.

In the two experiments, seeding was made with ESX5200 and EJX7C5110 sweet sorghum hybrids on 01/21/2014, using 50 kg ha^{-1} P_2O_5 and 30 kg ha^{-1} K_2O fertilizing and density of approximately 16 seeds per linear meter. As top dressing, 40 kg ha^{-1} N were used, in the urea form. Seeding was performed in twin rows, using 0.45 m distance between simple rows and 0.90 m between double rows; each experimental unit occupied a 20 m^2 area.

The application of herbicide treatments in the two experiments was performed on the same day, using a costal sprayer constantly pressurized by CO_2, under 207 kPa pressure, equipped with a six-AVI 110.02 VS nozzle bar, spaced 50 cm apart and at 50 cm height from soil, with 3.6 km h^{-1} travel speed and 200 L ha^{-1} spray consumption. In application during pre- (01/21/2014) and post-emergence (02/19/2014), the average conditions of relative air humidity, temperature and wind speed were, respectively, 28 and 30 ^oC, 56 and 48% and 0.8 and 1.8 km h^{-1}.

It is important to highlight that the experiments were kept free from weed infestation and interference during all culture cycle, through three manual weeding in all treatments. In addition, in order to control caterpillars such as the fall armyworm, two applications of lamba cyhalothrin + thiamethoxam insecticide (Engeo Pleno®, in the 150 mL pc ha^{-1} dose) were performed during all culture cycle.

Phytointoxication evaluations of the culture aerial part were performed on day 7, 14, 21, 28, 35 after culture emergence (DAE), using the visual grading scale of the European Weed Research Council (EWRC, 1964), with grades from 1 to 9, being 1 injury absence and 9 plant death. The evaluated agronomic variables were: plant height (soil to leaf +1); stalk average diameter (measured at 10cm height in relation to soil); number of internodes per stalk (10 plants were evaluated in each experimental unit); and stand, in which the number of plants in four linear meters in two rows was quantified. These evaluations were performed on day DAE.

Evaluations for stalk productivity and soluble solid content (^{o}Brix) were performed on day 85 DAE. In order to evaluate stalk productivity, three linear meters of two central simple rows from each part were collected, and results were extrapolated to kg ha^{-1}. For soluble solid content evaluation, 10 plants per experimental unit were sampled, and the ^{o}Brix was determined with the help of a portable digital refractometer.

The obtained data were submitted to analysis of variation by F test, and the averages were compared by *t* test (LSD) and 5% probability ($p<0,05$).

RESULTS AND DISCUSSION

The association of atrazine + S-metolachlor herbicides, applied during pre- or post-emergence, did not cause expressive intoxication in ESX5200 and EJX7C5110 sweet sorghum hybrids (Table 1). On the whole, symptoms were represented by at most grade two from the EWRC (1964) scale, constituted by slight discoloration and size reduction, only visible in some plants, mainly for the absence of naphthalic anhydride seed treatment. Geier et al. (2009) also reported low intoxication levels with the application of atrazine + S-metolachlor on grain sorghum.

On the other hand, the atrazine + S-metolachlor + isoxaflutole mix caused higher intoxication levels in sweet sorghum hybrids, mainly for the absence of naphthalic anhydride seed treatment, in which visual grades higher than 6.0 in the EWRC (1964) scale were observed. In this treatment, symptoms were leaf depigmentation (whitening), followed by purplish striated spots and consequent foliar tissue necrosis, easily identified up to day 21 and 35 DAE respectively, for ESX5200 and EJX7C5110 cultures (Table 1). Whitening symptoms that occur on sorghum leaves are quite known and directly related to the action mechanism of isoxaflutole herbicide, which acts on plants blocking the p-hydroxyphenylpyruvate dioxygenase (HPPD) enzyme; it is a key-enzyme in

Table 1 - Grades with intoxication levels on day 7, 15, 21 and 35 DAE for ESX 5200 and EJX7C5110 sweet sorghum hybrids, submitted to herbicide associations and seed treatment (TS) with naphthalic anhydride chemical protector. Campo Mourão, Paraná state, 2014

Herbicide treatment	Intoxication (EWRC scale) - ESX 5200 hybrid							
	7 DAE		15 DAE		21 DAE		35 DAE	
	With TS(4)	Without TS	With TS	Without TS	With TS	Without TS	With TS	Without TS
Control sample	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Atrazine + S-metolachlor(1)	1.25	1.25	1.25	1.75	1.25	1.75	1.00	1.00
Atrazine + S-metolachlor+isoxaflutole(2)	4.50	6.00	3.50	6.25	3.50	6.25	3.50	4.25
Atrazine + S-metolachlor(3)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Intoxication (EWRC scale) - EJX7C5110 hybrid							
Control sample	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Atrazine + S-metolachlor(1)	1.25	2.25	1.25	2.00	1.25	2.00	1.00	1.00
Atrazine + S-metolachlor+isoxaflutole(2)	3.50	5.50	2.00	3.75	2.00	3.75	1.00	1.00
Atrazine + S-metolachlor(3)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

(1) (2,640 + 480 g ha^{-1}) in pre-emergence; (2) (2,640 + 480 + 11.25 g ha^{-1}) in pre-emergence; (3) (1,500 + 384 g ha^{-1}) in post-emergence; (4) (5 g kg^{-1}) in seeds.

the carotenoides biosynthesis route (Senseman, 2007; Rodrigues and Almeida, 2011). The whitening symptom is the result of a set of factors that involve carotenoids biosynthesis inhibition, chlorophyll destruction by light and chlorophyll biosynthesis inhibition (Hess, 2000).

The protective action of treating seeds with naphthalic anhydride (safener) was evident in sweet sorghum hybrids, mainly against the atrazine + S-metolachlor + isoxaflutole mix (Table 1). With this mix, injuries were reduced by approximately 50%, but it was not enough to completely nullify visual damages in the aerial part of plants. During intoxication evaluations, it was observed that EJX7C5110 hybrid appeared to be more tolerant than ESX 5200. As for the protective effect of treating seeds with naphthalic anhydride, similar results were reported in other researches for grain sorghum (Maciel, 2004), maize (Maciel et al., 2012), and white oats (Rizzardi and Serafini, 2001) cultures.

So far, the accepted hypothesis is that protectors activate the metabolic mechanisms of plants (Galon et al., 2011), acting over the already known detoxification tracts, such as enzymes from the P450 cytochrome complex and reactions from the connection with glutathione S-transferase (GST) and glucosyltransferase (Cataneo et al., 2013). For sorghum culture, one of the mechanisms that naturally give selectivity to HPPD inhibitor herbicides is metabolism. Abit and Al-Khatib (2009) demonstrated that a grain sorghum hybrid that is tolerant to HPPD inhibitor herbicide (mesotrione) presented higher metabolic rate of this herbicide. Thus, the lowest intoxication possibly observed in plants treated with naphthalic anhydride could be due to metabolic mechanisms of sweet sorghum. Differences between hybrids may also be associated to the metabolic ability resulting from each hybrid's genetics.

As for cultural characteristics referring to plant height, stalk diameter, internodes number and stand of sweet sorghum culture, on day 60 DAE no significant difference was observed between the herbicide treatments and the sample with no application, as well as for the treatment or non-treatment of seeds with naphthalic anhydride (Table 2). These results comply with the ones observed by Geier et al. (2009), who did not identify significant reductions in the grain sorghum stand with the application during pre-emergence of atrazine + S-metolachlor, in the 1.12 + 1.4 and 1.12 + 2.8 kg ha^{-1} doses.

The results indicate that, despite noticing visual intoxication mainly for the atrazine + S-metolachlor + isoxaflutole mixes and, in lower intensity, for atrazine + S-metolachlor in pre-emergence application, the effects were not enough to damage recovery and proper plant development of ESX5200 and EJX7C5110 sweet sorghum cultures. However, high soil contents of clay and organic matter may also have positively influenced culture selectivity due to the lower herbicide availability for soil solution, since the sorption of atrazine (Procópio et al., 2001), isoxaflutole (Oliveira Jr et al., 2006) and S-metolachlor (Gannon et al., 2013) herbicides presents direct correlation with soil organic matter.

Stalk productivity results indicate that the ESX5200 hybrid was less tolerant to the effects of the studied herbicide treatments, especially for the atrazine + S-metolachlor + isoxaflutole association, regardless of seed treatment with naphthalic anhydride (Table 3), supporting intoxication evaluations. Correia and Gomes (2015) also observed differentiated tolerance to saflufenacil herbicide among sweet sorghum hybrids. As for soluble solid content of the mixture, it was observed that treating seeds with naphthalic anhydride significantly increased this variable for the ESX5200 hybrid.

In relation to EJX7C5110 hybrid, it was observed that the use of naphthalic anhydride protector in seed treatment showed an effective strategy to guarantee raw material quality of stalks that received the application of atrazine + S-metolachlor + isoxaflutole tank-mix during pre-emergence (Table 3).

Table 2 - Plant height (cm), stalk diameter (cm), number of internodes per stalk (n) and stand (plants in 4 linear meters) on day 60 DAE of ESX 5200 and EJX7C5110 sweet sorghum hybrids, submitted to herbicide associations and seed treatments (TS) with naphthalic anhydride chemical protector. Campo Mourão, Paraná state, 2014

ESX 5200 hybrid	Plant height		Stalk diameter		Internodes number		Stand	
Herbicide treatment	60 DAE							
	With TS(4)	Without TS	With TS	Without TS	With TS	Without TS	With TS	Without TS
Control sample	232.6 Aa	228.7 Aa	5.47 Aa	4.51 Aa	8.35 Aa	8.45 Aa	31.4 Aa	37.9 Aa
Atrazine + S-metolachlor(1)	203.9 Aa	240.7 Aa	5.14 Aa	5.38 Aa	7.60 Aa	8.75 Aa	32.3 Aa	39.0 Aa
Atrazine + S-metolachlor+isoxaflutole(2)	213.7 Aa	206.3 Aa	5.08 Aa	4.91 Aa	7.70 Aa	7.45 Aa	32.3 Aa	30.8 Aa
Atrazine + S-metolachlor(3)	238.7 Aa	230.9 Aa	5.68 Aa	5.59 Aa	8.85 Aa	8.45 Aa	33.6 Aa	33.8 Aa
VC (%)	15.61		13.44		14.32		17.54	
EJX7C5110 hybrid	60 DAE							
Control sample	216.9 Aa	214.9 Aa	5.08 Aa	4.75 Aa	8.20 Aa	8.20 Aa	62.9 Aa	60.1 Aa
Atrazine + S-metolachlor(1)	216.9 Aa	216.2 Aa	4.86 Aa	4.92 Aa	8.05 Aa	7.75 Aa	64.3 Aa	58.1 Aa
Atrazine + S-metolachlor+isoxaflutole(2)	198.4 Aa	219.1 Aa	4.75 Aa	5.24 Aa	7.55 Aa	8.15 Aa	56.6 Aa	58.4 Aa
Atrazine + S-metolachlor(3)	209.6 Aa	221.6 Aa	4.88 Aa	4.89 Aa	8.05 Aa	8.35 Aa	60.2 Aa	62.3 Aa
VC (%)	7.06		9.58		10.51		13.11	

(1) (2,640 + 480 g ha^{-1}) in pre-emergence; (2) (2,640 + 480 + 11.25 g ha^{-1}) in pre-emergence; (3) (1,500 + 384 g ha^{-1}) in post-emergence; (4) (5 g kg^{-1}) in seeds. - Averages with the same lowercase letter in the column and the same capital letter on the line do not different among themselves by *t* test at 5% probability.

Table 3 - Stalk productivity (kg ha^{-1}) and soluble solid content (°Brix) on day 85 DAE of ESX 5200 and EJX7C5110 sweet sorghum hybrids, submitted to herbicide associations and seed treatment (TS) with naphthalic anhydride chemical protector. Campo Mourão, Paraná state, 2014

Herbicide treatment	ESX 5200 hybrid				EJX7C5110 hybrid			
	Productivity (kg ha^{-1})		°Brix		Productivity (kg ha^{-1})		°Brix	
	With TS(4)	Without TS	With TS	Without TS	With TS	Without TS	With TS	Without TS
Control sample	67046 Aa	57539 Aab	10.54 Aa	9.84 Aa	82929 Aa	75354 Aa	8.31 Aa	9.08 Aa
Atrazine + S-metolachlor(1)	56683 Aab	71720 Aa	10.78 Aa	8.95 Aa	69111 Aab	69704 Aa	8.09 Aa	8.23 Aab
Atrazine + S-metolachlor+isoxaflutole(2)	40713 Ab	42237 Ab	10.60 Aa	8.31 Aa	64218 Ab	65212 Aa	8.01 Aa	7.34 Ab
Atrazine + S-metolachlor(3)	65248 Aa	65884 Aa	9.71 Aa	8.15 Aa	80416 Aab	67731 Aa	7.55 Aa	8.14 Aab
Average	57422 A	59345 A	10.41 A	8.81 B	74169 A	69500 A	7.99 A	8.20 A
VC (%)	26.69		19.44		16.51		13.39	

(1) (2,640 + 480 g ha^{-1}) in pre-emergence; (2) (2,640 + 480 + 11.25 g ha^{-1}) in pre-emergence; (3) (1,500 + 384 g ha^{-1}) in post-emergence; (4) (5 g kg^{-1}) in seeds. - Averages with the same lowercase letter in the column and the same capital letter on the line do not different among themselves by *t* test at 5% probability.

Geier et al. (2009) also observed that the application of atrazine + S-metolachlor (1.12 + 1.4 and 1.12 + 2.8 kg ha^{-1}) during pre-emergence was selective for grain sorghum. Kondo et al. (2016) evaluated the effect of two weed management systems (atrazine + 2.4-D, 2.000 + 200 g ha^{-1}, complementing with chemical control versus only mechanical control) in five sweet sorghum hybrids and concluded that chemical control did not damage hybrids stalk productivity and technological characteristics (°Brix, mixture Pol, wet bolus weight, purity, fiber content and total recoverable sugar).

The use of naphthalic anhydride in seed treatment appeared to be a feasible alternative in preventing the phytotoxic action of herbicide treatments in sweet sorghum culture, despite these benefits were not observed for productivity. However, new studies are necessary, both on the field and with higher numbers of cultures, in order to confirm its feasibility as a management strategy. Grichar et al. (2005) demonstrated that herbicide selectivity may vary from one year to the other, according to climate differences.

Moreover, it is important to highlight that the atrazine + S-metolachlor tank-mix, applied during pre- or post-emergence, did not affect stalk growth, development, productivity or quality of ESX5200 and EJXC5110 sweet sorghum hybrids. Generally speaking, treating sweet sorghum seeds with naphthalic anhydride provided partial protection against the action of the atrazine + S-metolachlor and atrazine + S-metolachlor + isoxaflutole mixes, being more evident for the ESX5200 hybrid.

ACKNOWLEDGMENT

To Fundação Araucária, for the contribution and the incentive with scientific initiation scholarships.

REFERENCES

Abit M.J., Al-Khatib K. Absorption, translocation and metabolism of mesotrione in grain sorghum. **Weed Sci.** 2009;57:563-6.

Sistemas de Agrotóxicos Fitossanitários - AGROFIT. **Consulta de ingredientes ativos**. 2018. [Acess on: Jul. 4th 2016] Availabre at: http: http://agrofit.agricultura.gov.br/ agrofit_cons/principal_agrofit_cons..

Almodares A., Hadi M.R. Production of bioethanol from sweet sorghum: a review. **Afr J Agric Res.** 2009;4:772-80.

Alterman M.K., Jones A.P. **Herbicidas:** fundamentos fisiológicos y bioquímicos del modo de accíon. Santiago do Chile: Universidad Católica de Chile; 2003.

Cataneo A.C. et al. Mefenpyr-diethyl action on fenoxaprop-p-ethyl detoxification in wheat varieties. **Planta Daninha**. 2013;31:387-93.

Correia N.M., Gomes L.J.P. Selectivity of saflufenacil for sweet sorghum and potencial use of Na-bentazon as a safener. **Planta Daninha**. 2015;33:267-74.

Empresa Brasileira de Pesquisa Agropecuária – Embrapa. **Sistema brasileiro de classificação de solos**. 3ª.ed. Brasília: 2013.

European Weed Research Council – EWRC. Report of 3rd and 4th meetings of EWRC Committee of Methods in Weed Research. **Weed Res.** 1964;4:88.

Galon L. et al. Seletividade de herbicidas às culturas pelo uso de protetores químicos. **Rev Bras Herbic.** 2011;10:291-304.

Gannon T.W. et al. Sorption of simazine and S-metolachlor to soils from a chronosequence of turfgrass systems. **Weed Sci.** 2013;61:508-14.

Geier P.W. et al. Preemergence herbicide efficacy and phytotoxicity in grain sorghum. **Weed Technol.** 2009;23:197-201.

Grichar W.J. et al. Weed control and grain sorghum (*Sorghum bicolor*) response to post emergence applications of atrazine, pendimethalin, and trifluralin. **Weed Technol.** 2005;19:999-1003.

Hess F.D. Light-dependent herbicides: an overview. **Weed Sci.** 2000;48:160-70.

Instituto Agronômico do Paraná - IAPAR. **Cartas climáticas do Estado do Paraná**. Londrina: IAPAR, 2000.

Kondo P.N.Y. et al. Caracterização agronômica e industrial de genótipos de sorgo sacarino para produção de etanol e eficiência de herbicidas. **J Agron Sci.** 2016;5:18-28.

Maciel C.D.G. **Uso do anidrido naftálico para reduzir os efeitos fitotóxicos de herbicidas em gramíneas** [tese]. Botucatu: Universidade Estadual Paulista "Júlio de Mesquita Filho", 2004.

Maciel C.D.G. et al. Corn seed treatment with naphthalic anhydride against isoxaflutole phytotoxication. **J Food Agric Environ.** 2012;10:612-6.

May A. Sorgo sacarino: tecnologia agronômica e industrial para alimentos e energia. In: Boas Práticas agrícolas para o cultivo do sorgo sacarino. **Agro Rev.** 2011;1:14-5.

Oliveira Jr R.S. et al. Influência do período de restrição hídrica na atividade residual de isoxaflutole no solo. **Planta Daninha.** 2006;24:733-40.

Procópio S.O. et al. Sorção do herbicida atrazine em complexos organominerais. **Planta Daninha.** 2001;19:391-400.

Rizzardi M.A., Serafini M.C. Ação do anidrido naftálico na seletividade de herbicidas aplicados para controle de azevém em aveia-branca. **Planta Daninha**. 2001;19:367-74.

Rodrigues B.N., Almeida F.S. **Guia de herbicidas**. 6ª.ed. Londrina: Edição dos autores, 2011.

Senseman S.A. **Herbicide handbook.** 9th. ed. Lawrence: Weed Science Society of America; 2007.

Teixeira C.G. et al. Utilização do sorgo sacarino como matéria-prima complementar à cana-de-açúcar para obtenção de etanol em microdestilaria. **Ci Tecnol Alim.** 1997;17:248-51.

Teixeira C.G. et al. Influência da época de corte sobre o teor de açúcares de colmos de sorgo sacarino. **Pesq Agropec Bras.** 1999;34:1601-6.