Arquivos do Instituto Biológico
ISSN 1808-1657
https://doi.org/10.1590/1808-1657000222021

SCIENTIFIC ARTICLE
Plant Health Defense

Can a successional crop system associated with preemergent herbicides be a tool to control weeds?

Pedro Eduardo Rampazzo[1] https://orcid.org/0000-0003-2351-5405
Tavvs Micael Alves[1] https://orcid.org/0000-0002-4660-9191
Adriano Jakelaitis[1] https://orcid.org/0000-0003-0093-9846
Jorge Luis Tejada[2,*] https://orcid.org/0000-0002-2102-1578

1. Instituto Federal Goiano – Câmpus Rio Verde –– Rio Verde (GO), Brazil.
2. Universidade Estadual Paulista "Júlio de Mesquita Filho" – Faculdade de Ciências Agrárias e Veterinárias – Departamento de Biologia – Jaboticabal (SP), Brazil.

*Corresponding author: jorge.tejada@unesp.br

ABSTRACT

The objective of this research was to evaluate weed control in a successional soybean-sorghum system by using preemergent herbicides. Two trials were conducted in soybean and two in sorghum, in different soil types (sandy in Rio Verde city and clayey in Montividiu city). All trials were established in a completely randomized block design with five preemergent herbicides in soybean (rates in): diclosulam 35.3 g a.i.·ha^{-1}, chlorimuron 20 g a.i.·ha^{-1}, sulfentrazone 200 g a.i.·ha^{-1}, flumioxazin 50 g a.i.·ha^{-1}, S-metolachlor 1728 g a.i.·ha^{-1}, and two controls (hand weeded and untreated). Treatments in sorghum trials were the same to the soybean plus atrazine 1250 g a.i.·ha^{-1} and atrazine 1250 g a.i.·ha^{-1} + S-metolachlor 1728 g a.i.·ha^{-1}. All treatments had four replicates. Weed control was assessed at 7, 14, 21 and 28 days after planting (DAP) in both crops. In addition, yield was measured when grains reached physiological maturity. All preemergent herbicide treatments successfully controlled weeds, specially *Commelina benghalensis*, *Cenchrus echinatus* and *Eleusine indica*, in both soybean trials until 28 DAP. In some weeds of sorghum, sulfentrazone, diclosulam and chlorimuron sprayed at soybean preemergence performed better than atrazine sprayed at sorghum preemergence. All preemergent herbicides sprayed at soybean preemergence did not affect soybean and sorghum yield, showing similarity with the hand weeded treatment. The results of this research provide evidence that the mix of crop succession and preemergent herbicide applications can be a strong strategy for integrated weed management.

Keywords: weed management; residual herbicides; *Glycine max*; *Sorghum bicolor*.

INTRODUCTION

Weeds strongly compete for water, nutrients, and light with the main crops, thus reducing yield (JHA et al., 2017) and causing serious economic losses. According to SOLTANI et al. (2017), it has been reported losses of US$ 16.2 billion annually due to weeds in soybean crop in the United States. In addition, new cases of increasing resistance require a paradigm shift for agricultural professionals, especially towards an integrated weed management approach (OWEN, 2016).

Consecutive practices without rotational herbicide applications improve pressure resistance, resulting in the selection of dangerous weed biotypes. This justifies the use of intercropping or crop succession as a manner to insert diversity in the system (VILELA et al., 2011). The tropical conditions of most of the Brazilian territory allow second season cropping in some regions, bringing good possibilities for growers to insert preemergent herbicides and crops into the system (CABRAL et al., 2013; MACHADO et al., 2016). Due to its agronomic traits, sorghum is a crop more adapted to drought, having been planted in the Cerrado region after soybean grown in the summer season (CÂNDIDO et al., 2002; ZWIRTES et al., 2015).

Preemergent herbicides are usually more available for crops with high global importance such as soybean. Notwithstanding, weed management in sorghum is currently a problem. The few herbicides available for sorghum require that a mix of crop succession and herbicide strategies be deployed (MACHADO et al., 2016).

Received: Sept 17, 2021. Accepted: Oct 06, 2022
Associate Editor: Silvia Galleti
Peer Review History: Double-blind Peer Review.

Preemergent herbicides may control weeds and minimize replenishment of the soil seed bank in soybean during the summer season; however, it is unknown whether herbicides applied in soybean could favor sorghum crop in succession, which would be useful especially when herbicide options are scarce. Therefore, the objective of this research was to evaluate weed control in a successional soybean-sorghum system by using preemergent herbicides.

MATERIAL AND METHODS

Two trials were conducted under field conditions in Rio Verde and Montividiu cities, state of Goiás, Brazil (17°45'28.7"S/ 51°02'06.6"W and 17°26'37.2"S/51°08'35.8"W, 819 and 878 m altitude, respectively). The climate of both locations is the Aw type, according to the Köppen climate classification, characterized by distinct wet and dry seasons, with most of the precipitation occurring in the summer (ARNFIELD, 2020). Figure 1 describes the monthly temperature averages and rainfall conditions during the experimental period.

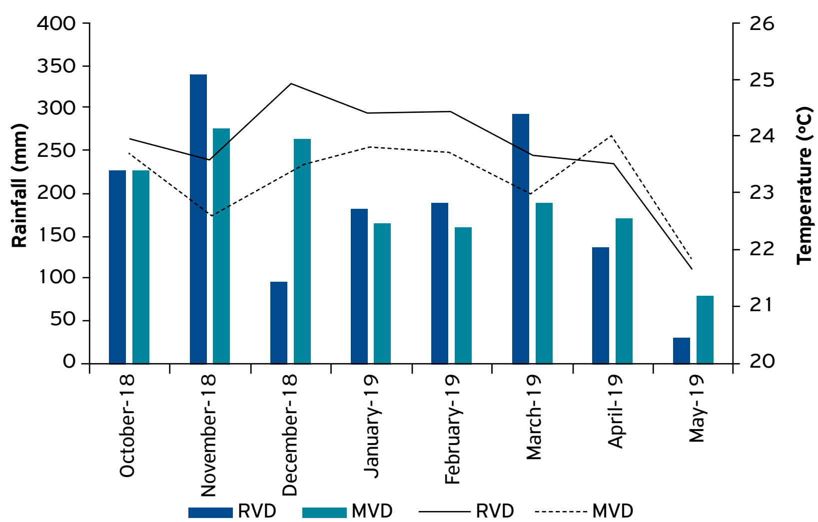

Figure 1. Monthly average values of temperature (lines) and rainfall (bars) throughout the experimental period from October 2018 to May 2019 in two locations (Rio Verde – RVD, Montividiu - MVD).

Trials conducted in the summer season were installed first (Oct. 02, 2018 in Rio Verde and Oct. 03, 2018 in Montividiu). The second season trials took place after soybean cycle (Jan. 17, 2019 in Rio Verde and Jan. 14, 2019 in Montividiu). Sandy soil in Rio Verde was a quartzarenic neosol (sand = 82%, silt = 10% and clay = 8%, pH ($CaCl_2$) = 5.6, organic matter = 1.4 g·dm^{-3}, P = 61.3 mg·dm^{-3}, K = 23 mg·dm^{-3}, Ca^{+2} = 2.3 cmol$_c$ dm^{-3}; Mg^{+2} = 0.7 cmol$_c$·dm^{-3} and H+Al = 2.1 cmol$_c$·dm^{-3}) and clayey soil in Montividiu was a dystrophic red latosol (sand = 20%, silt = 12% and clay = 68%, pH ($CaCl_2$) = 5.7, organic matter = 3.7 g·dm^{-3}, P = 54 mg·dm^{-3}, K = 54 mg·dm^{-3}, Ca^{+2} = 5.3 cmol$_c$·dm^{-3}; Mg^{+2} = 1.9 cmol$_c$·dm^{-3} and H+Al = 3.9 cmol$_c$·dm^{-3}).

Soybean preemergent herbicides were sprayed immediately after sowing, establishing the treatments showed in the Table 1. After soybean harvest, two new trials were established with sorghum in the same areas, establishing the same treatments to the soybean (taking advantage of the residual activity, the herbicides used on soybean were not applied) and adding atrazine isolated and in mixture with S-metolachlor, which were sprayed only at the sorghum planting time (Table 1). The respective plots of these additional treatments were maintained without weed competition during soybean cultivation through the application of glyphosate (432 g a.i.·ha^{-1}). Four replicates of all treatments were arranged in a completely randomized block design.

Herbicides were sprayed with a CO_2-backpack sprayer set to deliver 40 pounds per square inch (PSI) and work with 1 m·s^{-1}. The spray boom (3.0 m length) contained four flat air-induction nozzles (TEEJET, AIXR 110.015), spaced 0.5, delivering a spray volume equivalent to 100 L·ha^{-1}. The herbicides were applied under good environmental conditions.

Plant density was 20 and 12 plants·m^{-1} for soybean and sorghum, respectively, with 0.5 m between rows. The experimental unit was a plot with 4 m in length and eight sowing lines, totaling 16 m^2 per plot. Soybean cultivar 'Pionner 96Y90 RR' and sorghum cultivar 'Brevant 1G233' were grown keeping all good agronomic practices, with insecticide and fungicide maintenance.

Table 1. Treatments applied in soybean and sorghum experiments.

Active ingredient (a.i.)	Composition	Rate ($g\ a.i.\cdot ha^{-1}$)	Application timing
Diclosulam	$840\ g\cdot kg^{-1}$	35.3	Soybean pre-emergence
Chlorimuron	$250\ g\cdot kg^{-1}$	20	Soybean pre-emergence
Sulfentrazone	$500\ g\cdot L^{-1}$	200	Soybean pre-emergence
Flumioxazin	$500\ g\cdot L^{-1}$	50	Soybean pre-emergence
S-metolachlor	$960\ g\cdot L^{-1}$	1728	Soybean pre-emergence
Atrazine	$500\ g\cdot L^{-1}$	1250	Sorghum pre-emergence
Atrazine + S-metolachlor	$500 + 960\ g\cdot L^{-1}$	1250 + 1728	Sorghum pre-emergence
Hand weeded	-	-	-
Untreated	-	-	-

Weed control was evaluated at 7, 14, 21, and 28 days after planting (DAP) each crop according to the EUROPEAN WEED RESEARCH COUNCIL (1964) scale from 0 to 100%, in which 0 = absence of control, and 100% = total control of weeds. Yield was evaluated by harvesting the two central rows of each plot, colleting physiologically mature grains. Grain moisture was adjusted to 13% and the results were extrapolated to $kg\cdot ha^{-1}$.

The percentage of control was normalized by arcsine transformation through Eq. 1:

$$Y = arcsine\sqrt{(X/100)} \tag{1}$$

where: Y = transformed data, X = original data. Data were subjected to ANOVA and mean values were compared using the Tukey's test ($p \leq 0.05$).

RESULTS AND DISCUSSION

All preemergent herbicide treatments successfully controlled weeds in soybean until 28 DAP. In sandy soil, all herbicides showed similar control of *Commelina benghalensis*, slightly lower than hand weeded treatment. This is an important result because *C. benghalensis* is one of the weeds classified as hard to eradicate in Brazil, and some factors impair the control of this weed by postemergent herbicides in soybean (TAKANO et al., 2013). This weed is a decumbent plant and its biology and architecture promote further challenges in the management with postemergent herbicides. In clayey soil, the best herbicide treatments were S-metolachlor, diclosulam, and sulfentrazone. This excellent control until 28 DAP reinforces that all preemergent herbicides under study show effectiveness to avoid crop-weed competition and propagule production, remaining efficient for more than three weeks in soybean (Table 2).

Cenchrus echinatus and *Eleusine indica* were also controlled by all herbicides, with a highlight to the excellent residual control until 21 DAP in both soils. At 28 DAP, diclosulam and S-metolachlor promoted the best control. In clayey soil infested with *C. echinatus*, S-metolachlor promoted better control, behind only the hand weeded treatment. S-metolachlor is highly effective against grass weeds, overcoming chlorimuron, sulfentrazone and flumioxazin in this evaluation. In clayey soil infested with *E. indica*, S-metolachlor also promoted good control at 28 DAP, performing better than chlorimuron, sulfentrazone and flumioxazin (Table 2).

As a result of the development of herbicide resistance from biotypes of *E. indica*, especially to ACCase and EPSPs inhibitors in Brazil (CORREIA, 2017), alternatives for chemical control of this species are increasingly scarce. Therefore, S-metolachlor can be a strategic tool for managing this weed, considering it a very prolific plant, producing more than 120,000 of seeds with high viability (TAKANO et al., 2016).

All preemergent herbicides used in soybean benefited the sorghum in succession (Table 3). Moreover, soybean plants protected from weed competition were able to grow quickly and thus promote the rapid canopy development, preventing the entry of sunlight, which results in the inhibition of germination of positive photoblastic species (very dependent on light to germinate). Thus, a reduction in the number of viable weed seeds in the seed bank competing with sorghum could have occurred. In sandy soil infested with *C. echinatus*, sulfentrazone performed better than atrazine at 28 DAP (Table 3), despite this herbicide was sprayed at sorghum preemergence.

Table 2. Weed control (%) of *Commelina benghalensis*, *Cenchrus echinatus* and *Eleusine indica* at 7, 14, 21, and 28 days after planting (DAP) in two soybean experiments.

Treatment	*Commelina benghalensis*				*Cenchrus echinatus*				*Eleusine indica*			
Sandy Soil												
	7 DAP	14 DAP	21 DAP	28 DAP	7 DAP	14 DAP	21 DAP	28 DAP	7 DAP	14 DAP	21 DAP	28 DAP
Diclosu-lam	98.3b	98.8ab	98.3ab	97.3ab	98.8b	98.3b	96.8b	93.0b	99b	98.8b	97.5b	92.0b
Chlo-rimuron	98.3b	98.0b	95.5b	89.5b	98.8b	97.8b	94.5b	82.3bc	99b	98.8b	95.5b	82.8b
Sulfentra-zone	98.8b	97.5b	98.5ab	97.5ab	98.8b	98.3b	97.3b	91.0bc	99b	99b	97.3b	88.8b
Flumiox-azin	98.8b	98.0b	95.8b	88.0b	98.8b	97.0b	92.5b	79.0c	99b	98.3b	95.8b	80.8b
S-metolachlor	98.8b	97.8b	96.5b	95.8ab	98.8b	97.8b	97.0b	92.8b	98.8b	98.0b	97.3b	92.81b
Hand weeded	100.0a	100.0a	100.0a	100.0a	100a	100a	100a	100a	100a	100a	100a	100a
Clayey soil												
	7DAP	14 DAP	21 DAP	28 DAP	7 DAP	14 DAP	21 DAP	28 DAP	7 DAP	14 DAP	21 DAP	28 DAP
Diclosu-lam	98.3b	91.0a	97.3bc	93.8bc	98.3b	97.5b	95.8bc	90.3bc	98.8b	98.5b	95.8bc	86.0c
Chlo-rimuron	97.8b	95.3a	93.0c	88.3c	99b	96.5b	92.5c	84.5c	99b	96.8b	93.3c	87.8c
Sulfentra-zone	98.3b	99.0a	99.0ab	97.0bc	98.8b	96.3b	93.3c	87.3c	99b	97.0b	94.0c	86.5c
Flumiox-azin	98.5b	97.3a	95.3bc	89.3bc	98.8b	95.8b	93.8c	87.0c	98.8b	97.8b	94.3c	89.3c
S-metolachlor	99.0b	98.8a	98.5ab	97.3ab	99b	98.8b	98.5b	94.8b	99b	99b	98.5b	96.0b
Hand weeded	100.0a	100.0a	100.0a	100.0a	100a	100a	100a	100a	100a	100a	100a	100a

*Means followed by the same lowercase letters do not differ by the Tukey's test ($p < 0.05$).

Table 3. Weed control (%) of *Cenchrus echinatus* and *Eleusine indica* at 7, 14, 21, and 28 days after planting (DAP) in two sorghum experiments.

Treatment	*Cenchrus echinatus*				*Eleusine indica*			
Sandy Soil								
	7 DAP	14 DAP	21 DAP	28 DAP	7 DAP	14 DAP	21 DAP	28 DAP
Diclosulam	99b	98.8ab	95.5bc	92.3b	98.8b	98.8b	96.0bc	94.0bc
Chlorimuron	98.5b	97.8b	94.8bc	91.5b	99.0b	98.5b	95.8bc	92.5bcd
Sulfentrazone	98.8b	98.5b	97.0b	93.8b	98.8b	98.8b	97.3b	96.5b
Flumioxazin	98.5b	98.0b	91.3bcd	87.5b	99b	99b	91.3bcd	88.0bcd
S-metolachlor	99b	98.3b	89.0cd	87.0b	99b	99b	90.0cd	87.8cd
Atrazine	98.8b	97.3b	86.0d	82.8b	99b	98.3b	85.8d	84.3d
Atrazine + S-metolachlor	98.5b	96.0b	91.5bcd	88.3b	98.5b	98.3b	95.0bc	91.5bcd
Hand weeded	100a	100a	100a	100a	100a	100a	100a	100a
Clayey soil								
	7 DAP	14 DAP	21 DAP	28 DAP	7 DAP	14 DAP	21 DAP	28 DAP
Diclosulam	98.5ab	97.0b	80.8b	75.0b	98.8b	97.0b	87.3b	82.8bc
Chlorimuron	98.5ab	97.5ab	84.8b	77.8b	98.8ab	97.5b	89.5b	85.3bc
Sulfentrazone	98.3b	98.0ab	88.3b	83.5b	98.5b	98ab	94.3b	90.3b
Flumioxazin	96.8b	94.3bc	83.5b	75.0b	97.0b	94.3bc	89.3b	83.3bc
S-metolachlor	95.5b	92.8bc	83.5b	77.8b	96.5b	93.8bc	86.3b	82.0bc
Atrazine	94.5b	88.5c	76.0b	68.3b	96.0b	88.3c	82.0b	75.3c
Atrazine + S-metolachlor	97.8b	95.5bc	85.0b	81.5b	98.5b	96.5b	89.5b	86.8bc
Hand weeded	100a	100a	100a	100a	100a	100a	100a	100a

*Means followed by the same lowercase letters do not differ by the Tukey's test ($p < 0.05$).

Regarding *E. indica* in the same evaluation period, sulfentrazone, diclosulam, and chlorimuron performed better than atrazine (Table 3). Considering these results, atrazine application recommendations should be different considering a successional crop system. Thereby, herbicide management in soybean-sorghum could be a tool to avoid resistance issues in weeds that coexist with these crops.

During sorghum cultivation in clayey soil the good control exhibited for *C. echinatus* and *E. indica* was limited to 14 DAP, presumably due to a greater adsorption of molecules and less availability in the soil solution. All herbicides sprayed at soybean preemergence promoted a control similar to the treatment with atrazine and atrazine + S-metolachlor sprayed at sorghum preemergence (Table 3). These results reinforce that weeds are hard to control in sorghum, especially grass weeds, highlighting the need for alternative control methods to be used together to maximize crop yield (CABRAL et al., 2013). NUNES et al. (2010) evaluated herbicides, corn hybrids, and row spacing, obtaining results that point to the interaction of these combined practices. In other words, the implementation of various weed management strategies is more advantageous because it reduces dependence on herbicides, reducing the environmental and economic impact of the overuse of these products, in addition to the resistance of weeds.

Soybean yield revels that in sandy soil, all herbicides promoted similar results regarding grain production in relation to hand weeded treatment. In clayey soil, all herbicides provided the same yield, just different than the untreated control. The comparison of diclosulam and chlorimuron with untreated control in sandy soil showed that sorghum yield was protected by the spraying of the first herbicides at soybean preemergence. In clayey soil, diclosulam, chlorimuron, sulfentrazone and flumioxazin, sprayed at soybean preemergence, protected sorghum yield with results similar to those of the hand weeded treatment (Table 4).

Table 4. Soybean and sorghum yield ($kg \cdot ha^{-1}$) in sandy soil and clayey soil.

Treatment	Soybean		Sorghum	
	Sandy soil	Clayey soil	Sandy soil	Clayey soil
Diclosulam	2795.9a	4631.3a	3253.7ab	3520.1ab
Chlorimuron	3355.4a	5025.4a	3294.3ab	3254.1ab
Sulfentrazone	3028.5a	4645.7a	2780.0abc	3269.3ab
Flumioxazin	3218.3a	5011.6a	2837.1abc	3317.1ab
S-metolachlor	3009.9a	4590.3a	2631.5bc	2677.7bc
Atrazine	-	-	2776.4abc	2744.7abc
Atrazine + S-metolachlor	-	-	2477.0bc	2493.4bc
Hand weeded	3324.2a	4591.6a	3478.9ab	3922.6a
Untreated	2713.8a	3546.8b	1950.8c	1802.1c

*Means followed by the same lowercase letters for yield do not differ by the Tukey's test ($p < 0.05$).

Crop productivity was higher in clayey soil compared to sandy soil due to the clayey soil showed better fertility conditions but less weed control compared to the sandy soil. This means that the good fertility of the clayey soil possibly attenuated the effects of weed interference on the crops, therefore it did not compromise the productivity of both soybean and sorghum. FREITAS et al. (2019) claimed the intensity of the interference between weeds and the crop varies according to the edaphoclimatic conditions of each region and the characteristics of the weed and the crop.

CONCLUSION

In the successional soybean-sorghum system, preemergent herbicides promoted benefits to crops by avoiding weed competition. In clayey soil in comparison to sandy soil, these benefits can be greater due to its good soil fertility.

AUTHORS' CONTRIBUTIONS

Conceptualization: Rampazzo, P.E. **Data curation:** Rampazzo, P.E. **Formal analysis:** Rampazzo, P.E.; Tejada, J.L. **Investigation:** Rampazzo, P.E. **Methodology:** Rampazzo, P.E. **Project administration:** Rampazzo, P.E.; Jakelaitis, A.; Alves, T. **Resources:** Jakelaitis, A.; Alves, T. Software: Alves, T. **Supervision:** Jakelaitis, A.; Alves, T. Validation: Rampazzo, P.E.; Alves, T. **Visualization:** Rampazzo, P.E.; Tejada, J.L. **Writing – original draft:** Rampazzo, P.E.; Alves, T.; Tejada, J.L. **Writing – review & editing:** Rampazzo, P.E.; Tejada, J.L.

AVAILABILITY OF DATA AND MATERIAL

The datasets generated and analyzed during the current study are available from the first author on reasonable request.

FUNDING

Instituto Federal Goiano
Grant no: 23218.004134.2022-73

CONFLICTS OF INTEREST

All authors declare that they have no conflict of interest.

ETHICAL APPROVAL

Not applicable.

ACKNOWLEDGEMENTS

Not applicable.

REFERENCES

ARNFIELD, A. J. Köppen climate classification. *Encyclopedia Britannica*. Available from: https://www.britannica.com/science/Koppen-climate-classification. Access on: 15 Sept. 2020.

CABRAL, P.H.R.; JAKELAITIS, A.; CARDOSO, I.S.; ARAÚJO, V.T.; PEDRINI, E.C.F. Interferência de plantas daninhas na cultura do sorgo cultivado em safrinha. *Pesquisa Agropecuária Tropical*, Goiânia, v.43, n.3, p.308–314, 2013. https://doi.org/10.1590/S1983-40632013000300008

CÂNDIDO, M.J.D.; OBEID, J.A; PEREIRA, O.G.; CECON, P.R.; QUEIROZ, A.C.; PAULINO, M.F.; GONTIJO NETO, M.M. Valor nutritivo de silagens de híbridos de sorgo (*Sorghum bicolor* (L.) Moench) sob doses crescentes de adubação. *Revista Brasileira de Zootecnia*, Viçosa, v.31, n.1, p.20-29, 2002. https://doi.org/10.1590/S1516-35982002000100003

EUROPEAN WEED RESEARCH COUNCIL. Report of the 3rd and 4rd meetings of EWRC. Committees of methods in weed research. *Weed Research*, v.4, p.88, 1964.

FREITAS, A.F.; MACIEL, J.C.; SILVA, M.M.; SANTOS, J.B. *Urochloa brizantha* interference in the *Phaseolus vulgaris* radicular system fertilized with phosphorus. *Planta Daninha*, Viçosa, v.37, p. e019185690, 2019. https://doi.org/10.1590/s0100-83582019370100055

CORREIA, N. Multiple Resistant Goosegrass (*Eleusine indica*). *International Herbicide-Resistant Weed Database*. [S.l.]: 2017. Available from: http://www.weedscience.org/Pages/Case.aspx?ResistID=17112. Access on: 17 Oct. 2022.

JHA, P.; KUMAR, V.; GODARA, R.K.; CHAUHAN, B.S. Weed management using crop competition in the United States: A review. *Crop Protection*, Lincoln, v.95, p.31-37, 2017. https://doi.org/10.1016/j.cropro.2016.06.021

MACHADO, F.G.; JAKELAITIS, A.; GHENO, E.A.; OLIVEIRA JUNIOR, R.S.; RIOS, F.A.; FRANCHINI, L.H.M.; LIMA, M.S. Performance de herbicidas para o controle de plantas daninhas no sorgo. *Revista Brasileira de Herbicidas*, Londrina, v.15, n.3, p.281-289, 2016. https://doi.org/10.7824/rbh.v15i3.476

NUNES, A.L.; TREZZI, M.M.; DEBASTIANI, C. Integrated weed management in maize cultivation. *Bragantia*, Campinas, v.69, n.2, p.299-304, 2010. https://doi.org/10.1590/S0006-87052010000200006

OWEN, M.D.K. Diverse Approaches to Herbicide-Resistant Weed Management. *Weed Science*, Cambridge, v.64, n.S1, p.570-584, 2016. https://doi.org/10.1614/WS-D-15-00117.1

SOLTANI, N.; DILLE, J.A.; BURKE, I.C.; EVERMAN, W.J.; VANGESSEL, M.J.; DAVIS, V.M.; SIKKEMA, P.H. Perspectives on Potential Soybean Yield Losses from Weeds in North America. *Weed Technology*, Cambridge, v.31, n.1, p.148-154, 2017. https://doi.org/10.1017/wet.2016.2

TAKANO, H.K.; OLIVEIRA JUNIOR, R.S.; CONSTANTIN, J.; BIFFE, D.F.; FRANCHINI, L.H.M.; BRAZ, G.B.P.; RIOS, F.A.; GHENO, E.A.; GEMELLI, A. Efeito da adição do 2, 4-D ao glyphosate para o controle de espécies de plantas daninhas de difícil controle. *Revista Brasileira de Herbicidas*, Londrina, v.12, n.1, p.1-13, 2013. https://doi.org/10.7824/rbh.v12i1.207

TAKANO, H.K.; OLIVEIRA JUNIOR, R.S.; CONSTANTIN, J.; BRAZ, G.B.P.; PADOVESE, J.C. Growth, Development and Seed Production of Goosegrass. *Planta Daninha*, Viçosa, v.34, n.2, p.249-258, 2016. https://doi.org/10.1590/S0100-83582016340200006

VILELA, L.; MARTHA JUNIOR, G.B.; MACEDO, M.C.M.; MARCHÃO, R.L.; GUIMARÃES JÚNIOR, R.; PULRONILK, K.; MACIEL, G.A. Sistemas de Integração Lavoura-Pecuária na região do Cerrado. *Pesquisa Agropecuária Brasileira*, Brasília, v.46, n.10, p.1127-1138, 2011. https://doi.org/10.1590/S0100-204X2011001000003

ZWIRTES, A.L.; CARLESSO, R.; PETRY, M.T.; KUNZ, J.; REIMANN, G.K. Desempenho produtivo e retorno econômico da cultura do sorgo submetida à irrigação deficitária. *Engenharia Agrícola*, Jaboticabal, v.35, n.4, p.676-688, 2015. https://doi.org/10.1590/1809-4430-Eng.Agric.v35n4p676-688/2015