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CROP PROTECTION

Integrated management of tough lovegrass (*Eragrostis plana* Nees): associating chemical control tools and plant physiology

Eduardo Avelino Faleiro[1*] Diego Martins Chiapinotto[2] Fabiane Pinto Lamego[3] Carlos Eduardo Schaedler[4] Eduardo Bohrer de Azevedo[1]

[1]Universidade Federal do Pampa (UNIPAMPA), 97650-000, Itaqui, RS, Brasil. E-mail: eduardo.faleiro15@hotmail.com. *Corresponding author.
[2]Programa de Pós-graduação em Fitossanidade, Universidade Federal de Pelotas Pelotas (UFPEL), Pelotas, RS, Brasil.
[3]Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA Pecuária Sul), Bagé, RS, Brasil.
[4]Instituto Federal de Educação, Ciência e Tecnologia Sul-rio-grandense (IFSul), Bagé, RS, Brasil.

ABSTRACT: *The objective of the study was to evaluate the efficiency of herbicides use in the control of tough lovegrass according to the availability of solar radiation and the presence or absence of flooded. Two experiments were conducted in a completely randomized design, in a 2x2x4 and 2x2x5 factorial scheme, where factor A was equivalent to the environment (natural or reduced radiation); factor B to water condition (with a 2 cm flooded or without); and, factor C the herbicides: cyhalofop butyl (315 g ha^{-1}), glyphosate (1080 g ha^{-1}), cyhalofop butyl + glyphosate (315 g ha^{-1} + 1080 g ha^{-1}) and control (without application) in the first experiment. In the second experiment, the herbicides used were cyhalofop butyl (315 g ha^{-1}), glyphosate (1080 g ha^{-1}), sethoxydim (184g ha^{-1}), imazethapyr (106 g ha^{-1}) and control (without application). Glyphosate efficiently controls plants of tough lovegrass with four tillers (>90%), being superior to cyhalofop, imazethapyr and sethoxydim; independently, of resource conditions. Reduction in the availability of solar radiation generates less shoot dry mass production from the weed, and improves the control only by imazethapyr and cyhalofop. In general, a flooded condition does not affect tough lovegrass control by herbicides.*
Key words: *flooded, glyphosate, pasture, shading, weed control.*

Manejo integrado de capim-annoni (*Eragrostis plana* Nees): associando ferramentas do controle químico e fisiologia da planta

RESUMO: *O objetivo do trabalho foi avaliar a eficiência de uso de herbicidas no controle de capim-annoni em função da disponibilidade de radiação solar e da presença ou ausência de lâmina de água. Para isso, foram conduzidos dois experimentos em delineamento inteiramente casualizado, em esquema fatorial 2x2x4 e 2x2x5, em que o fator A equivaleu ao ambiente (radiação natural ou reduzida); fator B à condição hídrica (com lâmina d'água de 2 cm ou sem); e, o fator C aos herbicidas: cyhalofop butyl (315 g ha^{-1}), glyphosate (1080 g ha^{-1}), cyhalofop butyl + glyphosate (315 g ha^{-1} + 1080 g ha^{-1}) e testemunha (sem aplicação) no primeiro experimento. No segundo experimento, os herbicidas utilizados foram: cyhalofop butyl (315 g ha^{-1}), glyphosate (1080 g ha^{-1}), sethoxydim (184 g ha^{-1}), imazethapyr (106 g ha^{-1}) e testemunha (sem aplicação). Glyphosate controla eficientemente plantas de capim-annoni com quatro afilhos (>90%), sendo superior a cyhalofop butyl, imazethapyr e sethoxydim, independente das condições. A redução da disponibilidade de radiação solar gera menor produção de matéria seca da parte aérea pelo capim-annoni, podendo inclusive, contribuir para maior eficiência de controle somente por imazethapyr e cyhalofop. De maneira geral, a condição de lâmina d'água não afeta o controle de capim-annoni pelos herbicidas.*
Palavras-chave: *lâmina d'água, glifosato, pastagem, sombreamento, controle de planta daninha.*

INTRODUCTION

Tough lovegrass (*Eragrostis plana* Nees) is a grass from South Africa, present in Rio Grande do Sul since the '50 (KISSMANN, 1991). Due to its high fiber content, it has low intake by ruminants and ends up standing out with other species, occupying the ecological niche and prevailing in space, reducing the diversity of the fields where it lives (GUIDO & PILLAR, 2017). Tough lovegrass spread successfully, displaced native plants and caused problems for Brazilian livestock cattle herds (BARBOSA et al., 2013). Thus, it is considered the main weed of native pastures in southern Brazil (GOULART et al., 2012).

Control of an invasive species is often difficult to implement after its establishment (BARBOSA et al., 2013). Among the methods used for the management of weeds such as grass, the chemical control is widely used (GREEN & OWEN, 2011). However, given its proximity to other

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species of Poaceae present in the native grassland, it is difficult to control tough lovegrass with the use of herbicides in the form of total application, since desirable forage plants are also eliminated in this case (GOULART et al., 2012). Thus, the *Campo Limpo* selective applicator has allowed advances in chemical control (PEREZ, 2015). In this case, foliar-applied herbicides (POST herbicides) can be used directly on tough lovegrass and other weeds.

The main foliar-applied herbicide used in chemical weed management of tough lovegrass is glyphosate (HEAP & DUKE, 2018), that inhibits the 5-enolpyruvyl-shikimate-3-phosphate synthase enzyme – EPSPs. However, with the evolution of resistance to herbicides, another modes of action as acetolactate synthase (ALS) (YU & POWLES, 2014) and acetyl-coenzyme A carboxylase (ACCase) inhibiting herbicides (TAKANO et al., 2020) are needed to be evaluated as alternative options to glyphosate. Glyphosate has broad-spectrum of action and ALS inhibiting herbicides have action on monocotyledons and/or dicotyledons plants according to the molecule (HEAP & DUKE, 2018; YU & POWLES, 2014). ACCase inhibiting herbicides are specific to grass weed control (TAKANO et al., 2020).

Studies carried out in the '2000s showed low efficiency by some ALS and ACCase inhibiting herbicides in tough lovegrass control (GOULART et al., 2012). Being a perennial plant, an efficient absorption and translocation of herbicides is needed. Thus, glyphosate has been the most efficient in the field, mainly in areas highly infested by "old" plants. Recent studies have shown quizalofop-*p*-ethyl, also and ACCase inhibitor herbicide, with potential of controlling species of the genus *Eragrostis* and can be used in future studies (KAUR et al., 2019). In general, 80% of control based on SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS (1995) is considered a good weed control. However, when leading with difficult weeds, >90% as glyphosate shown that security regrowth will not happen soon (once the weed is perennial).

The effectiveness of herbicides is affected by the physiological state of the plants (ZHOU et al., 2007), which may be linked to edaphoclimatic conditions such as solar radiation and soil moisture (CIESLIK et al., 2013; SCHERNER et al., 2017). Furthermore, environmental conditions can directly affect herbicide absorption, translocation, and detoxification (MATZRAFI, 2019). Thus, physiological approaches can be used to the improvement of chemical control (BASHTANOVA et al., 2009).

The reduction in available solar radiation interferes with the growth and development of some grasses (LOPES et al., 2017). Studies conducted with the C4 physiology tough lovegrass concluded that in an environment with limited solar radiation, there is a reduction of up to 75% in the number of inflorescences compared to those in an environment without resource limitation (PEREZ, 2015). In the case of the water resource, tough lovegrass can complete its cycle even in water soaking conditions, prolonging its vegetative period; although, tillering decreases (CARLOTO et al., 2019). The opposite condition also is true. Comparing with *Paspalum notatum*, one of the main native species in grasslands at Southern Brazil, tough lovegrass and the forage show tolerance to water deficit, but they use different strategies to withstand stress, according to studies conducted at Embrapa. (unpublished).

The hypothesis of this research are: i) alternative herbicides to glyphosate (ALS and ACCase inhibiting herbicides), applied isolated or in association with it, can control efficiently tough lovegrass and, ii) association of chemical control and resources availability as solar radiation and water, can improve weed management. Thus, the objective of this study was to investigate the efficiency of EPSPs, ALS and ACCase inhibiting herbicides in tough lovegrass control, depending on the availability of solar radiation and water conditions (with or without flooded), aiming to establish integrated weed management strategies.

MATERIALS AND METHODS

Two experiments were conducted in a greenhouse of the Federal University of Pampa, Campus Itaqui - RS with coordinates of latitude 29 ° 9 ′ 21.37 ″ S and longitude 56 ° 33 ′ 9.97 ″ W. Seeds of tough lovegrass harvested at the site were sown in cells of trays with the use of commercial substrate in November 2015 and 2016. When the seedlings had three leaves, they were transplanted into 1.5 L pots, containing soil classified as Plintossoil. After transplantation, the seedlings stayed for five days in a protected environment until they established themselves, and from then on they were allocated in an environment with natural or reduced light (structure with 50% sombrite® screen). In both, plants were submitted to a 2 cm water slide or not. For herbicides application, a back pressure sprayer pressurized to CO_2 was used, with fan tips (XR 110.02) and pressure of 250 kPa. The spray volume was 150 L ha^{-1}.

Experiment I was conducted in a completely randomized design with four replications, in a 2 × 2

× 4 factorial scheme, where factor A was equivalent to the environment (natural or reduced light); factor B at the condition with or without flooded (2 cm); and factor C to herbicides: cyhalofop-butyl (315 g ha^{-1}) – ACCase inhibitors, glyphosate (1080 g ha^{-1}) – EPSPs inhibitors, cyhalofop-butyl + glyphosate (315 g ha^{-1} + 1080 g ha^{-1}) and control (without application). Seedlings were transplanted on 22/11/2015 and the herbicides were applied on 08/12/2015 when plants were at a stage of up to four tillers.

Experiment II was conducted similarly, with only a difference in factor C, when the herbicides used were cyhalofop-butyl (315 g ha^{-1}), glyphosate (1080 g ha^{-1}), sethoxydim (184 g ha^{-1}) – ACCase inhibitors, imazethapyr (106 g ha^{-1}) – ALS inhibitors and control (without application). Seedlings were transplanted on 28/11/2016 and the herbicides were applied on 10/12/2016.

The following parameters were evaluated: control of tough lovegrass through visual scale (%) at 28 days after application of treatments (DAT) and the shoot dry mass (SDM), determined at 28 DAT. The data obtained were analyzed for normality and submitted to analysis of variance. With statistical significance, the means were compared by Fisher's DMS test, at 5% using the software SISVAR (FERREIRA, 2014).

RESULTS

In Experiment I, at 28 DAT there was significant interaction only for levels of solar radiation and herbicides (P≤0.05). In this case, glyphosate stood out alone or in association with cyhalofop (Table 1). However, in reduced radiation, the control was much higher, above 90%. Cyhalofop-butyl alone did not control tough lovegrass efficiently. For shoot dry mass (SDM), there was an interaction between environment (with and without radiation) and water (with and without flooded), with the highest values observed in plants under natural radiation condition, associated with the presence of flooded (Figure 1). However, SDM was reduced by 60%, on average, when under low radiation condition even with available water.

In Experiment II, for the control at 28 DAT, there was a triple interaction of the studied factors (P≤0.05). In the flooded condition, cyhalofop control was greater when in the reduced radiation environment, being equivalent to 70% and not differing from imazethapyr and sethoxydim (Table 2). However, the control by sethoxydim in the presence of water did not differ comparatively between the radiation conditions, similar to glyphosate. We verified that this herbicide was superior in all conditions, with an average control close to 100%.

For SDM, there was an interaction between radiation and chemical control (P≤0.05) in Experiment II (Table 3). In this case, SDM was reduced in 91% and 85% by glyphosate and sethoxydim; respectively compared to the control, under natural radiation environment. In the condition of reduced radiation, the herbicides did not differ, only surpassing the control without application. However, cyhalofop and imazethapyr show interesting decreases in SDM due to the radiation reduction condition. In this case, on average, tough lovegrass SDM was reduced in 82% and 87%, respectively, when those herbicides were applied associated with low light availability.

The interaction between environmental factors with and without water and herbicides for SDM was also statistically significant (P≤0.05) (Table 4). Under flooded condition, glyphosate again stands out showing 94% reduction of SDM compared to the control; cyhalofop and imazethapyr were not efficient and did not differed from the untreated check. With no flooded, glyphosate is efficient but does not differ statistically from sethoxydim. The presence of the flooded, in general, does not contribute to improving

Table 1 - Control (%) of tough lovegrass at 28 days after application of treatments in a natural and/or reduced radiation environment, depending on the chemical control. UNIPAMPA, Itaqui-RS, Experiment I, 2015-2016.

Herbicides	-------Doses (g ha^{-1})-------	-----Natural radiation----			-----Reduced radiation-----		
Cyhalofop-butyl	315	B	06.8	a	B	06.2	a
Glyphosate	1080	A	25.0	b	A	94.5	a
Cyhalofop + Glyphosate	315 + 1080	A	28.4	b	A	94.6	a
Control		C	00.0	a	C	00.0	a
CV	---17.5--						

Means followed by the same uppercase letter in the column and lowercase in the row, do not differ by Fisher's LSD test (P≤0.05), CV = Coefficient of variation.

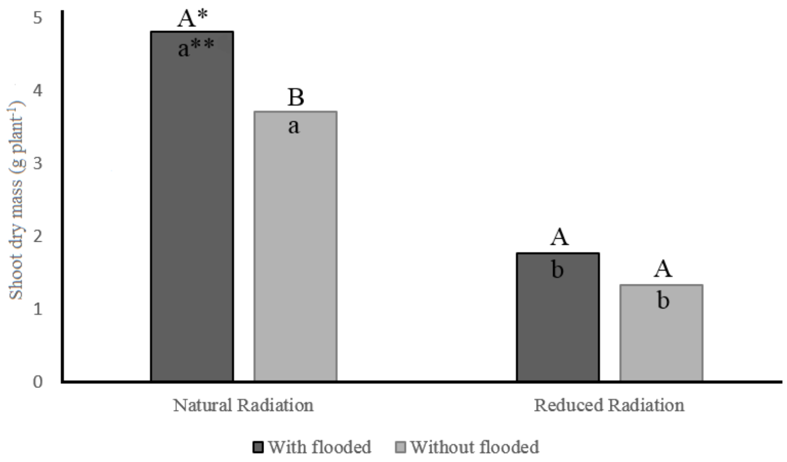

Figure 1 - Shoot dry mass (SDM, g plant-1) in tough lovegrass plants, evaluated at 28 days after application of treatments grown in a natural environment and under reduced radiation depending on the flooded. Itaqui-RS, Experiment I, 2015-2016. *Averages followed by the same uppercase letter compare conditions with and without flooded within the same radiation environment. **Averages followed by lowercase letters compare the SDM, in the same water condition in different radiation environments. Treatment means, followed by different letters, differ from each other by Fischer's DMS test (P≤0.05), Coefficient of variation = 31.09.

the efficiency of herbicides. The untreated check even produced greater SDM when in the absence of water.

DISCUSSION

Cyhalofop, sethoxydim and imazethapyr herbicides did not presented superior control of tough lovegrass, when compared to glyphosate. Even with>80% of control as showed by sethoxydim, we believed this is not enough to avoid the weed regrowth soon. In this case, we are more confident with glyphosate (>90% of control). Studies carried out in the '2000s also showed low efficiency by some inhibitors of ALS and ACCase enzymes in controlling tough lovegrass (GOULART et al., 2012). However, quizalofop-*p*-ethyl, also and ACCase

Table 2 - Visual control (%) of tough lovegrass, at 28 days after application of treatments in a natural and/or reduced radiation environment, with and without water, depending on the chemical control. UNIPAMPA, Itaqui-RS, Experiment II, 2016-2017.

Herbicides	Doses (g ha^{-1})	Natural radiation						Reduced radiation					
		Flooded condition											
		With			Without			With			Without		
Cyhalofop	315	D[1]	16.00	*b	C	35.00	*a	B	70.00	a	C	54.50	b
Glyphosate	1080	A	99.50	nsa	A	98.75	nsa	A	99.75	a	A	99.75	a
Imazethapyr	184	C	42.25	*a	C	34.25	*a	B	61.25	b	B	80.25	a
Sethoxydim	106	B	81.00	nsa	B	75.25	nsa	B	74.75	a	B	86.50	a
Control	---	E	00.00	nsa	D	00.00	nsa	C	00.00	a	D	00.00	a
CV	18.0												

[1]Uppercase letter compare in the column, herbicides within each radiation environment depending on the flooded (with/without). Lowercase letters compare on the line, herbicides depending on the flooded. Means followed by * or ns compare herbicide depending on radiation. Fisher LSD test (P≤0.05). CV= Coefficient of variation.

Table 3 - Shoot dry mass (g plant^{-1}) of tough lovegrass plants, under natural and/or reduced radiation, depending on chemical control, at 28 days after application of treatments. UNIPAMPA, Itaqui-RS, Experiment II, 2016-2017.

Herbicides	--------Doses (g ha^{-1})--------	-----Natural radiation-----			---------Reduced radiation-------		
Cyhalofop	315	B*	1.47	a	B	0.26	b
Glyphosate	1080	D	0.20	a	B	0.07	a
Imazethapyr	184	C	0.82	a	B	0.11	b
Sethoxydim	106	D	0.31	a	B	0.19	a
Control		A	2.14	a	A	1.45	b
CV	------------69.25------------						

Averages followed by the same uppercase letter in the column and lowercase in the row, at the same radiation level, do not differ by Fisher's LSD test (p≤0.05), CV = Coefficient of variation.

inhibitor herbicide, have been efficient in controlling species of the genus *Eragrostis* and can be used in future studies (KAUR et al., 2019). Based on that, we decided to evaluate the molecules chosen in different environmental conditions. Unfortunately, we did not evaluate quizalofop in this research.

At reduced radiation condition, cyhalofop and imazethapyr demonstrated improved control of tough lovegrass control. In some cases, there is a direct correlation between shoot dry mass accumulation and the increased dose required for effective control with herbicides (TRAVLOS & CHACHALIS, 2010). Results of this study corroborated those of Travlos and Chachalis (2010), due low radiation condition causes reduction of 60% on average in SDM and increased the control. Furthermore, the reduction of solar radiation can create a microclimate with a higher degree of humidity (STANHILL & COHEN, 2001). High humidity conditions can improve the effectiveness of ACCase-inhibiting herbicides due to increased hydration of the cuticle and delay in drop evaporation (CIESLIK et al., 2013).

As a C_4 perennial plant with several tillers, tough lovegrass requires excellent translocation by the herbicide. The control near to 100% observed in the present study with glyphosate, in plants with up to four tillers, regardless of the environment or water condition that the plant was inserted in, is shown to be a good management option. The selective applicator *Campo Limpo* developed by Embrapa (PEREZ, 2015) has been the option for controlling tough lovegrass in infested areas, based on glyphosate use but maintaining native vegetation and/or pasture and opening the niche for these "muffled" species, which development can be grazed on by catlle. However, this management requires rotation of mechanisms of herbicidal action for its sustainability as a technology, aiming to avoid herbicide resistance evolution - a current global dilemma (HEAP, 2020).

Plants of the genus *Brachiaria* tested under flooding conditions, showed a reduction in photosynthetic rate due to the absence of oxygen in the root system (DIAS-FILHO & CARVALHO, 2000). This condition naturally reduces the production of ATP (adenosine triphosphate), slowing down the metabolism

Table 4 - Shoot dry mass (g plant^{-1}) of tough lovegrass evaluated at 28 days after application of treatments, in the presence or absence of water, depending on the chemical control. UNIPAMPA, Itaqui-RS, Experiment II, 2016-2017.

		------------Flooded condition------------					
Herbicides	Doses (g i/e.a ha^{-1})	----------With----------			----------Without----------		
Cyhalofop	315	A*	0.84	a	B	0.88	a
Glyphosate	1080	C	0.08	a	C	0.19	a
Imazethapyr	184	AB	0.54	a	B	0.40	a
Sethoxydim	106	B	0.24	a	BC	0.27	a
Control		A	1.26	b	A	2.33	a
CV	------------69.25------------						

*Averages followed by the same uppercase letter in the column and lowercase in the row, within the same water condition do not differ by Fisher's LSD test (P≤0.05), CV = Coefficient of variation.

and reducing the process of photosynthesis, which reflects in lower accumulation of SDM. In the present study, it was observed that tough lovegrass tolerates the flooding condition but producing less SDM. Tolerance can be explained by the presence of aerenchyma in the roots, already reported by FAVARETTO et al. (2015). In the current experiments, the association of the water factor with chemical control, as a physiological strategy, did not demonstrate success. The research has been searching for efficient tools to reducing the infestation of the natural grasslands by tough lovegrass, especially on Pampa Biome. The association of chemical strategy with the use of plant physiology knowledge can help the integrated weed management. Among the stresses hitherto investigated in the literature, whether due to limitation or excess of water (present study) and also solar radiation PEREZ (2015), the latter seems to open possibilities to improve the management. In the present study, the radiation availability provided increased control by some herbicides evaluated as alternates. Thus, the research should continue to understand and investigate how to take an advantage of this evidence to add management tools for this important weed pasture in southern Brazil.

CONCLUSIONS

Glyphosate herbicide in the dose of 1080 g ha^{-1}, efficiently controls plants of tough lovegrass with four tillers (>90%), being superior to cyhalofop, imazethapyr and sethoxydim; independently of resources conditions. Sethoxydim can be an alternative mode of action to glyphosate, however with <90% of control. The reduction in the availability of solar radiation generates less shoot dry mass production from tough lovegrass, improving the control only by imazethapyr and cyhalofop herbicides.A flooded condition does not improve tough lovegrass control by cyhalofop, sethoxydim, imazethapyr and glyphosate herbicides.

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DECLARATION OF CONFLICTS OF INTERESTS

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of de manuscript.

REFERENCES

BARBOSA, F.G. et al. Predicting the current distribution and potential spread of the exotic grass *Eragrostis plana* Nees in South America and identifying a bioclimatic niche shift during invasion. **Austral Ecology**, v.38, n.3, may 2013. Available from: <https://doi.org/10.1111/j.1442-9993.2012.02399.x>. Accessed: May, 30, 2020. doi: 10.1111/j.1442-9993.2012.02399.x.

BASHTANOVA, U.B. et al. Review: physiological approaches to the improvement of chemical control of japanese knotweed (*Fallopia japonica*). **Weed Science**, v.57, n.6, p.584-592, dec. 2009. Available from: <https://doi.org/10.1614/WS-09-069.1>. Accessed: May, 30, 2020. doi: 10.1614/WS-09-069.1.

CARLOTO, B.W. et al. Morphological and phenological responses of *Eragrostis plana* Nees and *Eragrostis pilosa* (l.) p. beauv. plants subjected to different soil moisture conditions. **Planta daninha**. 2019. vol.37, Available from: <http://www.scielo.br/pdf/pd/v37/0100-8358-PD-37-e019217246.pdf>. Accessed: Mar. 07, 2020. doi: 10.1590/s0100-83582019370100128.

CIESLIK, L.F. et al. Environmental factors affecting the efficacy of ACCase-inhibiting herbicides: a review. **Planta Daninha**, v.31, n.2, p.483-489, 2013. Available from: <https://www.scielo.br/scielo.php?pid=S0100-83582013000200026&script=sci_abstract&tlng=pt>. Accessed: May, 30, 2020. doi: 10.1590/S0100-83582013000200026.

DIAS-FILHO, M.B, DE CARVALHO, C.J.R. Physiological and morphological responces of *Brachiaria* spp. to flooding. **Pesquisa Agropecuária Brasileira**. v.35, p.1959–1966, 2000. Available from: <http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0100-204X2000001000006&lng=en&nrm=iso>. Accessed: Mar. 07, 2020. doi: 10.1590/S0100-204X2000001000006.

FAVARETTO, A. et al. The first anatomical and histochemical study of tough lovegrass (*Eragrostis plana* Nees, Poaceae). **African Journal of Agricultural Research**, v.10, p.2940-2947, 2015. Avaliable from: <https://academicjournals.org/journal/AJAR/article-abstract/8D2FE4254408>. Accessed: Mar. 07, 2020. doi: 10.5897/AJAR2014.9145.

FERREIRA, D.F. Sisvar: A guide for its bootstrap procedures in multiple comparisons. **Ciência e Agrotecnologia**, v.38, p.109-112, 2014. Available from: <http://www.scielo.br/pdf/cagro/v38n2/a01v38n2.pdf>. Accessed: Mar. 07, 2020.

GOULART, I.C.G.R. et al. Interactions among herbicides and safeners for the south African lovegrass control in natural grassland. **Ciência Rural**, v.42, n.10, p.1722-1730, 2012. Available from: <https://doi.org/10.1590/S0103-84782012001000002>. Accessed: May, 30, 2020. doi: 10.1590/S0103-84782012001000002.

GREEN J.M.; OWEN M.D.K. Herbicide-resistant crops: utilities and limitations for herbicide-resistant weed management. **Journal of Agricultural and Food Chemistry**, v.59, p.5819-5829, (2011).

Avaliable from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3105486/>. Accessed: Mar. 07, 2020. doi: 10.1021/jf101286h.

GUIDO A. & PILLAR V. D. Invasive plant removal: assessing community impact and recovery from invasion. **Journal of Applied Ecology**. v.54, p.1230-1237, 2017. Avaliable from: <https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2664.12848>. Accessed: Mar. 07, 2020. https://doi.org/10.1111/1365-2664.12848.

HEAP, I.; DUKE, S.O. Overview of glyphosate-resistant weeds worldwide. **Pest Management Science**, v.74, n.5, p.1040–1049, 2018. Available from: <https://doi.org/10.1002/ps.4760>. Accessed: May, 30, 2020. doi: 10.1002/ps.4760.

HEAP, I. The International Herbicide-Resistant Weed Database. Avaliable from: <http://weedscience.org/Graphs/SOAGraph.aspx>. Accessed: Mar. 14, 2020.

KAUR, T. et al. Management of grass weeds with quizalofop in soybean [*Glycine max* (L.) Merrill]. **Phytoparasitica**, v.47, n.1, p.155-162, feb. 2019. Available from: <https://doi.org/10.1007/s12600-019-00717-2>. Accessed: May 30, 2020. doi: 10.1007/s12600-019-00717-2.

Kissmann, K.G. *Eragrostis plana Nees*. In: Kissmann K.G. **Plantas Infestantes e Nocivas: Plantas Inferiores – Monocotiledôneas**. 1991. Vol. 1, p. 420.tantes E Nocivas: Plantas Inferiores – Monocotiledôneas, Vol.1 (ed. K. G. Kissmann) pp.420–3. BASF, São Paulo.

LOPES, C.M. et al. Herbage mass, morphological composition and nutritive value of signalgrass, submitted to shading and fertilization levels. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.69, p.225-233, 2017. Avaliable from: <http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0102093520170001 00225&lng=en&nrm=iso>. Accessed: Mar. 07, 2020 https://doi.org/10.1590/1678-4162-9201.

MATZRAFI, M. Climate change exacerbates pest damage through reduced pesticide efficacy. **Pest Managament Science**, v.75, n.1, p.9-13, 2019. Available from: <https://doi.org/10.1002/ps.5121>. Accessed: May 30, 2020. doi: 10.1002/ps.5121.

PEREZ, N. B. **Método integrado de recuperação das pastagens MIRAPASTO: foco capim-annoni**. Embrapa Pecuária Sul, 2015, 24p. (Folheto). Avaliable from: <https://www.embrapa.br/busca-de-publicacoes/-/publicacao/1023496/metodo-integrado-de-recuperacao-de-pastagens-mirapasto-foco-capim-annoni>. Accessed: Mar. 07, 2020.

SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS (SBCPD). **Procedimentos para instalação, avaliação e análise de experimentos com herbicidas**. Londrina - PR: S.B.C.P.D., 42 p. 1995

SCHERNER, A. et al. Susceptibility of peruvian watergrass and rice cutgrass to glyphosate under soil moisture variations. **Crop Protection**, v.98, p.1-7, 2017. Available from: <https://doi.org/10.1016/j.cropro.2017.03.003>. Accessed: May, 30, 2020. doi: 10.1016/j.cropro.2017.03.003.

STANHILL, G.; COHEN, S. Global dimming: a review of the evidence for a widespread and significant reduction in global radiation with discussion of its probable causes and possible agricultural consequences. **Agricultural and Forest Meteorology**, v.107, n.4, p.255-278, 2001. Available from: <https://doi.org/10.1016/S0168-1923(00)00241-0>. Accessed: May, 30, 2020. doi: 10.1016/S0168-1923(00)00241-0.

TAKANO, H.K. et al. ACCase-inhibiting herbicides: mechanism of action, resistance evolution and stewardship. **Scientia Agricola**, v.78, n.1, e20190102, 2020. Available from: <http://dx.doi.org/10.1590/1678-992X-2019-0102>. Accessed: May, 30, 2020. doi: 10.1590/1678-992X-2019-0102.

TRAVLOS, I.S.; CHACHALIS, D. Glyphosate-resistant hairy fleabane (*Conyza bonariensis*) is reported in Greece. **Weed Technology**, v.24, n.4, p.569-573, 2010. Available from: <https://doi.org/10.1614/WT-D-09-00080.1>. Accessed: May, 30, 2020. doi: 10.1614/WT-D-09-00080.1.

YU, Q.; POWLES, S.B. Resistance to AHAS inhibitor herbicides: current understanding. **Pest Management Science**, v.70, n.9, p1340-1350, set. 2014. Available from: <https://doi.org/10.1002/ps.371>. Accessed: May, 30, 2020. doi: 10.1002/ps.371.

ZHOU, J. et al. Glyphosate efficacy on velvetleaf (*Abutilon theophrasti*) is affected by stress. **Weed Science**, v.55, n.3, p.240-244, 2007. Available from: <https://doi.org/10.1614/WS-06-173.1>. Accessed: May, 30, 2020. doi: 10.1614/WS-06-173.1.