weedcontrol journal
RESEARCH ARTICLE

# Auxinic herbicides and tembotrione sprayed on seed-propagated elephant grass

# Aplicação de herbicidas auxínicos e do tembotrione em capim-elefante propagado por semente

Alexandre M. Brighenti[a]*, Maurílio F. de Oliveira[b], Francisco J. da S. Ledo[a], Juarez C. Machado[a]

[a] Embrapa Gado de Leite, Juiz de Fora, MG, Brasil. [b] Embrapa Milho e Sorgo, Sete Lagoas, MG, Brazil.

**Abstract: Background**: Elephant grass plants propagated by seeds are more likely to have injuries to herbicides, in their initial cultivation phase, when compared to those from cuttings. There are selective herbicides for elephant grass developed from seeds.
**Objective**: This work evaluated the tolerance of elephant grass implanted by seeds to auxinic herbicides and tembotrione.
**Methods**: Two experiments were conducted in the municipalities of Valença, Rio de Janeiro State, Brazil, and Coronel Pacheco, Minas Gerais State, Brazil. The experimental design was in randomized complete blocks, with four replications. The experimental treatments were: Auxinic herbicides {fluroxypyr + picloram [160 + 160 g a.e. ha$^{-1}$]; fluroxypyr + aminopyralid [160 + 80 g a.e. ha$^{-1}$]; fluroxypyr + triclopyr [160 + 480 g a.e. ha$^{-1}$]; 2,4-D amine (1,340 g a.e. ha$^{-1}$); 2,4-D amine + picloram [720 + 45 g a.e. ha$^{-1}$]}, and tembotrione (84 g a.i. ha$^{-1}$ without mineral oil), in addition to the control without herbicides.
**Results**: Tembotrione was the most phytotoxic treatment to elephant grass propagated by seed, causing leaf bleaching and, consequently, reducing forage dry matter yield. The treatments with fluroxypyr + picloram, fluroxypyr + aminopyralid, fluroxypyr + triclopyr, 2,4-D and 2,4-D + picloram did not cause symptoms of phytotoxicity capable of providing a reduction in forage productivity, being potential herbicides for spraying in seed-propagated elephant grass fields.
**Conclusions**: the herbicides: fluroxypyr + picloram, fluroxypyr + aminopyralid, fluroxypyr + triclopyr, 2,4-D and 2,4-D + picloram can be sprayed in the elephant grass developed from seeds.

**Keywords**: synthetic auxins, bleacher, HPPD-Inhibitors, weeds.

**Resumo: Introdução**: Plantas de capim-elefante propagadas por sementes têm maior possibilidade em apresentar injúrias a herbicidas, na sua fase inicial de cultivo, quando comparadas àquelas provenientes de estacas. Há herbicidas seletivos para o capim-elefante proveniente de sementes.
**Objetivo**: Este trabalho avaliou a tolerância do capim-elefante implantado por sementes a herbicidas auxínicos e ao tembotrione.
**Métodos**: Dois experimentos foram conduzidos nos municípios de Valença, RJ, e em Coronel Pacheco, MG. O delineamento experimental foi em blocos casualizados, com quatro repetições. Os tratamentos foram: herbicidas auxínicos {fluroxypyr + picloram [160 + 160 g e.a. ha$^{-1}$]; fluroxypyr + aminopyralid [160 + 80 g e.a. ha$^{-1}$]; fluroxypyr + triclopyr [160 + 480 g e.a. ha$^{-1}$); 2,4-D (1.340 g e.a. ha$^{-1}$); 2,4-D + picloram [720 + 45 g e.a. ha$^{-1}$]} e o tembotrione (84 g i.a. ha$^{-1}$ sem adição de óleo mineral), além da testemunha sem aplicação.
**Resultados**: O tembotrione foi o tratamento mais fitotóxico ao capim-elefante propagado por sementes, causando branqueamento de folhas e, consequentemente, redução na produtividade de matéria seca de forragem. Os tratamentos com fluroxypyr + picloram, fluroxypyr + aminopyralid, fluroxypyr + triclopyr, 2,4-D e 2,4-D + picloram não causaram sintomas de fitotoxicidade capazes de proporcionar redução na produtividade de forragem, sendo herbicidas potenciais para aplicação em capim-elefante propagado por sementes.
**Conclusões**: os herbicidas fluroxypyr + picloram, fluroxypyr + aminopyralid, fluroxypyr + triclopyr, 2,4-D e 2,4-D + picloram podem ser aplicados em capim-elefante propagado por sementes.

**Palavras-chave**: auxinas sintéticas, branqueamento, 4-hidroxifenilpiruvato dioxigenase (HPPD), plantas daninhas.

**Journal Information:**
ISSN: 2763-8332
Website: https://www.weedcontroljournal.org/
Jornal da Sociedade Brasileira da Ciência das Plantas Daninhas

**Como citar:** Brighenti AM, Oliveira MF, Ledo FJS, Machado JC. Auxinic herbicides and tembotrione sprayed on seed-propagated elephant grass. Weed Control J. 2022;21:e202200763.
**https://doi.org/10.7824/wcj.2022;21:00763**

**Aprovado por:**
Editor-Chefe: Daniel Valadão Silva
Editor Associado: Giliardi Dalazen

**Conflitos de interesse:** Os autores declaram não haver conflito de interesses em relação à publicação deste manuscrito.

**Recebido:** Agosto 26, 2021
**Aprovado:** Março 07, 2022

*** Corresponding author:**
<alexandre.brighenti@embrapa.br >



## 1. Introduction

The lack of knowledge about chemical weed control in pastures and the scarcity of available herbicides are considered limitations for forage plants to express all of their productive potential.

Elephant grass [*Cenchrus purpureus* (Schumachu.) Morrone (syn. *Pennisetum purpureum* Schumach.)] is one of the most important forage species in animal nutrition and very widespread in tropical and subtropical regions of the world (Moreira et al., 2008). It comes from Africa, where it occurs naturally in several countries, such Guinea, Angola, Zimbabwe, Mozambique, and Kenya (Ferreira and Pereira, 2005). In Brazil, elephant grass was introduced in the 1920s and is grown in all regions of the country (Quéno et al., 2011). The species is perennial, with a high production of dry matter and used mainly in cattle feed, dairy, and beef herds (Lima et al., 2010). Due to the high production of biomass, it has also been used for energy purposes (Oliveira et al., 2014; Borges et al., 2016; Silva et al., 2017).

Although elephant grass is well adapted and widespread forage throughout Brazil, weed interference in crops is still considered one of the problems during implantation, conduction, and also after harvest (Brighenti et al., 2017b; 2017c). Weeds cause damage to elephant grass production and losses can reach up to 42% of forage dry matter yield depending on weed species and its density (Brighenti et al., 2017a).

The task of implanting elephant grass is mostly done by vegetative propagation, using cuttings, which makes the activity expensive and laborious. However, elephant grass cultivars that can be implanted by seeds have been researched and obtained through traditional breeding techniques. Plants propagated by seeds are less tolerant to herbicides in their initial phase, due to their smaller size and reduced amounts of nutritional reserves when compared to plants from cuttings (MacNeill et al., 2017; Santos et al., 2018a; Costa et al., 2021). So, it is necessary to evaluate herbicide tolerance in elephant grass crops propagated by seeds to manage weeds efficiently and safely.

The objective of this work was to evaluate the tolerance of elephant grass propagated by seeds to auxinic herbicides and tembotrione.

## 2. Material e Methods

Two experiments were conducted in the municipalities of Valença, Rio de Janeiro State, Brazil (22° 21′35.29″ S, 43° 41′40.92″ W) and Coronel Pacheco, Minas Gerais State, Brazil (21° 32'55.60" S, 43° 15'57.58" W). The experiments were implemented on May 23, 2016 (experiment 1- Valença) and on May 30, 2016 (experiment 2 - Coronel Pacheco, MG). The average values of maximum and minimum air temperatures and rainfall during the experiment conductions are shown in Figures 1 and 2.

The soils are Argisol Red Yellow and Cambisol Fluvic, respectively (Santos et al., 2018b). Soil samples were collected from 0-20 cm depth at both sites to carry out chemical analyzes. The results for Valença and Coronel Pacheco were as follows: pH ($H_2O$) = 5.2 and 5.1, P = 53.6 and 24.5 mg dm$^{-3}$, K = 185 and 168 mg dm$^{-3}$, $Ca^{2+}$ = 2.0 and 3.7 cmolc dm$^{-3}$, $Mg^{2+}$ = 0.9 and 1.4 cmolc dm$^{-3}$, CEC (t) = 3.4 and 5.7 cmolc dm$^{-3}$, CEC (T) at pH = 7.0) = 7.3 and 10.3 cmolc dm$^{-3}$, V = 46 and 54%, organic matter = 2.8 and 3.3 dag kg$^{-1}$, respectively.

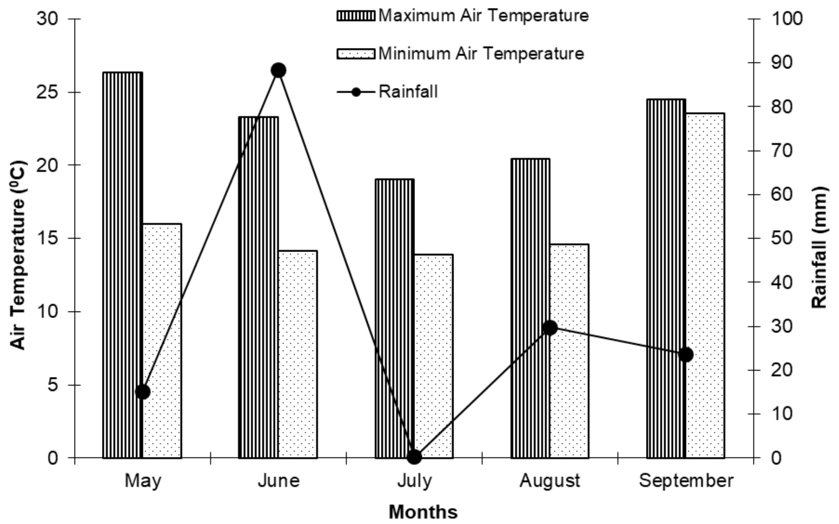


Figure 1. Average values of maximum and minimum air temperatures and rainfall during the experiment conduction in Valença, Rio de Janeiro State, Brazil.

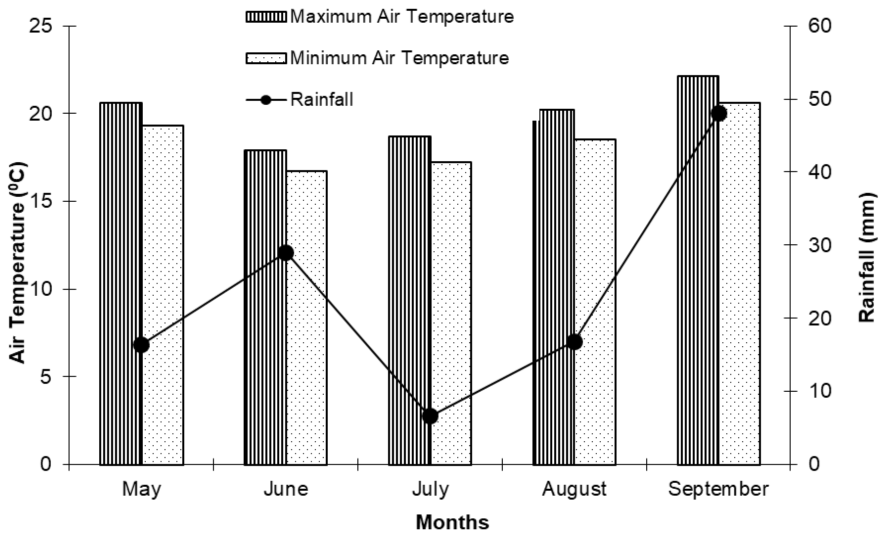


Figure 2. Average values of maximum and minimum air temperatures and rainfall during the experiment conduction in Coronel Pacheco, Minas Gerais State, Brazil.

The experimental design was in randomized complete blocks, with four replications. The treatments were as follows: auxinic herbicides {fluroxypyr + picloram [160 + 160 g a.e. $ha^{-1}$]; fluroxypyr + aminopyralid [160 + 80 g a.e. $ha^{-1}$]; fluroxypyr + triclopyr [160 + 480 g a.e. $ha^{-1}$]; 2,4-D amine (1,340 g a.e. $ha^{-1}$); 2,4-D amine + picloram [720 + 45 g a.e. $ha^{-1}$]}, and tembotrione (84 g a.i. $ha^{-1}$ without mineral oil), in addition to the control without herbicides. The experimental plots covered an area of 12 $m^2$ (3x4 m).

The soils were plowed and harrowed. Furrows were opened spaced 0.8 m apart and fertilized with a seeder machine (SAM 200, Semeato, Brazil). Formulation of NPK (8-28-16) was used in the amount of 350 kg $ha^{-1}$. A mixture of 25 g of the elephant grass seeds genotype (PCEA cultivar) in 1.33 kg of substrate was placed manually in the furrows. The measure of 40 g of the mixture was used to sow 3 linear meters, resulting in approximately 135 seeds per linear meter of the furrow. Plant thinning was not carried out.

Herbicidal treatments were sprayed in post-emergence of elephant grass been approximately 20 cm high. It was used one backpack sprayer ($CO_2$ pressurized) to spray the syrup maintained 2 kgf $cm^{-2}$ constant pressure, providing a spray volume of 150 L $ha^{-1}$. The spray boom (1.5 m wide) was composed of four flat fan nozzles (110.02 - Magno ADGA). The treatments were applied on July 7, 2016 (experiment 1- Valença) and August 2, 2016 (experiment 2- Coronel Pacheco).

Visual symptoms of injury due to herbicides were evaluated at 7, 14, and 21 days after its spray (DAA). Percentage scale ranging from 0 to 100% was used which zero corresponded to no symptoms of phytotoxicity and 100% to the death of plants (SBCPD, 1995). The SPAD index values were obtained at 14 and 21 DAA using the SPAD determiner Konica Minolta, Japan.

Fresh matter from elephant grass plants was collected on September 5, 2016 (Valença) and September 26, 2016 (Coronel Pacheco). The plants in 1.0 x 1.0 m (1.0 $m^2$) square were cut close to the soil surface, packed in Kraft paper bags, and placed in a forced-air ventilation oven for 65 ºC during 72 h to obtain the dry matter production. Then, the plants were weighed on a graduated scale and data were converted to kg $ha^{-1}$.

The phytotoxicity percentage values were normalized by square root transformation (x + 1) to perform analysis of variance (ANOVA) tests. Data were submitted to ANOVA and the means were compared using the Scott-Knott test ($p \leq 0.05$). Statistical analyses were performed using SAEG software for both experiments (Ribeiro Jr., 2001).

## 3. Results and Discussion

There were visual symptoms of phytotoxicity at 7 DAA in all herbicides treatments in the experiment in Valença (Table 1). The symptoms were less intense at 14 DAA and disappeared at 21 DAA, except for tembotrione. In the experiment conducted in Coronel Pacheco, the most phytotoxic treatments at 7 DAA were the mixture of fluroxypyr plus aminopyralid and tembotrione. The plants recovered at 14 DAA and no injury symptoms were detected for fluroxypyr plus aminopyralid. However, in the tembotrione treatment, the plants still showed visual injury symptoms at the second evaluation. None of the treatments showed visual symptoms of phytotoxicity at 21 DAA, not even tembotrione.

**Table 1**. Percentage of phytotoxicity at 7 (P7), 14 (P14) and 21 (P21) days after spraying the treatments. Valença (RJ) and Coronel Pacheco (MG), Brazil, 2016.

| Treatments | Doses (g $ha^{-1}$) | Valença | | | Coronel Pacheco | | |
|---|---|---|---|---|---|---|---|
| | | P7 | P14 | P21 | P7 | P14 | P21 |
| Fluroxypyr +picloram | 160.0 + 160.0 | 5.0 D[1] | 1.6 B | 0.0 B | 0.0 C | 0.0 B | 0.0 |
| Fluroxypyr + aminopyralid | 160.0 + 80.0 | 6.6 C | 2.3 B | 0.0 B | 2.2 B | 0.0 B | 0.0 |
| Fluroxypyr + triclopyr | 160.0 + 480.0 | 5.3 D | 1.6 B | 0.0 B | 0.0 C | 0.0 B | 0.0 |
| 2,4-D | 1,340.0 | 4.6 D | 1.6 B | 0.0 B | 0.0 C | 0.0 B | 0.0 |
| 2,4-D + picloram | 720.0 + 45.0 | 7.6 B | 2.6 B | 0.0 B | 0.0 C | 0.0 B | 0.0 |
| Tembotrione | 84.0 | 10.3 A | 7.3 A | 1.3 A | 8.2 A | 2.2 A | 0.0 |
| Check | - | 0.0 E | 0.0 C | 0.0 B | 0.0 C | 0.0 B | 0.0 |
| CV | - | 3.6 | 8.4 | 6.5 | 4.2 | 4.5 | - |

[1]Mean values followed by different letters are significantly ($p \leq 0.05$) different by Scott–Knott test.

Auxinic herbicides are widely used in pastures, mainly in forages of the genus *Brachiaria* (Vendrame et al., 2014). Grasses are tolerant to these herbicides due to several factors. One of them is related to the low herbicide penetration in the leaves of the plants and also by the limited translocation by the phloem, due to anatomical structures such as nodes and intercalated meristem, favoring conjugation reactions (Oliveira Júnior, 2011).

Tembotrione was the most phytotoxic herbicide for elephant grass plants in both experiments. The characteristic symptoms caused by tembotrione were the bleaching of new leaves. Herbicides that belong to this group are called carotenoid biosynthesis inhibitors and act on some enzymatic sites in the carotenoid pigment synthesis route, more specifically on the enzyme 4-hydroxyphenylpyruvate dioxygenase (HPPD) (Oliveira Júnior, 2011). Blocking the synthesis of these pigments is the phenomenon responsible for the appearance of the characteristic symptom of albinism, bleaching, or depigmentation (Van Almsick, 2009). These herbicides represent one of the most successful classes of inhibitors for controlling broadleaf and grass weeds in cereal crops, and several attributes contributed to the commercial success of carotenoid-inhibiting herbicides, especially in corn production systems (Rodrigues and Almeida, 2018). It is possible to obtain a broadleaf weed control and flexibility in application time. Besides having compatibility in mixing with compounds belonging to various mechanisms of action, they also can synergize with photosystem II herbicides (Choe et al., 2014; Stephenson et al., 2015). Although tembotrione has been registered for maize in post-emergence spraying (Idziak and Woznica, 2014), some sweet corn genotypes are susceptible to the herbicide (Bollman et al., 2008). The hybrid corn cultivar "Merit" has a low tolerance to tembotrione applied alone or in tank-mix with atrazine.

In both elephant grass experiments, treatments with tembotrione were those that caused the greatest reductions in SPAD index values (Table 2). These results reinforce those obtained in visual injury symptoms, considering this treatment the most phytotoxic to seed-propagated elephant grass plants. The SPAD index values at 14 and 21 DAA obtained in the treatment of tembotrione in the municipality of Valença were 14.1 and 23.9, respectively. These values were 35.6 and 39.2 when no herbicide was applied. This behavior was similar to the experiment conducted in Coronel Pacheco. The values obtained at 14 and 21 DAA were 24.5 and 35.7 while for the control without herbicides the values were 48.4 and 48.0, respectively.

**Table 2**. SPAD index at 14 and 21 days after application of the treatments and dry matter weight (DMW) of elephant grass plants. Valença (RJ) and Coronel Pacheco (MG), Brazil, 2016.

| Treatments | Doses (g ha$^{-1}$) | Valença | | | Coronel Pacheco | | |
|---|---|---|---|---|---|---|---|
| | | SPAD | | DMW (kg ha$^{-1}$) | SPAD | | DMW (kg ha$^{-1}$) |
| | | 14 | 21 | | 14 | 21 | |
| Fluroxypyr + picloram | 160.0 + 160.0 | 33.6 A[1] | 31.5 B | 19,942.4 A | 43.9 B | 46.1 A | 18,853.2 A |
| Fluroxypyr + aminopyralid | 160.0 + 80.0 | 29.1 B | 31.5 B | 18,918.0 A | 44.5 B | 48.5 A | 15,774.5 A |
| Fluroxypyr + triclopyr | 160.0 + 480.0 | 30.1 B | 34.1 B | 19,144.7 A | 44.2 B | 48.6 A | 16,174.2 A |
| 2,4-D | 1,340.0 | 30.5 B | 30.8 B | 17,831.4 A | 44.3 B | 47.6 A | 15,430.2 A |
| 2,4-D + picloram | 720.0 + 45.0 | 31.6 B | 33.2 B | 18,117.1 A | 43.5 B | 48.2 A | 17,293.2 A |
| Tembotrione | 84.0 | 14.1 C | 23.9 C | 13,664.3 B | 24.5 C | 35.7 B | 11,004.1 B |
| Check | - | 35.6 A | 39.2 A | 19,942.4 A | 48.4 A | 48.0 A | 19,139.1 A |
| CV (%) | - | 7.3 | 4.8 | 10.1 | 3.5 | 3.0 | 13.9 |

[1]Mean values followed by different letters are significantly ($p \leq 0.05$) different by Scott–Knott test.

Tembotrione was sprayed on elephant grass isolated and mixed with atrazine, with and without mineral oil (Brighenti et al., 2017b). The results obtained by these authors indicated that tembotrione was the most phytotoxic herbicide to vegetative-propagated elephant grass. It caused significant losses in forage production whether or not adding mineral oil.

The treatments with auxinic herbicides did not affect the dry mass productivity of elephant grass compared to the control without herbicides (Table 2). However, tembotrione reduced the dry matter productivity of elephant grass plants by 31.4% and 42.5% compared to the control, for the experiments conducted in Valença and Coronel Pacheco, respectively.

## 4. Conclusions

Tembotrione was the most phytotoxic herbicide to elephant grass propagated by seed, causing a reduction on forage dry matter yield.

The treatments with fluroxypyr + picloram, fluroxypyr + aminopyralid, fluroxypyr + triclopyr, 2,4-D and 2,4-D + picloram did not cause symptoms of phytotoxic capable of providing a reduction in forage dry matter yield, being potential herbicides to spray in seed-propagated elephant grass fields.

## Acknowledgments

Financial support from *Fundação de Amparo à Pesquisa do Estado de Minas Gerais* (FAPEMIG) and the *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq) is gratefully acknowledged.

## References

Borges LS, Aquino FC, Evangelista AF. Potencial do capim elefante para geração de energia-revisão. Nutritime Revista Eletrônica. 2016;13(1):4518-4523.

Brighenti AM, Calsavara LHF, Varotto YVG. Preemergence herbicides on weed control in elephant grass pasture. Ciência e Agrotecnologia. 2017a;41(1):52-59. doi.org/10.1590/1413-70542017411024516

Brighenti AM, Machado JC, Ledo FJS, Calsavara LHF, Varotto YVG. HPPD-Inhibiting herbicides alone or in tank-mix with atrazine in elephant grass. Journal of Agricultural Science. 2017b;9(11):234-241. doi.org/10.5539/jas.v9n11p234

Brighenti AM, Ledo FJS, Machado JC, Calsavara LHF, Varotto YVG. Elephant grass response to aminoacid synthesis inhibitor herbicides. Australian Journal of Crop Science. 2017c;11(1):38-42. doi: 10.21475/ajcs.2017.11.01.pne187

Bollman JD, Boerboom CM, Becker RL, Fritz VA. Efficacy and tolerance to HPPD-inhibiting herbicides in sweet corn. Weed technology. 2008;22(4):666-674. https://doi.org/10.1614/WT-08-036.1

Choe E, Williams II MM, Boydstn RA, Huber JL, Huber SC, Pataky JK. Photosystem II-Inhibitors play a limited role in sweet corn response 4-hydroxyphenyl pyruvate dioxygenase-Inhibiting herbicides. Agronomy Journal. 2014;106(4):1317-1323. https://doi.org/10.2134/agronj13.0570.

Costa NB, Bezerra GA, Pinheiro Filho GO, Moraes MG. Distribution of non-structural carbohydrates in the vegetative organs of upland rice. Ciência e Agrotecnologia. 2021;45:e008721. http://dx.doi.org/10.1590/1413-7054202145008721

Ferreira RP, Pereira AV. Melhoramento de forrageiras. In: Borém, A. (Ed.). Melhoramento de espécies cultivadas. 1ª.edição, Viçosa: UFV; 2005.

Idziak R, Woznica Z. Impact of tembotrione and flufenacet plus isoflutole application timings, rates and adjuvant type on weed and yield of maize. Chilean Journal of Agricultural Research. 2014;72(2):129-134. http://dx.doi.org/10.4067/S0718-58392014000200001

Lima ES, Silva JFC, Vásquez HM, Andrade EN, Dominicis BB, Morais JPG, et al. Características agronômicas e nutritivas das principais cultivares de capim-elefante do Brasil. Veterinária e Zootecnia. 2010;17(3):324-334.

MacNeill GJ, Mehrpouyan S, Minow MAA, Patterson JA, Tetlow IJ, Emes MJ. Starch as a source, starch as a sink: the bifunctional role of starch in carbono allocation. Journal Experimental Botany. 2017;68(16):4433-4453. https://doi.org/10.1093/jxb/erx291

Moreira PC, Wascheck RC, Dutra AR, Grandsire C, Almeida OC, Moreira SOL, et al. Utilização do capim-elefante para bovinos. Estudos. 2008;35(3):429-449. http://dx.doi.org/10.18224/est.v35i3.743

Oliveira Júnior RS. Mecanismos de ação de herbicidas. In: Oliveira Júnior RS, Constantin J, Inoue MH. Biologia e manejo de plantas daninhas. Curitiba - Editora Omnipax, 2011, p. 141-192.

Oliveira MFL, Gravina G, Daher RF, Silva VB. Pre-breeding of elephant grass for energy purposes and biomass analysis in Campos dos Goytacazes, RJ, Brazil. African Journal of Agricultural Research. 2014;9(36):2743-2758. DOI: 10.5897/AJAR2014.8900

Quéno LMR, de Souza AN, Ângelo H, do Vale AT, Martins IS. Custo da produção das biomassas de eucalipto e capim elefante para energia. Cerne. 2011;17(3):417–426. https://doi.org/10.1590/S0104-77602011000300017

Ribeiro Jr JI. Análises estatísticas no SAEG. 1ª.edição. Viçosa: UFV; 2001.

Rodrigues BN, Almeida FS. Guia de Herbicidas. 7ª. edição. Londrina; 2018.

SBCPD. Procedimentos para instalação e análises de experimentos com herbicidas. Sociedade Brasileira da Ciência das Plantas Daninhas. 1ª.edição. Londrina; 1995.

Santos EA, Andrade VC, Sousa AS, Okumura F, Simeone MLF, Santos JB, et al. Selectivity of pre-emergent herbicides in sweet potatoe genotypes. Revista Brasileira de Ciências Agrárias. 2018a;13(1):e5511. https://doi.org/10.5039/agraria.v13i1a5511

Santos HG, Jacomine PKT, Anjos LHC, Oliveira VA, Lumbreras JF, Coelho MR, et al. Sistema Brasileiro de Classificação de Solos. 5a edição. Brasília: Embrapa; 2018b.

Silva VB, Daher RF, Menezes BRS, Oliveira MLF, Araujo MSB, Novo AAC. Different stability methods for cultivar recommendation in elephant-grass for energy purposes. Cerne. 2017;23(4):507-515. https://doi.org/10.1590/01047760201723042292

Stephenson DO, Bond JA, Landry RL, Edwards HM. Weed management in corn with postemergence application of tembotrione or thiencarbazone. Weed Technology. 2015;29(3):350-358. https://doi.org/10.1614/WT-D-14-00104.1

Van Almsick A. New HPPD-inhibitors – a proven mode of action as a new hope to solve current weed problems. Outlooks on Pest Management. 2009;20(1):27–30. https://doi.org/10.1564/20feb09

Vendrame GHM, Yamashita OM, Carvalho MAC, Campos OR, Dallacort R, Koga PS, et al. Manejo químico de *Vismia guianensis* com diferentes misturas de herbicidas auxínicos em área de pastagem de *Brachiaria brizantha*. Revista de Ciências Agroambientais. 2014;12(1):35-41.