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***Short Communication***

# Screening pre-emergence herbicides for weed control during early elephant grass growth

## *Evaluación de herbicidas preemergentes para el control de malezas en el desarrollo temprano del pasto elefante*

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**Abstract**

Two experiments were carried out in the municipality of Coronel Pacheco, Minas Gerais State, Brazil in 2020 and 2021 to identify additional herbicide options for weed control during early elephant grass pasture establishment. Thirteen pre-emergence herbicides were compared to weed-free and weedy controls in a randomized complete block design with 4 replications. Forage yield losses were significant as a result of weed interference throughout the entire crop cycle. The most phytotoxic treatments were trifluralin and diuron + hexazinone. Weed control was effective for all treatments, except for trifluralin applied alone. Elephant grass dry matter yield was not influenced by diuron, ametryne, flumioxazin and metribuzin, identifying them as potential pre-emergence herbicides for weed control in elephant grass pastures.

**Keywords:** *Cenchrus purpureus*, napier grass, pastures, *Pennisetum purpureum*, selectivity, tolerance.

**Resumen**

Se realizaron dos experimentos en el município de Coronel Pacheco, Estado de Minas Gerais, Brasil, el 17 de marzo de 2020 (experimento 1) y el 26 de febrero de 2021 para identificar opciones adicionales de herbicidas para el control de malezas en el desarrollo temprano del pasto elefante. El diseño experimental fue de bloques completos al azar, con cuatro repeticiones. Se compararon trece herbicidas preemergentes versus tratamientos control desmalezado y enmalezado. Las pérdidas en el rendimiento del forraje fueron significativas como resultado de la interferencia de malezas durante todo el ciclo de cultivo. Los tratamientos más fitotóxicos fueron trifluralina y diurón + hexazinona. El control de malezas fue efectivo para todos los tratamientos, excepto para la aplicación de trifluralina sola. El redimiento de materia seca de pasto elefante no fue influenciado por el diurón, ametrina, flumioxazina y metribuzina, siendo estos herbicidas preemergentes de uso potencial para el control de malezas en pasto elefeante.

**Palabras clave:** *Cenchrus purpureus*, pasto napier, pasturas, *Pennisetum purpureum*, selectividad, tolerancia.

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## Introduction

Elephant grass [*Cenchrus purpureus* (Schumach.) Morrone formerly *Pennisetum purpureum* (Schumach.)] is one of the tropical forage grasses with potential for high dry matter yield that is used mainly for cattle in Brazil (Rosa et al. 2019). In addition, it can be used as raw material for biofuel as energy (Borges et al. 2016; Silva et al. 2017; Rocha et al. 2018) and conserved forage as silage (Bonfá et al. 2015; Lira Júnior et al. 2018).

Elephant grass breeding programs have been established in Brazil to identify cultivars with desirable agronomic characteristics, including high forage production, and excellent nutritive value (Rosa et al. 2019; Pereira et al. 2021). Cultivars 'BRS Capiaçu' and 'BRS Kurumi' were recently developed and provide options for cutting, grazing and silage (Pereira et al. 2016; Pereira et al. 2021). The rapid expansion of elephant grass cultivation in Brazil prompted research on optimum management of the crop.

Despite elephant grass 'BRS Capiaçu' and 'BRS Kurumi' having rapid initial development and covering the soil surface, weed competition can cause serious yield losses (Rosa et al. 2019). In some cases, productivity losses of elephant grass dry matter can reach 41% due to 17.5 plants/m$^2$ total weed density of *Urochloa decumbens*, *Megathyrsus maximus* (syn. *Panicum maximum*), *Ipomoea grandifolia*, *Commelina benghalensis*, *Amaranthus retroflexus* and *Portulaca oleracea* (Brighenti et al. 2017a).

Narrow-leaf weed control is a specific problem in elephant grass pastures. Grass weeds such as *Urochloa* species and *Megathyrsus maximus* are especially difficult to control in elephant grass fields (Abreu et al. 2006; Pereira et al. 2021). Morning glories (*Ipomoea* species) are another long-standing weeds in elephant grass crops (Pereira et al. 2021). Vines wrap tightly around the plants and migrate laterally across the rows. Clusters of stems choke farm equipment, making elephant grass harvest a struggle for smallholders (Pereira et al. 2021). Yellow nutsedge (*Cyperus esculentus*) and purple nutsedge (*Cyperus rotundus*) are also considered invasive weeds in elephant grass crops (Pereira et al. 2021). The total growth period for preventing interference from *C. esculentus* was 42 d after elephant grass planting (Brighenti and Oliveira 2018).

Although some preliminary results in chemical weed control in elephant grass were recorded previously (Silva et al. 2002; Brighenti et al. 2017b), none of them evaluated herbicides that control both broad-leaf weeds, such as morning glories, and grass weeds, mainly *Urochloa* and *Megathyrsus maximus*. Herbicides which have been on the market for a long time, including trifluralin, ametryne, diuron, and metribuzin, could be used because they tend to be found more easily at affordable prices in different regions of Brazil. Identifying correct weed management strategies during early elephant grass establishment is crucial to achieve successful weed control in the subsequent stages of cultivation. The objective of this study was to identify additional pre-emergence herbicide options for simultaneous control of broad and narrow-leaf weeds during early elephant grass development.

## Materials and Methods

Two experiments were carried out in the experimental field of Embrapa Dairy Cattle, municipality of Coronel Pacheco, Minas Gerais State, Brazil (21°33`03.45" S, 43°15'23.30" W). The climate was identified as Cwa (Köppen 1948). This is the typical climate of the middle East region of Brazil, characterized by dry winters and rainy summers (Alvares et al. 2013). The average values of air temperature (maximum and minimum) and rainfall during the experimental period are shown in Table 1.

**Table 1.** Average maximum and minimum monthly air temperatures (T) (°C) and rainfall (mm) during the experimental periods in years 2020 and 2021 at Coronel Pacheco, Minas Gerais State, Brazil.

| Air temperatures/ Monthly precipitation | Experiment 1 (2020) | | | | | Experiment 2 (2021) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mar | Apr | May | Jun | Jul | Feb | Mar | Apr | May | Jun |
| Maximum Temperature (ºC) | 25.9 | 24.1 | 21.4 | 21.8 | 21.9 | 26.7 | 27.3 | 24.1 | 22.7 | 20.9 |
| Minimum Temperature (ºC) | 25.0 | 23.2 | 20.3 | 20.5 | 20.7 | 25.5 | 25.8 | 22.5 | 21.3 | 19.5 |
| Rainfall (mm) | 237.8 | 48.20 | 33.38 | 11.0 | 2.20 | 279.4 | 88.00 | 69.40 | 22.00 | 18.20 |

The soil of the area is classified as Red-Yellow Argisol (Santos et al. 2018). Soil texture properties are 44% clay, 11% silt and 45% sand. The soil chemical properties (0–20 cm depth) of the experiments 1 and 2 are pH ($H_2O$)=4.8 and 5.6, P=2.7 and 5.0 mg/dm$^3$, K=140 and 135 mg/dm$^3$, $Ca^{2+}$=0.34 and 1.7 cmol$_c$/dm$^3$, $Mg^{2+}$=0.22 and 0.96 cmol$_c$/dm$^3$, $Al^{3+}$=0.6 and 0.0 cmol$_c$/dm$^3$, H+Al=4.29 and 3.63 cmol$_c$/dm$^3$, CEC$_{(t)}$=1.52 and 3.08 cmol$_c$/dm$^3$, CEC (T$_{pH=7.0}$)=5.2 and 3.08 cmol$_c$/dm$^3$, V%=17.7 and 45.9, and C organic 1.56 and 2.11 dag/kg, respectively.

The experiments were implemented on March 17, 2020 (experiment 1) and February 26, 2021 (experiment 2) arranged in randomized complete blocks with 4 replications. Treatments of pre-emergence herbicide applications of trifluralin (1.5 kg ai/ha), trifluralin + atrazine (0.75+1.25 kg ai/ha), pendimethalin (1.5kg ai/ha), atrazine + S-metolachlor (1.48+1.16 kg ai/ha), diuron (2.0 kg ai/ha), diuron + hexazinone (1.17+0.33 kg ai/ha), tebuthiuron (1.0 kg ai/ha), sulfentrazone (0.15 kg ai/ha), ametryne (3.0 kg ai/ha), flumioxazin (0.045 kg ai/ha), S-metolachlor (2.4 kg ai/ha), metribuzin (0.96 kg ai/ha), metribuzin + S-metolachlor (0.48+0.96 kg ai/ha) were used. Weed-free (hand-weeded) and no weeding treatments were also included as controls.

A preliminary survey of the main weed species in the plots was carried out before planting. Predominant weeds inside a 0.25 m$^2$ quadrat were counted at 10 randomly chosen points and values converted into plants/m$^2$. Prevalent weed species and their densities were *Amaranthus spinosus* (117 and 32 plants/m$^2$); *Ipomoea purpurea* (17 and 1 plants/m$^2$); *Commelina benghalensis* (16 and 12 plants/m$^2$); *Megathyrsus maximus* (20 and 29 plants/m$^2$); *Portulaca olearaceae* (2 and 8 plants/m$^2$), and *Triumfetta bartramia* (1 and 2 plants/m$^2$) for experiments 1 and 2, respectively.

The experimental areas were ploughed, harrowed and levelled before planting elephant grass stem cuttings. Plots of 20.8 m$^2$ were planted in furrows at 0.3 m deep in 4 rows of 4 m length with 1.3 m between rows. Fertilizer application was done using 400 kg NPK/ha (08% N, 28% P, 16% K). Stem cuttings of elephant grass ('BRS Capiaçu') of 3 m length were laid in furrows and cut with a large knife to approximately 0.4 m. Furrows were covered with a thin layer of soil. Elephant grass plants were side dressed with 400 kg NPK/ha (20% N, 05% P, 20% K) 40 days after planting.

Herbicide treatments were applied the day after planting using a backpack sprayer (Herbicat Ltda, Catanduva, São Paulo State, Brazil). The pressure of $CO_2$ was maintained at 2 kgf/cm$^2$ to deliver a volume of 150 L/ha. The sprayer boom (1.5 m length) comprised 4 flat fan nozzles (110.02 - Magno ADGA). The environmental conditions during the herbicide spraying were temperatures of 26 °C and 28 °C, relative humidity of 67% and 69% and wind speed of 3 m/s and 2 m/s for the experiments 1 and 2, respectively. Sprinkler irrigation was once after the herbicide sprays (20 mm water layer).

Phytotoxicity symptoms on elephant grass plants were assessed at 7, 14 and 21 days after herbicide applications (DAA). Weed control was evaluated at 7 and 21 DAA. Both evaluations were done by using a scale of 0–100% (Velini et al. 1995), where zero corresponded to no symptoms of phytotoxicity on elephant grass plants or no weed control, and 100% to elephant grass death or complete weed control.

Weed densities were obtained for both experiments at 30 and 60 DAA by counting the species in a 0.25 m$^2$ quadrat randomly placed inside the plots and counts converted to plants/m$^2$. In experiment 2, a second evaluation of weed density was performed at elephant grass harvest using the same procedure. Weed species were cut at soil level in a 0.25 m$^2$ quadrat at 30 and 60 DAA (experiment 1) and at elephant grass harvest (experiment 2). Plants were placed in paper bags and dried in a forced ventilation air oven at 55 °C for 72 h. The dry matter was weighed and data converted to g/m$^2$.

Elephant grass plants were harvested at 120 days after planting. Two central rows of 4 m length were cut close to soil level and weighed. Values for fresh matter yield were converted to kg/ha. Sub-samples of the harvested fresh matter were taken from each plot, weighed and packed in paper bags and placed in an oven with forced air ventilation at 55 °C for 72 h. The samples were reweighed, and data converted to kg/ha for elephant grass dry matter.

The percentage values of phytotoxicity on elephant grass plants and the weed control percentages were normalized by square root tansformation (x + 1) to perform analysis of variance (ANOVA). Data were subjected to ANOVA and mean values were compared using Scott-Knott test ($P<0.05$). The joint analysis was used for elephant grass dry matter yield to confirm the most selective herbicides. Statistical analyses were performed using SAEG software (Ribeiro Júnior 2001).

## Results and Discussion

Treatments with pendimethalin and the formulated mixture of diuron + hexazinone caused slight symptoms of injury on elephant grass plants in experiment 1 (Table 2). The characteristic symptoms of pendimethalin were yellowing on younger leaves. However, the symptomatology for diuron + hexazinone were higher than pendimethalin with total plant chlorosis. Intensity of symptoms decreased during the evaluation period. However, injury signs were still visible for both treatments at 21 DAA (2.5%). Similar results were obtained by Brighenti et al. (2017a) when using diuron + hexazinone. Although the treatment provided efficient weed control (99–100%), injury symptoms were extremely severe. Assimilation of carbon dioxide ($CO_2$) after hexazinone application in post-emergence of elephant grass plants (Cutts et al. 2011) showed carbon dioxide assimilation was reduced to zero, indicating plant death of treated elephant grass 2 days after herbicide application.

The treatment with trifluralin + atrazine caused slight symptoms of injury on elephant grass plants in experiment 2 (Table 3). However, phytotoxicity symptoms disappeared at the last evaluation.

The formulated mix of diuron + hexazinone was the most phytotoxic treatment in experiment 2 (Table 3), similar to that observed in experiment 1. Injured plants had symptoms of generalized chlorosis and necrosis on the leaf tips, which is typical of photosynthetic inhibitors. As in experiment 1, injury symptoms declined over time, but injury was still present at the last evaluation. Similar results were obtained by Brighenti et al. (2017a). The mix of diuron + hexazinone was one of the most phytotoxic treatments for elephant grass plants, with 29% of injury compared to the control at 23 d after planting. Although the formulated mixture of diuron plus hexazinone is registered for similar crops in Brazil, such as sugarcane (*Saccharum officinarum*) (MAPA 2024), some cultivars (‘RB925345’, ‘RB867515’, ‘RB855146’ and ‘SP80-1816’) showed different degrees of sensitivity, varying according to genotype (Ferreira et al. 2012). Diuron + hexazinone caused decreases of 63% and 40% in dry matter yield of cultivars ‘RB925345’ and ‘RB867515’ when compared to the control without application, respectively. Losses in sugarcane dry matter productivity were even greater in ‘RB855146’ and ‘SP80-1816’, reaching values greater than 70% (Ferreira et al. 2012).

**Table 2.** Percentage elephant grass injury at 7 (P7), 14 (P14) and 21 (P21) days after herbicide application (DAA) and percent weed control at 7 (WC7) and 21 (WC21) DAA in experiment 1 at Coronel Pacheco, Minas Gerais State, Brazil, 2020.

| Treatments | P7 | P14 | P21 | WC7 | WC21 |
|---|---|---|---|---|---|
| Trifluralin | 0.0(1.0)[1b] | 0.0(1.0)[b] | 0.0(1.0)[b] | 79.00(8.94)[d] | 77.25(8.84)[f] |
| Trifluralin + Atrazine | 0.0(1.0)[b] | 0.0(1.0)[b] | 0.0(1.0)[b] | 99.25(10.0)[a] | 99.50(10.0)[a] |
| Pendimethalin | 5.50(2.54)[a] | 4.0(2.2)[a] | 2.5(1.8)[a] | 99.25(10.0)[a] | 85.75(9.31)[d] |
| Atrazine + S-metolachlor | 0.0(1.0)[b] | 0.0(1.0)[b] | 0.0(1.0)[b] | 99.25(10.0)[a] | 99.50(10.0)[a] |
| Diuron | 0.0(1.0)[b] | 0.0(1.0)[b] | 0.0(1.0)[b] | 96.25(9.86)[c] | 82.25(9.12)[e] |
| Diuron + Hexazinone | 5.75(2.59)[a] | 3.75(2.1)[a] | 2.5(1.8)[a] | 100.0(10.0)[a] | 99.75(10.0)[a] |
| Tebuthiuron | 0.0(1.0)[b] | 0.0(1.0)[b] | 0.0(1.0)[b] | 100.0(10.0)[a] | 99.75(10.0)[a] |
| Sulfentrazone | 0.0(1.0)[b] | 0.0(1.0)[b] | 0.0(1.0)[b] | 98.50(9.97)[a] | 89.25(9.49)[c] |
| Ametryne | 0.0(1.0)[b] | 0.0(1.0)[b] | 0.0(1.0)[b] | 99.50(10.0)[a] | 98.75(9.98)[a] |
| Flumioxazin | 0.0(1.0)[b] | 0.0(1.0)[b] | 0.0(1.0)[b] | 96.50(9.87)[c] | 89.50(9.51)[c] |
| S-metolachlor | 0.0(1.0)[b] | 0.0(1.0)[b] | 0.0(1.0)[b] | 98.00(9.94)[b] | 95.75(9.83)[b] |
| Metribuzin | 0.0(1.0)[b] | 0.0(1.0)[b] | 0.0(1.0)[b] | 99.75(10.0)[a] | 97.50(9.92)[b] |
| Metribuzin + S-metolachlor | 0.0(1.0)[b] | 0.0(1.0)[b] | 0.0(1.0)[b] | 100.0(10.0)[a] | 97.50(9.92)[b] |
| Weed free | 0.0(1.0)[b] | 0.0(1.0)[b] | 0.0(1.0)[b] | 100.0(10.0)[a] | 100.0(10.0)[a] |
| Weedy | 0.0(1.0)[b] | 0.0(1.0)[b] | 0.0(1.0)[b] | 0.00 (1.0)[e] | 0.00 (1.0)[g] |
| Coefficient of variation (%) | 3.13 | 4.86 | 5.06 | 0.49 | 0.97 |

[1]Mean values of control percentages (x) transformed into square root (x + 1).
Mean values followed by different letters are significantly (P<0.05) different by Scott-Knott test.

**Table 3.** Percentage elephant grass injury at 7 (P7), 14 (P14) and 21 (P21) days after herbicide application (DAA) and percent weed control at 7 (WC7) and 21 (WC21) DAA in experiment 2 at Coronel Pacheco, Minas Gerais State, Brazil in 2021.

| Treatments | P7 | P14 | P21 | WC7 | WC21 |
|---|---|---|---|---|---|
| Trifluralin | 0.00(1.0)[1]$^{c}$ | 0.00(1.0)$^{c}$ | 0.0(1.0)$^{b}$ | 95.7 (9.83)$^{c}$ | 99.5 (10.02)$^{a}$ |
| Trifluralin + Atrazine | 1.00(1.36)$^{b}$ | 0.5(1.20)$^{b}$ | 0.0(1.0)$^{b}$ | 100.0(10.04)$^{a}$ | 100.0(10.04)$^{a}$ |
| Pendimethalin | 0.00(1.0)$^{c}$ | 0.00(1.0)$^{c}$ | 0.0(1.0)$^{b}$ | 96.0 (9.84)$^{c}$ | 98.5 (9.97)$^{b}$ |
| Atrazine + S-metolachlor | 0.00(1.0)$^{c}$ | 0.00(1.0)$^{c}$ | 0.0(1.0)$^{b}$ | 95.7 (9.83)$^{c}$ | 100.0(10.04)$^{a}$ |
| Diuron | 0.00(1.0)$^{c}$ | 0.00(1.0)$^{c}$ | 0.0(1.0)$^{b}$ | 96.7 (9.88)$^{c}$ | 92.5 (9.66 )$^{d}$ |
| Diuron + Hexazinone | 2.75(1.92)$^{a}$ | 1.75(1.65)$^{a}$ | 0.75(1.31)$^{a}$ | 100.0 (10.04)$^{a}$ | 100.0 (10.04)$^{a}$ |
| Tebuthiuron | 0.00(1.0)$^{c}$ | 0.00(1.0)$^{c}$ | 0.0(1.0)$^{b}$ | 100.0 (10.04)$^{a}$ | 100.0 (10.04)$^{a}$ |
| Sulfentrazone | 0.00(1.0)$^{c}$ | 0.00(1.0)$^{c}$ | 0.0(1.0)$^{b}$ | 89.5 (9.51)$^{d}$ | 95.2 (9.81)$^{c}$ |
| Ametryne | 0.00(1.0)$^{c}$ | 0.00(1.0)$^{c}$ | 0.0(1.0)$^{b}$ | 99.2 (10.01)$^{b}$ | 100.0(10.04)$^{a}$ |
| Flumioxazin | 0.00(1.0)$^{c}$ | 0.00(1.0)$^{c}$ | 0.0(1.0)$^{b}$ | 88.0 (9.43)$^{e}$ | 95.0 (9.79)$^{c}$ |
| S-metolachlor | 0.00(1.0)$^{c}$ | 0.00(1.0)$^{c}$ | 0.0(1.0)$^{b}$ | 98.7 (9.98)$^{b}$ | 100.0 (10.04)$^{a}$ |
| Metribuzin | 2.50(1.86)$^{a}$ | 1.50(1.57)$^{a}$ | 0.5(1.20)$^{a}$ | 99.2 (10.01)$^{b}$ | 100.0(10.04)$^{a}$ |
| Metribuzin + S-metolachlor | 2.50(1.86)$^{a}$ | 1.50(1.57)$^{a}$ | 0.25(1.10)$^{b}$ | 99.0 (9.99)$^{b}$ | 100.0 (10.04)$^{a}$ |
| Weed-free | 0.00(1.0)$^{c}$ | 0.00(1.0)$^{c}$ | 0.0(1.0)$^{b}$ | 100.0 (10.04)$^{a}$ | 100.0 (10.04)$^{a}$ |
| Weedy | 0.00(1.0)$^{c}$ | 0.00(1.0)$^{c}$ | 0.0(1.0)$^{b}$ | 0.00 (1.0) f | 0.00 (1.0)$^{e}$ |
| Coefficient of variation (%) | 11.80 | 8.94 | 9.03 | 0.41 | 0.25 |

[1]Mean values of control percentages (x) transformed into square root (x + 1).
Mean values followed by different letters are significantly ($P<0.05$) different by Scott-Knott test.

Metribuzin and metribuzin + S-metolachlor caused mild symptoms of injury on elephant grass leaves at the first evaluation in experiment 2 (Table 3). Symptoms declined over time but were still present at 21 DAA.

Herbicide performance on weed control reached satisfactory values in both experiments with percent means higher than 82% at 21 DAA (Tables 2 and 3), except for trifluralin applied alone in experiment 1 (77.2%) (Table 2).

All treatments presented densities statistically equal to the weed-free control when analyzing the densities and dry matter of weeds at 30 DAA (experiment 1) (Table 4). However, trifluralin, flumioxazin and treatments with metribuzin resulted in higher density values than the weed-free control at 60 DAA. Also, trifluralin, ametryne, S-metolachlor, and those treatments with metribuzin resulted in higher weed dry matter than the weed-free control at 60 DAA (Table 4).

The mean values of weed density at 30 and 60 DAA, as well as, the weed dry matter were statistically the same as the weed-free control for all herbicide treatments in experiment 2 (Table 5).

Metribuzin was the only treatment statistically different from the weed-free control for the weed density at elephant grass harvest (Table 5). Considering results from both experiments for elephant grass dry matter weight and the joint analysis for this variable, the herbicides that resulted in higher values when compared with weed-free controls were diuron, ametryne, flumioxazin and metribuzin (Table 6). These 4 herbicides were selective for elephant grass plants and provided satisfactory weed control in both experiments (Figures 1 and 2).

The yield decrease in amount of elephant grass dry matter due to coexistence with weeds throughout the entire cycle is evident when comparing weedy and weed-free controls. Elephant grass dry matter losses were 69% and 65% for experiments 1 and 2, respectively (Table 6).

**Table 4.** Weed density (plants/m$^2$) at 30 (WD30) and 60 (WD60) days after herbicide application (DAA) and dry matter of weeds (g/m$^2$) at 30 (DMW30) and 60 (DMW60) DAA, in function of the treatments in Experiment 1 at Coronel Pacheco, Minas Gerais State, Brazil in 2020.

| Treatments | WD30 | WD60 | DMW30 | DMW60 |
|---|---|---|---|---|
| Trifluralin | 31.0$^b$ | 37.0$^b$ | 12.10$^b$ | 64.84$^c$ |
| Trifluralin + Atrazine | 7.0$^b$ | 12.0$^c$ | 1.83$^b$ | 28.44$^d$ |
| Pendimethalin | 6.0$^b$ | 17.0$^c$ | 5.28$^b$ | 46.79$^d$ |
| Atrazine + S-metolachlor | 4.0$^b$ | 19.0$^c$ | 2.09$^b$ | 31.68$^d$ |
| Diuron | 8.0$^b$ | 10.0$^c$ | 3.10$^b$ | 42.21$^d$ |
| Diuron + Hexazinone | 1.0$^b$ | 5.0$^c$ | 0.72$^b$ | 20.67$^d$ |
| Tebuthiuron | 1.0$^b$ | 6.0$^c$ | 0.70$^b$ | 20.99$^d$ |
| Sulfentrazone | 7.0$^b$ | 15.0$^c$ | 1.46$^b$ | 26.26$^d$ |
| Ametryne | 5.0$^b$ | 14.0$^c$ | 1.78$^b$ | 82.60$^c$ |
| Flumioxazin | 12.0$^b$ | 26.0$^b$ | 6.48$^b$ | 55.27$^d$ |
| S-metolachlor | 6.0$^b$ | 10.0$^c$ | 3.20$^c$ | 93.78$^c$ |
| Metribuzin | 25.0$^b$ | 34.0$^b$ | 6.09$^b$ | 134.67$^b$ |
| Metribuzin + S-metolachlor | 8.0$^b$ | 26.0$^b$ | 6.21$^b$ | 73.52$^c$ |
| Weed-free | 0.0$^b$ | 0.0$^c$ | 0.0$^b$ | 0.0$^d$ |
| Weedy | 175.0$^a$ | 90.0$^a$ | 204.38$^a$ | 554.75$^a$ |
| Coefficient of variation (%) | 89.98 | 36.91 | 89.67 | 33.78 |

Mean values followed by different letters are significantly ($P<0.05$) different by Scott-Knott test.

**Table 5.** Weed density (plants/m$^2$) at 30 (WD30), 60 (WD60) days after herbicide application and at elephant grass harvest (WDH) and dry matter of weeds (g/m$^2$) at 60 (DMW60) DAA, in function of the treatments in Experiment 2 at Coronel Pacheco, Minas Gerais State, Brazil in 2021.

| Treatments | WD30 | WD60 | WDC | DMW60 |
|---|---|---|---|---|
| Trifluralin | 10.0$^b$ | 7.0$^b$ | 8.0$^c$ | 2.0$^b$ |
| Trifluralin + Atrazine | 7.0$^b$ | 6.0$^b$ | 10.0$^c$ | 6.1$^b$ |
| Pendimethalin | 9.0$^b$ | 11.0$^b$ | 7.0$^c$ | 1.9$^b$ |
| Atrazine + S-metolachlor | 6.0$^b$ | 4.0$^b$ | 8.0$^c$ | 2.5$^b$ |
| Diuron | 6.0$^b$ | 11.0$^b$ | 9.0$^c$ | 4.4$^b$ |
| Diuron + Hexazinone | 0.0$^b$ | 5.0$^b$ | 10.0$^c$ | 0.4$^b$ |
| Tebuthiuron | 3.0$^b$ | 5.0$^b$ | 9.0$^c$ | 2.4$^b$ |
| Sulfentrazone | 11.0$^b$ | 10.0$^b$ | 8.0$^c$ | 5.0$^b$ |
| Ametryne | 9.0$^b$ | 11.0$^b$ | 12.0$^c$ | 9.3$^b$ |
| Flumioxazin | 9.0$^b$ | 12.0$^b$ | 16.0$^c$ | 5.9$^b$ |
| S-metolachlor | 9.0$^b$ | 6.0$^b$ | 13.0$^c$ | 3.3$^b$ |
| Metribuzin | 8.0$^b$ | 10.0$^b$ | 26.0$^b$ | 6.3$^b$ |
| Metribuzin + S-metolachlor | 9.0$^b$ | 7.0$^b$ | 13.0$^c$ | 8.8$^b$ |
| Weed-free | 0.0$^b$ | 0.0$^b$ | 13.0$^c$ | 0.0$^b$ |
| Weedy | 91.0$^a$ | 99.0$^a$ | 49.0$^a$ | 212.3$^a$ |
| Coefficient of variation (%) | 87.53 | 110.65 | 48.10 | 93.30 |

Mean values followed by different letters are significantly ($P<0.05$) different by Scott-Knott test.


**Figure 1**. Weed control in elephant grass at 30 DAA (days after herbicide application) in using diuron 2.0 kg ai/ha (4.0 L cp/ha) **(A);** weedy control **(B);** ametryne 3.0 kg ai/ha (6.0 L cp/ha) **(C)**. (ai=active ingredient, cp=commercial product).


**Figure 2**. Weed control in elephant grass at 30 DAA (days after herbicide application) using flumioxazin 0.045 kg ai/ha (90.0 g cp/ ha) **(A)**; weedy control **(B)**; metribuzin 0.96 kg ai/ha (2.0 L cp/ha) **(C)**. (ai=active ingredient, cp= commercial product).

**Table 6.** Elephant grass fresh matter weight (FM) (kg/ha) and dry matter weight (DM) (kg/ha) (individual analyses for experiments 1 and 2) and joint analysis of elephant grass dry matter weight (JADM) at Coronel Pacheco, Minas Gerais State, Brazil, 2020/2021.

| Treatments | Experiment 1 | | Experiment 2 | | JADM |
|---|---|---|---|---|---|
| | FM | DM | FM | DM | |
| Trifluralin | 21,794.87$^{b}$ | 9,700.63$^{a}$ | 29,358.97$^{c}$ | 5,405.10$^{b}$ | 7,552.87$^{b}$ |
| Trifluralin + Atrazine | 24,743.58$^{b}$ | 9,385.01$^{a}$ | 27,628.20$^{c}$ | 4,893.08$^{b}$ | 7,139.05$^{b}$ |
| Pendimethalin | 21,538.46$^{b}$ | 8,631.42$^{a}$ | 26,025.64$^{c}$ | 5,353.88$^{b}$ | 6,992.65$^{b}$ |
| Atrazine + S-metolachlor | 23,205.12$^{b}$ | 6,606.45$^{b}$ | 32,884.61$^{c}$ | 6,213.80$^{b}$ | 6,410.13$^{b}$ |
| Diuron | 30,769.23$^{a}$ | 8,999.05$^{a}$ | 46,858.97$^{a}$ | 8,282.98$^{a}$ | 8,641.02$^{a}$ |
| Diuron + Hexazinone | 23,076.92$^{b}$ | 7,282.49$^{b}$ | 40,128.20$^{b}$ | 8,060.90$^{a}$ | 7,671.70$^{b}$ |
| Tebuthiuron | 25,769.23$^{b}$ | 7,936.11$^{b}$ | 43,846.15$^{b}$ | 7,906.31$^{a}$ | 7,921.21$^{b}$ |
| Sulfentrazone | 22,564.10$^{b}$ | 6,422.39$^{b}$ | 44,871.79$^{b}$ | 7,818.83$^{a}$ | 7,120.61$^{b}$ |
| Ametryne | 31,794.87$^{a}$ | 11,899.99$^{a}$ | 49,807.69$^{a}$ | 7,354.74$^{a}$ | 9,627.37$^{a}$ |
| Flumioxazin | 33,333.33$^{a}$ | 10,400.09$^{a}$ | 42,948.71$^{b}$ | 8,000.04$^{a}$ | 9,200.07$^{a}$ |
| S-metolachlor | 30,641.02$^{a}$ | 8,913.59$^{a}$ | 30,576.92$^{c}$ | 5,752.18$^{b}$ | 7,332.89$^{b}$ |
| Metribuzin | 30,576.92$^{a}$ | 8,888.48$^{a}$ | 50,833.33$^{a}$ | 9,459.41$^{a}$ | 9,173.95$^{a}$ |
| Metribuzin + S-metolachlor | 21,987.17$^{b}$ | 6,997.49$^{b}$ | 39,358.97$^{b}$ | 7,847.04$^{a}$ | 7,422.27$^{b}$ |
| Weed-free | 32,948.71$^{a}$ | 10,595.93$^{a}$ | 35,512.82$^{c}$ | 6,705.37$^{a}$ | 8,650.65$^{a}$ |
| Weedy | 14,487.17$^{c}$ | 3,287.68$^{c}$ | 13,782.05$^{d}$ | 2,353.75$^{c}$ | 2,820.72$^{c}$ |
| Coefficient of variation (%) | 13.52 | 15.37 | 11.26 | 14.16 | 14.99 |

Mean values followed by different letters are significantly ($P<0.05$) different by Scott-Knott test.

## Conclusions

One of the great difficulties faced by livestock producers in Brazil is post-emergence control of narrow-leaf weeds in elephant grass pastures. This study confirmed that forage yield losses were significant due to weed competition throughout the entire elephant grass crop cycle. Weed control was effective for all herbicide treatments except for trifluralin applied alone. The most phytotoxic treatments were trifluralin and the formulated mixture of diuron + hexazinone. Elephant grass dry matter yield was not influenced by diuron, ametryne, flumioxazin and metribuzin, supporting their use as pre-emergence herbicides for weed control in elephant grass pastures. The lack of strategies and selective post-emergence herbicides to control grasses hinders the expansion of elephant grass fields in Brazil and could be solved by using new herbicide weed management techniques supported by the development of other herbicide molecules in the future.

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