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Article

# Sequential Application of Herbicides Alone and in Mixture With and Without Foliar Fertilizer after Pruning of Cassava Plants

*Aplicação Sequencial de Herbicidas Isolados e em Mistura Com e Sem Adubo Foliar após a Poda das Plantas de Mandioca*

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ABSTRACT - A new cycle of growth begins after pruning of cassava, and weed control is necessary. Thus, this study aimed to evaluate the selectivity and efficiency of sequential application of herbicides alone and in mixture with and without of foliar fertilizer after pruning of cassava. Two experiments were carried out in a randomized block design with four replications. The treatments of Experiment 1 consisted of control without weeding; control with weeding; mesotrione; mesotrione/mesotrione; mesotrione + foliar fertilizer/mesotrione + foliar fertilizer; mesotrione/mesotrione + foliar fertilizer; mesotrione + clethodim; mesotrione + clethodim + foliar fertilizer/mesotrione + clethodim + foliar fertilizer; mesotrione + clethodim/mesotrione + clethodim; mesotrione + clethodim/chlorimuron; mesotrione + clethodim/chlorimuron + foliar fertilizer; mesotrione + clethodim + foliar fertilizer/chlorimuron + clethodim + foliar fertilizer; mesotrione + clethodim/chlorimuron + clethodim]. Treatments of Experiment 2 consisted of control without weeding; control with weeding; chlorimuron; chlorimuron + foliar fertilizer/chlorimuron + foliar fertilizer; chlorimuron/chlorimuron; chlorimuron + clethodim; chlorimuron + clethodim + foliar fertilizer/chlorimuron + clethodim + foliar fertilizer; chlorimuron + clethodim/chlorimuron + clethodim; chlorimuron + clethodim/mesotrione + foliar fertilizer; chlorimuron + clethodim/mesotrione; chlorimuron + clethodim + foliar fertilizer/mesotrione + clethodim + foliar fertilizer; chlorimuron + clethodim/mesotrione + clethodim. The doses of mesotrione, clethodim, and chlorimuron used in both experiments were 240, 120, and 20 g $ha^{-1}$, respectively, while 2.5 L of the commercial product Amino Plus® was used as foliar fertilizer. The first application was carried out at 50 days after pruning and the second application at 22 days after the first application. In Experiment 1, the application of mesotrione, mesotrione/mesotrione, and mesotrione + clethodim/mesotrione + clethodim showed selectivity to cassava and were efficient in weed control. In Experiment 2, chlorimuron + clethodim/mesotrione, chlorimuron + clethodim + foliar fertilizer/mesotrione + clethodim + foliar fertilizer, and chlorimuron + clethodim/mesotrione + clethodim were efficient in weed control, but no treatment was selective. The addition of foliar fertilizer to the spray solution did not contribute to increase selectivity.

**Keywords:** *Manihot esculenta*, weeds, chemical control.

*RESUMO - Após a poda da mandioca, inicia-se um novo ciclo de crescimento, sendo necessário o controle das plantas daninhas. Portanto, objetivou-se neste estudo avaliar a seletividade e a eficiência da aplicação sequencial de herbicidas isolados e em misturas em tanque com e sem adição de adubo foliar, depois da poda da mandioca. Realizaram-se dois experimentos com delineamento*

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*experimental de blocos casualizados com quatro repetições. Os tratamentos do experimento 1 consistiram em: testemunha sem capina, testemunha capinada, mesotriona, mesotriona/mesotriona, [mesotriona+adubo foliar]/[mesotriona+adubo foliar], mesotriona/[mesotriona+adubo foliar], [mesotriona+cletodim], [mesotriona+cletodim+adubo foliar]/[mesotriona+ cletodim+adubo foliar], [mesotriona+cletodim]/[mesotriona+cletodim], [mesotriona+cletodim]/clorimuron, [mesotriona+ cletodim]/clorimuron+adubo foliar], [mesotriona+cletodim+adubo foliar]/[clorimuron+ cletodim+adubo foliar], [mesotriona+cletodim]/[clorimuron+cletodim]. Os tratamentos do experimento 2 consistiram em: testemunha sem capina, testemunha capinada, clorimuron, [clorimuron+adubo foliar]/[clorimuron+adubo foliar], clorimuron/clorimuron, clorimuron+cletodim, [clorimuron+cletodim+adubo foliar]/[clorimuron+cletodim+adubo foliar], [clorimuron+cletodim] / [clorimuron+cletodim], [clorimuron+cletodim]/[mesotriona+adubo foliar], [clorimuron+cletodim]/ mesotriona, [clorimuron+cletodim+adubo foliar]/[mesotriona+cletodim+adubo foliar], [clorimuron+cletodim]/[mesotriona+cletodim]. As doses utilizadas em ambos os experimentos de mesotriona, cletodim e clorimuron foram de 240, 120 e 20 g ha$^{-1}$, respectivamente, enquanto para o adubo foliar utilizaram-se 2,5 L do produto comercial (Amino Plus®). A primeira aplicação ocorreu 50 dias após a poda, e a segunda, aos 22 dias após a primeira aplicação. No experimento 1, a aplicação do mesotriona, mesotriona/mesotriona e [mesotriona+cletodim]/[mesotriona+cletodim] apresentaram seletividade à mandioca e foram eficientes no controle de plantas daninhas. No experimento 2, o clorimuron+cletodim]/mesotriona, [clorimuron+cletodim+adubo foliar] /[mesotriona+cletodim+ adubo foliar] e [clorimuron+cletodim]/[mesotriona+cletodim] foram eficientes no controle, porém todos os tratamentos não foram seletivos. A adição de adubo foliar à calda não contribuiu para o aumento da seletividade.*

**Palavras-chave:** *Manihot esculenta*, plantas daninhas, controle químico.

## INTRODUCTION

Among the crops grown in Brazil, cassava (*Manihot esculenta* Crantz) has stood out due to its social and economic importance in several regions. In 20016, the area cultivated with cassava in Brazil was 1.5 million hectares, with mean productivity of 14.9 thousand kg ha$^{-1}$, being the states of Pará, Bahia, Maranhão, and Paraná the largest producers (IBGE, 2017).

Cassava has a productive potential of 24 to 32 t ha$^{-1}$ in cycles of 10 to 12 months and of 35 to 73 t ha$^{-1}$ in cycles of 18 months (Fey et al., 2007; Otsubo et al., 2008; Devide et al., 2009; Costa et al., 2013). However, crop yield may be reduced due to competition with weeds, mainly because it has slow initial growth (Azevedo et al., 2000). It is believed that because it is a rustic crop, producers have neglected weed management (Silva et al., 2012).

Cassava can be grown in two cycles. The crop undergoes a period of physiological rest in the interval between the first and second crop cycle, characterized by the stoppage of vegetative growth and plant defoliation, which occur in the coldest or driest season of the year when pruning is carried out by farmers (Silva et al., 2012). After pruning, a new flow of growth of the crop and weed seed bank occur, making it necessary to elaborate control strategies with selective and efficient herbicides (Costa et al., 2013).

Among the weed management strategies, chemical control has stood out since it allows a reduction of labor in the field and a higher yield when compared to other methods (Chikoye et al., 2006). However, one of the significant problems related to chemical control of weeds in cassava has been the reduced number of herbicides registered for use in this crop, as well as the scarcity of studies on the selectivity of new herbicides (Oliveira Jr et al., 2001; Costa et al., 2014).

In Brazil, only the herbicides ametryn, clethodim, clomazone, isoxaflutole, metribuzin, S-metolachlor, flumioxazin, fluazifop-p-butyl, and the commercial mixture ametryn + clomazone are registered for cassava (ADAPAR, 2018; AGROFIT, 2018). However, the herbicides mesotrione and chlorimuron have the potential to be included in weed management programs in cassava, as they present low intoxication to the crop and effectiveness in weed control (Silveira et al., 2012; Silva et al., 2012; Ferreira et al., 2015).

In order to mitigate the low availability of herbicides for cassava cultivation, using mixtures and sequential applications of herbicides may increase the spectrum of action and residual effect. However, mixtures and sequential applications may reduce product selectivity and cause phytointoxication (Silva et al., 2014).

As a proposal to reduce phytointoxication caused by herbicides, the addition of foliar fertilizer to the spray solution has been efficient due to the exogenous replacement of amino acids, which are suppressed by the mechanism of action of herbicides (Zobiole et al., 2011; Machado et al., 2017).

Therefore, the sequential application or mixture of herbicides after pruning of cassava plants destined to the industry may be an alternative to weed management for the second crop cycle since new weed management is necessary at this stage. In this sense, this study aimed to evaluate the selectivity and efficiency of the sequential application of herbicides alone and in mixture with and without foliar fertilizer after pruning of cassava.

## MATERIAL AND METHODS

Two experiments, described as Experiment 1 and Experiment 2, were conducted simultaneously under field conditions in the 2015/2016 agricultural season, in Marechal Cândido Rondon, PR, at the geographical coordinates of 24°33'26" S and 54°02'32" W.

The experimental design was a randomized block design with four replications and 12 treatments for both experiments (Tables 1 and 2). Each plot had 18 $m^2$ and spacing of 0.9 × 0.7 m between cassava plants of the cultivar Cascuda, destined for the industry.

The foliar fertilizer used was the commercial product Amino Plus® at a dose of 2.5 L $ha^{-1}$, which has in its composition alanine (1.164%), arginine (0.189%), aspartic acid (1.943%), glutamic acid (3.316%), glycine (0.202%), isoleucine (0.171%), leucine (0.268%), lysine (0.240%), phenylalanine (0.143%), serine (0.179%), threonine (0.188%), tryptophan (0.175%), tyrosine (0.122%), valine (0.288%), N (11%), and $K_2O$ (1%) (Zobiole et al., 2011). It has been obtained through the microbiological fermentation of sugarcane, which is why compound concentrations may change.

Cassava was planted in September 2015. Weed management in the first crop cycle was carried out in total area with the herbicides clomazone + sulfentrazone (744 + 310 g $ha^{-1}$), applied in pre-emergence of the crop and weeds.

Pruning was performed 10 months after planting, in July 2016. The first herbicide application was carried out at 50 days after pruning when cassava sprouts were 15 to 20 cm in length. Climate conditions, such as temperature, humidity, and wind speed, during the applications were 23.5 °C, 48%, and 1.4 m $s^{-1}$, respectively.

***Table 1 -*** Treatments used in Experiment 1 after pruning of cassava plants of the cultivar Cascuda

| First application | | | Second application | | |
|---|---|---|---|---|---|
| Treatment | Dose (g $ha^{-1}$) | FF (L $ha^{-1}$) | Treatment | Dose (g $ha^{-1}$) | FF (L $ha^{-1}$) |
| Control without weeding | – | – | – | – | – |
| Control with weeding | – | – | – | – | – |
| Mesotrione | 240 | – | – | – | – |
| Mesotrione | 240 | 2.5 | Mesotrione | 240 | 2.5 |
| Mesotrione | 240 | – | Mesotrione | 240 | – |
| Mesotrione + clethodim | 240 + 120 | – | – | – | – |
| Mesotrione + clethodim | 240 + 120 | 2.5 | Mesotrione + clethodim | 240 + 120 | 2.5 |
| Mesotrione + clethodim | 240 + 120 | – | Mesotrione + clethodim | 240 + 120 | – |
| Mesotrione + clethodim | 240 + 120 | – | Chlorimuron | 20.0 | – |
| Mesotrione + clethodim | 240 + 120 | – | Chlorimuron | 20.0 | 2.5 |
| Mesotrione + clethodim | 240 + 120 | 2.5 | Chlorimuron + clethodim | 20 + 120 | 2.5 |
| Mesotrione + clethodim | 240 + 120 | – | Chlorimuron + clethodim | 20 + 120 | – |

The mineral oil Nimbus® at 0.5% v $v^{-1}$ was added in all spray solutions. FF = foliar fertilizer (Amino Plus®).

***Table 2 -*** Treatments used in Experiment 2 after pruning of cassava plants of the cultivar Cascuda

| First application | | | Second application | | |
|---|---|---|---|---|---|
| Treatment | Dose (g $ha^{-1}$) | FF (L $ha^{-1}$) | Treatment | Dose (g $ha^{-1}$) | FF (L $ha^{-1}$) |
| Control with weeding | – | – | – | – | – |
| Control without weeding | – | – | – | – | – |
| Chlorimuron | 20 | – | – | – | – |
| Chlorimuron + FF | 20 | 2.5 | Chlorimuron + FF | 20 | 2.5 |
| Chlorimuron | 20 + 120 | – | Chlorimuron | 20 | – |
| Chlorimuron + clethodim | 20 + 120 | – | – | – | – |
| Chlorimuron + clethodim + FF | 20 + 120 | 2.5 | Chlorimuron + clethodim + FF | 20 + 120 | 2.5 |
| Chlorimuron + clethodim | 20 + 120 | – | Chlorimuron + clethodim | 20 + 120 | – |
| Chlorimuron + clethodim | 20 + 120 | – | Mesotrione + FF | 240 | 2.5 |
| Chlorimuron + clethodim | 20 + 120 | – | Mesotrione | 240 | – |
| Chlorimuron + clethodim + FF | 20 + 120 | 2.5 | Mesotrione + clethodim + FF | 20 + 120 | 2.5 |
| Chlorimuron + clethodim | 20 + 120 | – | Mesotrione + clethodim | 20 + 120 | – |

The mineral oil Nimbus® at 0.5% v $v^{-1}$ was added in all spray solutions. FF = foliar fertilizer (Amino Plus®).

The sequential application of herbicides was carried out at 22 days after the first application, with temperature, humidity, and wind speed of 30 °C, 34%, and 1.5 m $s^{-1}$, respectively.

A sprayer pressurized ($CO_2$) at 2.6 kgf $pol^{-1}$, equipped with a boom with four tips (model Magno Jet 11002 AD) spaced at 0.5 m from each other and a flow rate of 200 L $ha^{-1}$, was used during the applications.

The weeds *Achyrocline satureioides*, *Richardia brasiliensis*, *Conyza* spp., *Bidens pilosa*, *Digitaria insularis*, *Parietaria* sp., and *Sonchus oleraceus* were found in the area at the flowering stage at the time of the first application.

The percentage of phytointoxication of cassava plants was evaluated at 7, 14, 21, 28, 35, 42, 49, and 56 days after the first application (DA1A) and at 7, 14, 21, 28, and 35 days after the second application (DA2A). Scores were attributed based on the percentage of phytointoxication proposed by the Brazilian Society of Weed Science (SBCPD, 1995). The characteristics of cassava plants observed to assign the scores were growth inhibition, quantity and uniformity of injuries or control, plant resprout ability, and number of dead plants.

Weeds present at each experiment were collected at 35 DA2A by sampling with a 0.25 $m^2$ (0.5 × 0.5 m) square randomly placed at each plot. The collected weeds were dried in a forced air circulation oven at 60 °C for 96 hours and then weighed in a precision scale (0.001 g).

Cassava plants were collected from the two central rows of each plot during the harvest of roots (three months after pruning), disregarding one plant at each end of the rows. Productivity (kg $ha^{-1}$) was determined after weighing the roots. The percentage of starch was determined using a sample of 5.0 kg of roots collected from each plot by the hydrostatic weighing method (Grossmann and Freitas, 1950). The data were transformed into starch productivity (kg $ha^{-1}$).

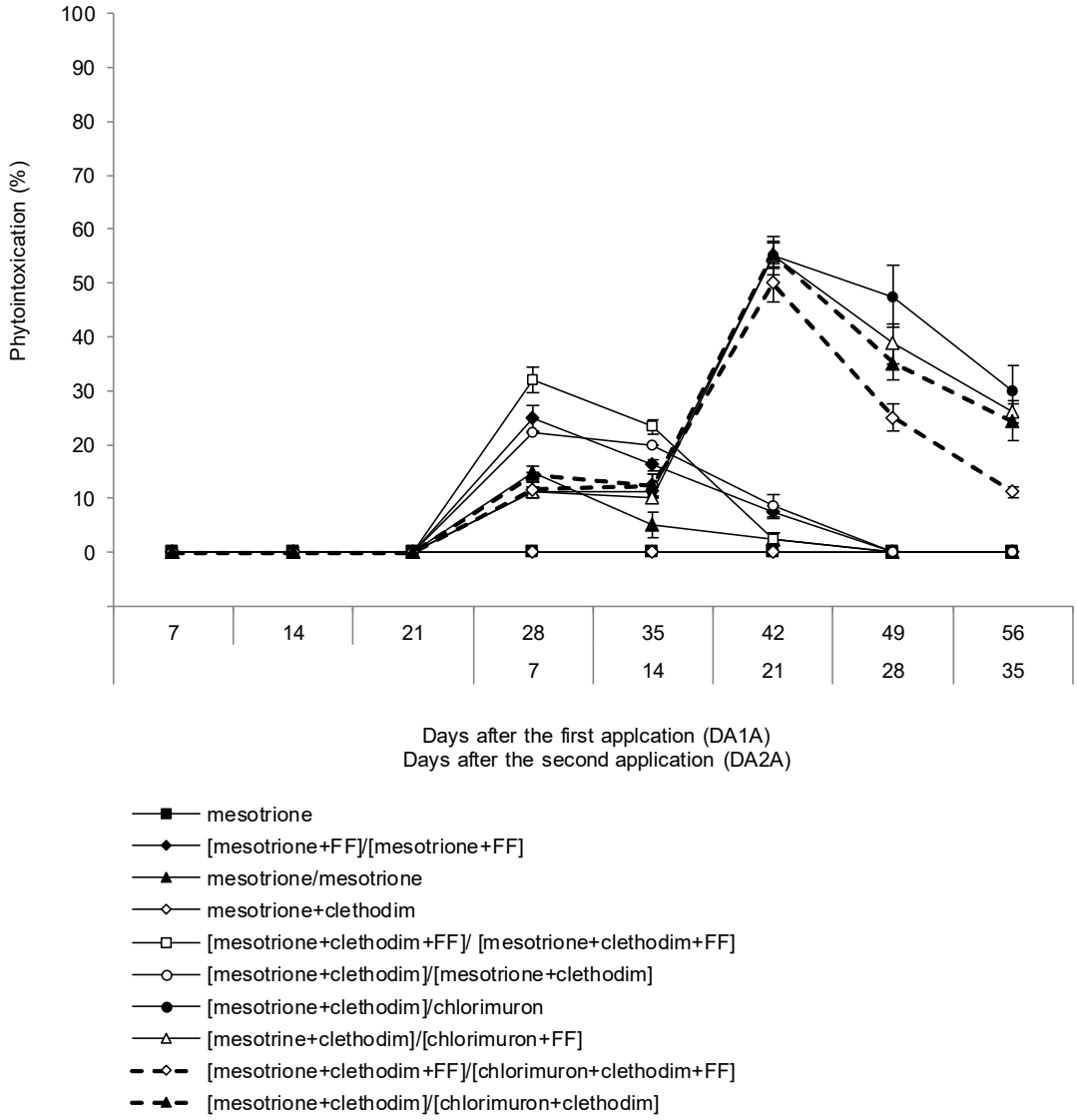
The results of phytointoxication were shown graphically using the error of the standard deviation of the means, while root productivity, starch productivity, and weed dry matter were submitted to the F-test and Scott-Knott mean comparison test at 5% probability.

## RESULTS AND DISCUSSION

### Experiment 1

The data of phytointoxication (%) caused by herbicides in single and sequential applications after pruning of cassava plants in Experiment 1 are shown in Figure 1.

The first herbicide application did not cause phytointoxication to cassava plants. Mesotrione and mesotrione + clethodim in single application caused no phytointoxication to cassava plants of the cultivar Cascuda throughout the evaluation period. Silva et al. (2005) observed a low




FF = foliar fertilizer.

***Figure 1*** **-** Phytointoxication caused by herbicides in single and sequential applications on cassava plants of the cultivar Cascuda after pruning in Experiment 1.

phytointoxication (2.5%) after mesotrione application (144 g $ha^{-1}$) in cassava of the cultivar IAC-12 at 35 days after application (DAA), while Silveira et al. (2012) found that mesotrione (216 g $ha^{-1}$) provided up to 18.8% phytointoxication at 35 DAA in cassava of the cultivar Coqueiro. These results can be explained by the varietal tolerance to the herbicide.

Herbicides in sequential application caused phytointoxication from 7 days after the second application (DA2A) (Figure 1). The sequential application of the mixtures mesotrione + clethodim + foliar fertilizer/mesotrione + clethodim + foliar fertilizer, mesotrione + foliar fertilizer/ mesotrione + foliar fertilizer, mesotrione + clethodim/mesotrione + clethodim, and mesotrione/ mesotrione caused 32, 25, and 15% phytointoxication at 7 DA2A, respectively, and injuries disappeared at 28 DA2A.

The highest phytointoxication (50 to 55%) was provided by the herbicides mesotrione + clethodim/chlorimuron, mesotrione + clethodim/chlorimuron + foliar fertilizer, mesotrione + clethodim/chlorimuron + clethodim, and mesotrione + clethodim + foliar fertilizer/chlorimuron + clethodim + foliar fertilizer at 21 DA2A, with subsequent reduction of injuries at 35 DA2A to 30, 26, 24, and 11%, respectively.

The addition of the herbicide chlorimuron to the spray solution intensified the phytointoxication of cassava plants. However, the addition of foliar fertilizer was able to reduce plant injuries by 13 and 54% for mesotrione + clethodim/chlorimuron + foliar fertilizer and mesotrione + clethodim/chlorimuron + clethodim, respectively, in relation to the same treatments without the addition of foliar fertilizer at 35 DA2A.

The addition of foliar fertilizer (Amino Plus®) to the spray solution was beneficial since it reduced the phytointoxication of cassava plants submitted to mixtures containing chlorimuron. This reduction in phytointoxication may be related to the exogenous amino acid replacement, which is suppressed by the mechanism of action of herbicides (Zobiole et al., 2011). However, no reduction in phytointoxication was observed for treatments in which the foliar fertilizer was used.

Table 3 shows the results of weed dry matter and root and starch productivity for cassava of the cultivar Cascuda after herbicide applications in Experiment 1.

All the herbicides reduced weed dry matter regardless of the adopted chemical management (single or sequential application), being considered efficient to control the species *Achyrocline satureioides*, *Richardia brasiliensis*, *Conyza* spp., *Bidens pilosa*, *Digitaria insularis*, *Parietaria* sp., and *Sonchus oleraceus* even out of the ideal stage of herbicide application (flowering). At pruning time, some species are at an advanced stage of development and out of the adequate stage to recommend the use of some herbicides. Therefore, these results show that the use of mixtures and sequential applications may be an alternative to weed control after cassava pruning.

The mixture mesotrione + clethodim and the sequential applications mesotrione/mesotrione, mesotrione + clethodim + foliar fertilizer/mesotrione + clethodim + foliar fertilizer, mesotrione + clethodim/mesotrione + clethodim, mesotrione + clethodim/chlorimuron, and mesotrione + clethodim/chlorimuron + clethodim were the most efficient to reduce weed dry matter.

The herbicides mesotrione, mesotrione/mesotrione, and mesotrione + clethodim/mesotrione + clethodim formed the most selective group considering root productivity since it did not differ from the control with weeding.

Although mesotrione + clethodim/chlorimuron was not selective, the addition of foliar fertilizer to the spray solution promoted an increase in root productivity by around 23.7%.

The results obtained for starch productivity corroborate those of root productivity since the herbicides that provided higher starch productivity were those that presented a higher root production.

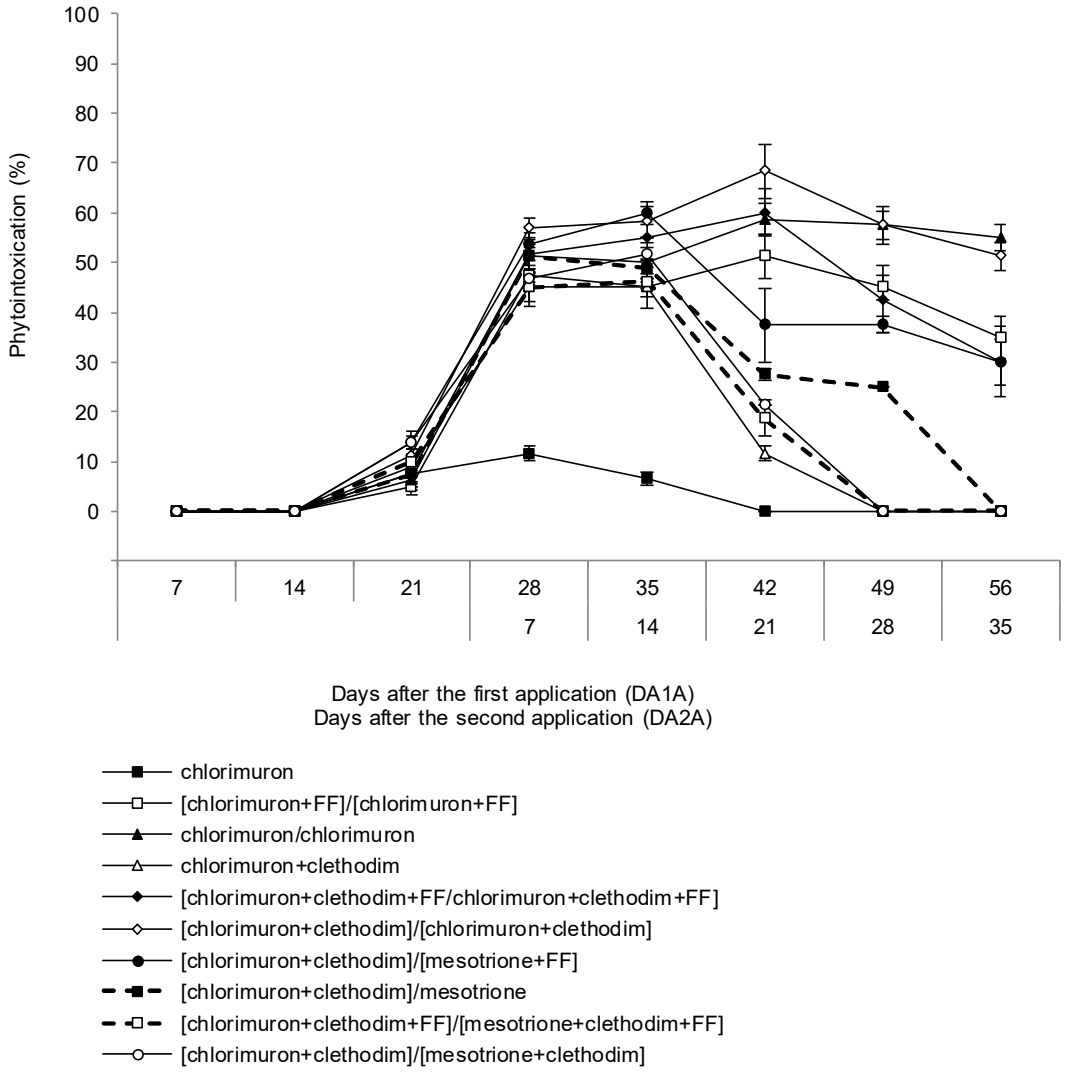
***Table 3 -*** Results of weed dry matter, productivity, and starch for cassava after sequential applications with herbicides in Experiment 1

| Treatment | Weed dry matter (kg ha$^{-1}$) | Root productivity (kg ha$^{-1}$) | Starch productivity (kg ha$^{-1}$) |
|---|---|---|---|
| Control without weeding | 1036.80 a | 34656.09 c | 7350.79 c |
| Control with weeding | – | 56738.95 a | 11843.96 a |
| Mesotrione | 317.40 c | 51404.32 a | 12559.05 a |
| Mesotrione + FF/mesotrione + FF | 297.48 c | 40596.78 b | 9188.84 b |
| Mesotrione/mesotrione | 182.80 d | 46590.91 a | 10953.24 a |
| Mesotrione + clethodim | 247.08 d | 37925.55 b | 6004.13 c |
| Mesotrione + clethodim + FF/mesotrione + clethodim + FF | 260.48 d | 40229.68 b | 9755.30 b |
| Mesotrione +clethodim/mesotrione + clethodim | 155.28 d | 52367.73 a | 12198.48 a |
| Mesotrione + clethodim/chlorimuron | 196.13 d | 31821.66 c | 9498.25 b |
| Mesotrione + clethodim/chlorimuron + FF | 304.53 c | 41747.50 b | 9463.84 b |
| Mesotrione + clethodim + FF/chlorimuron + clethodim + FF | 446.88 b | 38046.54 b | 9384.35 b |
| Mesotrione + clethodim/chlorimuron + clethodim | 232.33 d | 43327.45 b | 8104.50 c |
| MS Treatment | 242503.75** | 225456181.64** | 15551746.99** |
| MS Block | 4071.05 $^{ns}$ | 34172553.92 $^{ns}$ | 1483464.62$^{ns}$ |
| CV (%) | 19.87 | 10.52 | 15.98 |

** Significant at 1% probability. Means followed by the same letter do not differ from each other by the Scott-Knot test at 5% probability. FF = foliar fertilizer.

**Experiment 2**

Figure 2 shows the phytointoxication values (%) caused by herbicide application after pruning of cassava plants in Experiment 2. All herbicides caused phytointoxication to cassava plants from 21 DA1A.




FF = foliar fertilizer.

***Figure 2 -*** Phytointoxication caused by herbicides in single and sequential applications on cassava plants of the cultivar Cascuda after pruning in Experiment 2.

Chlorimuron + clethodim provided 45% phytointoxication at 35 DA1A. However, no injury was observed at 49 DA1A, while chlorimuron alone provided phytointoxication of 11.67% at 28 DA1A, with subsequent reduction to zero at 42 DA1A. It may have occurred because the mixture increased the potential damage of herbicides, characterizing an antagonism between products (Maciel et al., 2011; Costa et al., 2014). Silva et al. (2012) verified that a single application of chlorimuron (15 g $ha^{-1}$) in post-emergence of cassava of the cultivar IAC-12 provided 8.7% phytointoxication at 28 DAA, but this herbicide was not selective to the crop.

The herbicides provided a high phytointoxication (45 to 57%) at 7 DA2A in the sequential applications. However, chlorimuron + clethodim + foliar fertilizer/mesotrione + clethodim + foliar fertilizer and chlorimuron + clethodim/mesotrione + clethodim provided no phytointoxication symptoms in cassava plants at 28 DA2A.

Chlorimuron + clethodim/mesotrione also did not provide phytointoxication at 35 DA2A. However, chlorimuron + foliar fertilizer/chlorimuron + foliar fertilizer, chlorimuron + clethodim + foliar fertilizer/chlorimuron + clethodim + foliar fertilizer, and chlorimuron + clethodim/mesotrione + foliar fertilizer provided phytointoxication of 35, 30, and 30%, respectively, at 35 DA2A.

The highest phytotoxicity values were observed with chlorimuron/chlorimuron (55%) and chlorimuron + clethodim/chlorimuron + clethodim (51%).

Table 4 shows the results of weed dry matter and root and starch productivity for cassava after herbicide applications in Experiment 2.

***Table 4 -*** Results of weed dry matter, productivity, and starch for cassava after sequential applications with herbicides in Experiment 2

| Treatment | Weed dry matter (kg ha$^{-1}$) | Root productivity (kg ha$^{-1}$) | Starch productivity (kg ha$^{-1}$) |
|---|---|---|---|
| Control without weeding | 1213.70 a | 36859.41 c | 9085.72 c |
| Control with weeding | – | 54659.02 a | 13258.30 a |
| Chlorimuron | 419.47 b | 44411.38 b | 10780.67 b |
| Chlorimuron + FF/chlorimuron + FF | 428.70 b | 35369.57 c | 8574.18 c |
| Chlorimuron/chlorimuron | 423.53 b | 35476.19 c | 7902.68 c |
| Chlorimuron + clethodim | 451.30 b | 39939.53 c | 9173.29 c |
| Chlorimuron + clethodim + FF]/chlorimuron + clethodim + FF] | 410.17 b | 35318.36 c | 7085.44 c |
| Chlorimuron + clethodim/chlorimuron + clethodim | 421.00 b | 41320.23 c | 9207.18 c |
| Chlorimuron + clethodim/mesotrione + FF | 396.60 b | 30540.12 c | 7246.80 c |
| Chlorimuron + clethodim/mesotrione | 255.43 c | 37682.95 c | 9492.27 c |
| Chlorimuron + clethodim + FF/mesotrione + clethodim + FF | 161.53 c | 36114.05 c | 8825.42 c |
| Chlorimuron + clethodim/mesotrione + clethodim | 158.60 c | 42956.35 b | 10576.61 b |
| MS Treatment | 317032.20** | 153159887.09** | 11421628.12** |
| MS Block | 19652.58$^{ns}$ | 10837855.70$^{ns}$ | 1624844.06$^{ns}$ |
| CV (%) | 28.29 | 12.98 | 14.73 |

** Significant at 1% probability. Means followed by the same letter do not differ from each other by the Scott-Knot test at 5% probability. FF = foliar fertilizer.

All herbicides reduced weed dry matter regardless of the single or sequential application. The most efficient applications were chlorimuron + clethodim/mesotrione, chlorimuron + clethodim + foliar fertilizer/mesotrione + clethodim + foliar fertilizer, and chlorimuron + clethodim/mesotrione + clethodim.

Considering the data of root productivity, no herbicide was selective probably due to the phytointoxication they caused to cassava plants.

Moreover, the addition of foliar fertilizer to herbicides did not provide an increment in root productivity. Similarly, starch productivity was impaired by herbicide application since it was lower when compared to the control with weeding.

The use of with amino acid-enriched foliar fertilizers in the spray solution may be an alternative to maximize selectivity since other studies have shown that the exogenous supply of amino acids can reduce the effects of herbicides on plants, as they act on amino acid metabolism.

Zobiole et al. (2011) found that glyphosate (1.8 kg ha$^{-1}$) + foliar fertilizer (Amino Plus®, 2 L ha$^{-1}$) provided an increase of 81% in dry matter of RR soybean when compared to glyphosate alone (1.8 kg ha$^{-1}$). Similarly, Machado et al. (2017) found that glyphosate (2.16 kg ha$^{-1}$) + foliar fertilizer (Fertiactyl Post®, 8 L ha$^{-1}$) provided a 97% increase in dry matter of eucalyptus plants when compared to glyphosate (2.16 kg ha$^{-1}$) without foliar fertilizer, emphasizing the feasibility of adding foliar fertilizer to the herbicidal solution to increase herbicide selectivity.

Sequential applications and mixtures of herbicides have been widely used in agriculture because they allow long-term control infestations and increase the control spectrum due to the

use of different mechanisms of action (Maciel et al., 2011; Oliveira Neto et al., 2011; Melo et al., 2012; Costa et al., 2014). However, studies on the effects of mixtures of mesotrione, clethodim, and chlorimuron or their sequential application on the selectivity of cassava, as well as the use of foliar fertilizers for remediation of injuries, are scarce in the literature. It is worth mentioning that the cassava crop has a long cycle, with pruning being a sensitive stage to weed competition. Thus, sequential applications for weed management can provide the rotation of mechanisms of actions of herbicides, avoiding the selection of resistant species.

In Experiment 1, the herbicides mesotrione, mesotrione/mesotrione, and mesotrione + clethodim/mesotrione + clethodim showed selectivity to cassava plants and are efficient in weed control.

In experiment 2, chlorimuron + clethodim/mesotrione, chlorimuron + clethodim + foliar fertilizer/mesotrione + clethodim + foliar fertilizer, and chlorimuron + clethodim/mesotrione + clethodim are efficient in weed control. However, no herbicide was selective for cassava plants.

The addition of foliar fertilizer to spray solution did not contribute to increasing herbicide selectivity to cassava plants in Experiments 1 and 2.

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