Universidade Federal Rural do Semi-Árido
Pró-Reitoria de Pesquisa e Pós-Graduação
https://periodicos.ufersa.edu.br/index.php/caatinga

ISSN 0100-316X (impresso)
ISSN 1983-2125 (online)

EFFICACY AND SELECTIVITY OF HERBICIDES APPLIED IN CASSAVA PRE-EMERGENCE[1]

ANTONIO DIAS SANTIAGO[2], MANOEL HENRIQUE BOMFIM CAVALCANTE[3], GUILHERME BRAGA PEREIRA BRAZ[4]*, SERGIO DE OLIVEIRA PROCÓPIO[5]

ABSTRACT - The interference imposed by weeds can cause damages to cassava development. Thus, adopting control measures is fundamental. The use of pre-emergence herbicides is one of the control alternatives, since cassava presents a good tolerance to herbicides applied in this modality. However, herbicides may present differential selectivity due to the variety of cassava that is planted. The objective of this study was to evaluate both weed control effectiveness and selectivity of different herbicide combinations applied at pre-emergence of two cassava varieties. Two experiments were established in the field using a randomized complete block design, in a split plot scheme, with four replications. In the efficacy experiment, application of six combinations of herbicides, including clomazone + ametryn, clomazone + metribuzin, clomazone + flumioxazin, isoxaflutole + ametryn, isoxaflutole + metribuzin, isoxaflutole + flumioxazin were evaluated in the main plot. In addition, a non-treated control and a weeded control were evaluated. In the subplots, the Caravela and Pretinha varieties were planted. For the selectivity experiment, a non-treated control was not included. The combinations containing clomazone presented a longer residual period of weed control as well as a better control of benghal dayflower. Metribuzin exhibited lower efficacy than other herbicide combinations containing clomazone or isoxaflutole. The Pretinha variety showed greater tolerance to weed interference. Every herbicide combination that was applied in cassava pre-emergence presented selectivity for both Caravela and Pretinha varieties.

Keywords: Herbicides combinations. *Manihot esculenta* Crantz. Weeds.

EFICÁCIA E SELETIVIDADE DE HERBICIDAS APLICADOS EM PRÉ-EMERGÊNCIA DA MANDIOCA

RESUMO - A interferência de plantas daninhas prejudica o desenvolvimento da mandioca, sendo fundamental a adoção de medidas de controle. A utilização de herbicidas em pré-emergência é uma das alternativas de controle de plantas daninhas, visto que a mandioca apresenta boa tolerância a esta modalidade de aplicação. Mesmo herbicidas registrados podem apresentar seletividade diferencial em função da variedade de mandioca. Neste contexto, objetivou-se avaliar a eficácia no controle de plantas daninhas e a seletividade de associações herbicidas aplicados em pré-emergência de variedades de mandioca. Dois experimentos foram instalados a campo no delineamento de blocos completos ao acaso, em esquema de parcelas subdivididas, com quatro repetições. No experimento de eficácia, foram avaliadas na parcela principal seis associações herbicidas compostas pela aplicação de clomazone + ametryn, clomazone + metribuzin, clomazone + flumioxazin, isoxaflutole + ametryn, isoxaflutole + metribuzin, isoxaflutole + flumioxazin, além de testemunha sem capina e outra capinada. Nas subparcelas foram plantadas as variedades Caravela e Pretinha. Para o experimento de seletividade não houve a inclusão da testemunha sem aplicação e sem capina. As associações herbicidas contendo clomazone apresentaram maior período residual de controle de plantas daninhas, além de maior eficácia sobre trapoeraba. Entre os herbicidas associados ao clomazone ou isoxaflutole, o metribuzin foi o que apresentou menor eficácia. A variedade Pretinha apresenta maior tolerância a interferência das plantas daninhas. Todas as associações herbicidas aplicadas em pré-emergência da mandioca apresentaram seletividade para as variedades Caravela e Pretinha.

Palavras-chave: Associações herbicidas. *Manihot esculenta* Crantz. Plantas daninhas.

*Corresponding author
[1]Received for publication in 05/26/2017; accepted in 10/17/2017.
Paper extracted from several experiments conducted by Embrapa Tabuleiros Costeiros.
[2]Embrapa Tabuleiros Costeiros, Rio Largo, AL, Brazil; antonio.santiago@embrapa.br – ORCID: 0000-0002-6295-4825.
[3]Empresa Estadual de Assistência Técnica e Extensão Rural, Arapiraca, AL, Brazil; mhenriquebc@hotmail.com – ORCID: 0000-0002-2983-4506.
[4]Department of Agronomy, Universidade de Rio Verde, Rio Verde, GO, Brazil; guilhermebrag@gmail.com – ORCID: 0000-0002-0396-7140.
[5]Embrapa Tabuleiros Costeiros, Aracaju, SE, Brazil; procopio.so@gmail.com – ORCID: 0000-0002-4350-7288.

INTRODUCTION

Cassava presents preeminent importance in the Brazilian socioeconomic scenario, the cultivation of which is being explored in both small farms that function with a family-farming regime for local consumption and flour production, as well as in large scale plantations that focus on supplying the industry. Cassava represents an unusual crop due to its potential to be planted across all regions of Brazil. In Alagoas, cassava production is concentrated in the Agreste region, which accounts for approximately 60% of the cultivated area.

In order to provide noticeable development and to ensure the productive potential of cassava plantations are realized, several management practices are necessary during the crop cycle. Among these practices, weed control appears as an important technique to mitigate the influence of weeds on the quantity and quality of cassava roots (BIFFE et al., 2010a; SILVA et al., 2012a).

Weed emergence and development in cassava crops are favored by the facts that this crop exhibits gradual initial growth and is cultivated in wide arrangements, which facilitates the establishment of weeds (SILVA et al., 2012b). The beginning of weed interference on cassava occurs 18 days after planting (DAP). However, for a good yield, it is necessary to leave the cassava crops without co-existence until 100-135 DAP (CARVALHO; ARAÚJO; AZEVEDO, 2004). Productivity can reduce to 70% when weed control measures are not applied during cassava cultivation (PERESSIN; CARVALHO, 2002).

In small farms where cassava cultivation is traditionally conducted under a family regime, weed management is performed by manual weeding (ALBUQUERQUE et al., 2008). More recently, the adoption of chemical control has substantially grown due to a significant shortage of labor in rural areas. The benefits of this method include the ease of execution and effective control of a broad spectrum of weeds (COSTA et al., 2015).

Prior to choosing the herbicide, it is necessary to verify species that compose the weed community as this information allows the farmer to identify and choose a product that is most effective for a broader spectrum of weeds present (MONQUERO et al., 2011). Moreover, it is also essential to determine the mode in which the herbicide will be applied. The application of herbicides in pre-emergence is the most utilized method of weed control in cassava crop due to the great tolerance against herbicide application (BIFFE et al., 2010b).

There are several herbicides that can be applied in cassava pre-emergence; these are effective against different spectrum of weeds. Currently, the products registered for this crop in Brazil are ametryn, clomazone, isoxaflutole, metribuzin, flumioxazin, as well as mixtures of clomazone + ametryn (BRASIL, 2017). Considering that the floristic composition of weed community is heterogeneous (COSTA et al., 2013a), there is often a need to use more than one herbicide in the same application.

Thus, the advantages of weed management is undeniable, however, the selectivity that an herbicide portrays when applied individually may be compromised. In addition to the selectivity in the case of herbicide combinations, it is important to verify whether there is a differential tolerance between cassava varieties for the herbicides. Studies have shown that there is a differential response among cassava varieties in terms of sensitivity to herbicides (BIFFE et al., 2010b; SILVEIRA et al., 2012).

Thus, the objective of this study was to evaluate weed control effectiveness and the selectivity of herbicide combinations applied in pre-emergence of two cassava varieties.

MATERIAL AND METHODS

Two experiments were carried out in the field, one to evaluate the efficacy of different herbicide treatments in the residual control of weeds in cassava crop, and the other aiming to assess the selectivity of combinations of herbicides applied in crop pre-emergence. Both experiments were set up in adjacent areas in the municipality of Arapiraca (AL) (9°46′25″S; 36°33′77″W; altitude of 248 m). The experiments were performed from July 2014 to October 2015.

In this municipality, the predominant climate according to Köppen classification is the type As, tropical climate with dry season (savannah climate), exhibiting dry conditions during summer, and rainfall in the fall/winter. In this region, annual mean temperature is about 25°C and average annual rainfall is between 750 and 1000 mm (XAVIER; DORNELLAS, 2005). Rainfall data observed during the experiments are shown in Figure 1.

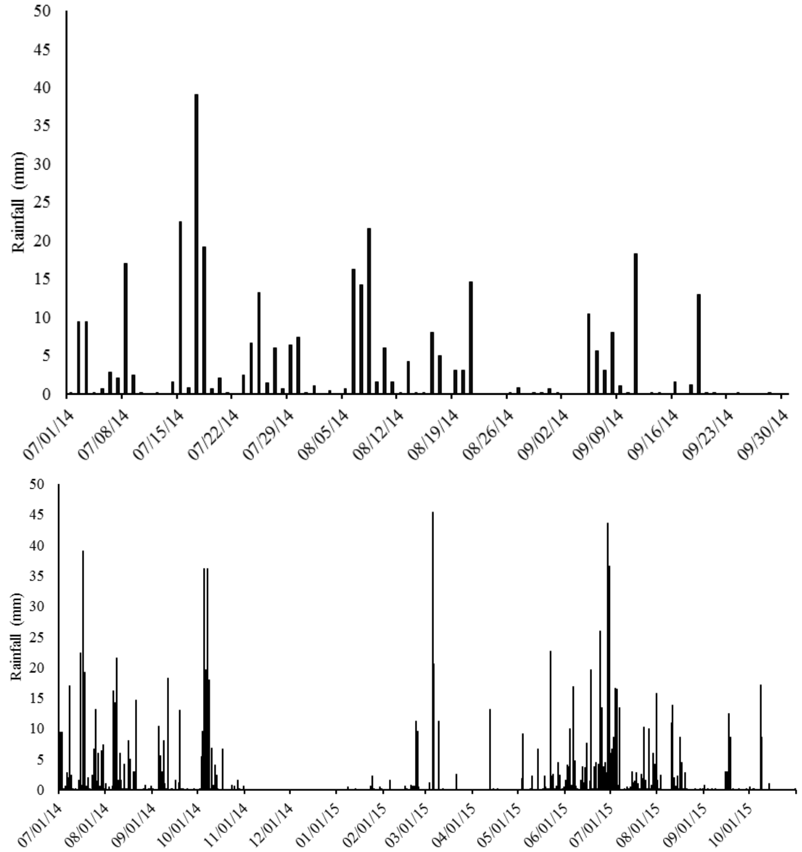

Figure 1. Rainfall Data (mm) in the first 90 days after herbicidal application (A) and during the entire period of experiments' conduction (B) Arapiraca (AL), 2014/2015.

The soil in the experimental area was classified as Latossolo amarelo (EMBRAPA, 2013). Before setting up of the experiments, soil samples were collected from the experimental area, which presented the following physicochemical profile: pH in H_2O, 5.7; $H^+ + Al^{3+}$, 1.9 $cmol_c\ dm^{-3}$; Al^{3+}, 0.03 $cmol_c\ dm^{-3}$; Mg^{2+}, 1.4 $cmol_c\ dm^{-3}$; K^+, 32 mg dm^{-3}; P, 59 mg dm^{-3}; organic matter, 1.02%; clay, 188 g kg^{-1}, silt, 174 g kg^{-1}; sand (sandy loam texture), 638 g kg^{-1}.

Both experiments were carried out in conventional planting area. Prior to planting, the soil was prepared by means of plowing followed by harrowing twice. In both experiments, the cassava were planted on July 1, 2014. The furrows were mechanically opened, reaching depth of 15 cm and the spacing between the furrows was 1.2 m. For planting, 20 cm stem cuttings were utilized, which were positioned at 10 cm depth. Moreover, the stem cuttings were placed 60 cm from the stem cuttings in the next planting line. At the time of planting, fertilizers equivalent to 18 kg ha^{-1} of urea (45% of N) + 70 kg ha^{-1} of potassium chloride (60% of K_2O) were applied in the furrows. Cover fertilization was also carried out 45 days after planting, providing the equivalent of 73 kg ha^{-1} of urea (45% of N).

Efficacy

A randomized complete block design was used for the efficacy experiment, with treatments applied to subdivided plots, with four replications. In the main plot, six combinations of herbicides, detailed in Table 1, applied in cassava pre-emergence were assessed. A control without application (without weed management) and a control manually managed throughout the crop cycle were also assessed. In the subplots, two varieties of cassava (Caravela and Pretinha), which are the most commonly cultivated varieties in this region and are widely planted in the Agreste of Alagoas, were evaluated.

The subplots included four lines planted with cassava. The lines were 6 m in length, with 1.2 m spacing between them (total area = 28.8 m^2). The useful area for evaluation corresponded to the two central lines, discounting 0.5 m from the initial and final subplot extremities (useful area = 12 m^2).

Table 1. Treatments and respective dosages used in the efficacy experiments of herbicides applied in cassava crop pre-emergence.

Treatments	Dosages (g ha^{-1})
Clomazone + ametryn	1080 + 2000
Clomazone + metribuzin	1080 + 480
Clomazone + flumioxazin	1080 + 80
Isoxaflutole + ametryn	93.7 + 2000
Isoxaflutole + metribuzin	93.7 + 480
Isoxaflutole + flumioxazin	93.7 + 80
Weeded control	-
Nontreated control	-

Treatments were applied one day after the cassava were planted (July 2, 2014), and hence was applied before the emergence of both crop and weeds. The temperature, relative humidity, and wind speeds at the study site varied between 28 to 32°C, 49 to 70%, and 7 to 10 km h^{-1}, respectively between the beginning and end of applications. A constant-pressure electric coastal sprayer, equipped with an eight-point XR 110.02 (fan type), spaced 0.5 m apart, providing an application volume equivalent to 160 L ha^{-1}.

Visual percentage of weed control was assessed at 28, 55, and 91 days after application (DAA) of herbicides. In these evaluations, the area that was infested by weeds in the control plots without herbicide and the control plots without weeding were used as a reference base. The weed species found in this study were horseweed (*Conyza* sp.), amaranth (*Amaranthus deflexus*), Benghal dayflower (*Commelina benghalensis*), carpetweed (*Mollugo verticillata*), rooster crest (*Heliotropium indicum*), and several species of Poaceae family (*Eleusine indica*, *Cenchrus echinatus* and *Digitaria insularis*). These species' outcomes were portrayed with gramineous nomenclature in the control tables.

To determine the level of efficacy, scores on a percentage scale (0-100%) were noted, where 0% meant symptoms were absent, i.e., the herbicide had no effect on the weed, and 100% signified death of every plant (SBCPD, 1995). The efficacy of an herbicide treatment was then presented as the means of the scores, disregarding the variety of the cassava. The following response-variables were assessed once the crop was harvested at 18 months after planting: green shoot mass (Mg ha^{-1}), starch content (%), and cassava roots productivity (Mg ha^{-1}). Starch content determination was performed in accordance with the hydrostatic balance method (GROSSMANN; FREITAS, 1950).

Selectivity

Experimental design, arrangement of plots, replications quantity, and plots size utilized in the selectivity experiment were similar to those adopted in the efficacy experiment. However, the difference was the non-inclusion of control plots where neither herbicides were applied, nor were they weeded (i.e., without any form of weed management). Thus, for the selectivity experiments, the six herbicidal combinations presented in Table 1 were evaluated in addition to control plots where weeds were managed without the application of any herbicides, totaling seven treatments. In this experiment also, the two varieties of cassava, namely Caravela and Pretinha were appraised.

The date and manner of application of treatments and fertilizers were similar to those applied in the efficacy experiment. In this experiment, every plot was cleaned during the whole growth cycle of the cassava, intending to eliminate the interference of the weed community on crop yield, leaving only the plants exposed to the herbicides.

Crop phytointoxication was evaluated at 28, 55, 91, and 132 DAA, on a percentage scale, where 0% signified absence of symptoms, i.e., the herbicide had no effect on the plant, and 100% denoted death of the plants. When the crops were harvested, green shoot mass (Mg ha^{-1}), starch content (%), and cassava roots productivity (Mg ha^{-1}) were measured.

Statistical analyzes

Statistical analyzes were performed using the Sisvar computer program (FERREIRA, 2011). All data were submitted to analysis of variance. When a significant effect was observed between the tested factors or among each factor levels, the means were compared by LSD fisher test ($p \leq 0.05$). Additionally, data on mean productivity from the efficacy experiment were compared by means of the contrasts as shown below:

$\hat{C}1$ = combinations with clomazone *versus* combinations with isoxaflutole
$\hat{C}2$ = combinations with clomazone *versus* weeded control
$\hat{C}3$ = combinations with clomazone *versus* non-treated control
$\hat{C}4$ = combinations with isoxaflutole *versus* weeded control
$\hat{C}5$ = combinations with isoxaflutole *versus* non-treated control

RESULTS AND DISCUSSION

Efficacy

Every herbicidal combination was effective in the pre-emergence control of weeds at 28 DAA wherein, levels of at least 93% were observed for the assessed weed species (Table 2). Benghal dayflower was the only species in which treatments differed in their performance, highlighting the slightly superior functioning of herbicide combinations containing clomazone and the isoxaflutole + metribuzin combination.

Table 2. Control percentage (28, 55 and 91 DAA) of different weed species that infest cassava crop.

Treatments	Horseweed		Amaranth		Benghal dayflower		Carpetweed		Rooster Crest		Grasses	
Control (%) – 28 DAA												
Clomazone + ametryn	100.0		99.5	a	100.0	a	100.0		100.0		100.0	a
Clomazone + metribuzin	100.0		100.0	a	100.0	a	100.0		100.0		100.0	a
Clomazone + flumioxazin	100.0		99.5	a	100.0	a	100.0		100.0		100.0	a
Isoxaflutole + ametryn	100.0		97.5	a	95.0	bc	100.0		100.0		100.0	a
Isoxaflutole + metribuzin	100.0		97.5	a	98.8	ab	100.0		100.0		98.5	a
Isoxaflutole + flumioxazin	100.0		97.5	a	93.0	c	100.0		100.0		97.5	a
Weeded control	100.0		100.0	a	100.0	a	100.0		100.0		100.0	a
Nontreated control	0.0		0.0	b	0.0	d	0.0		0.0		0.0	b
CV (%)	0.0		3.3		3.2		0.0		0.0		2.1	
LSD	-		4.2		4.0		-		-		2.7	
Control (%) – 55 DAA												
Clomazone + ametryn	99.8	a	96.5	a	100.0	a	98.8	a	99.5	a	100.0	a
Clomazone + metribuzin	95.3	b	87.8	b	100.0	a	92.5	b	97.5	a	100.0	a
Clomazone + flumioxazin	100.0	a	99.0	a	100.0	a	100.0	a	100.0	a	100.0	a
Isoxaflutole + ametryn	98.3	a	88.5	b	78.3	b	98.3	a	98.3	a	95.0	ab
Isoxaflutole + metribuzin	82.8	c	89.8	b	86.3	b	98.3	a	97.3	a	87.5	c
Isoxaflutole + flumioxazin	99.8	a	98.8	a	77.8	b	100.0	a	100.0	a	90.3	bc
Weeded control	100.0	a	100.0	a	100.0	a	100.0	a	100.0	a	100.0	a
Nontreated control	0.0	d	0.0	c	0.0	c	0.0	c	0.0	b	0.0	d
CV (%)	1.7		4.6		10.6		3.6		2.4		5.9	
LSD	2.1		5.6		12.5		4.6		3.1		7.3	
Control (%) – 91 DAA												
Clomazone + ametryn	96.0	a	75.0	bc	100.0	a	90.0	a	90.0	ab	97.0	a
Clomazone + metribuzin	77.5	b	58.8	d	100.0	a	51.3	b	78.8	ab	100.0	a
Clomazone + flumioxazin	100.0	a	96.8	a	100.0	a	97.5	a	85.0	ab	100.0	a
Isoxaflutole + ametryn	94.3	a	53.8	d	37.5	b	82.5	a	70.0	b	38.8	b
Isoxaflutole + metribuzin	27.5	c	63.8	cd	32.5	b	93.8	a	63.8	b	33.8	b
Isoxaflutole + flumioxazin	99.8	a	90.5	ab	30.0	b	100.0	a	97.5	a	52.8	b
Weeded control	100.0	a	100.0	a	100.0	a	100.0	a	100.0	a	100.0	a
Nontreated control	0.0	d	0.0	d	0.0	c	0.0	c	0.0	c	0.0	c
CV (%)	13.1		15.7		15.8		16.5		25.4		21.1	
LSD	14.3		15.6		14.5		18.6		27.4		20.2	

DAA = days after application of herbicides. Means followed by the same letters in the column do not differ from each other by Fisher LSD test ($p \leq 0.05$).

Based on published data, in untreated fields, the weeds start interfering with the cassava crop growth close to 18 days after planting. In our study, the efficacy observed at 28 DAA indicated that the residual herbicide in the soil was sufficient to ensure that the crops reached this stage of growth without interference of weeds (BIFFE et al., 2010a). It is possible to infer that there was a period of at least 10 days, before the control imposed by herbicides decreases because of the herbicides dissipating into the soil solution, to adopt a complementary weed management strategy. This inference is feasible when comparing the efficacy recorded in this study with those from earlier ones. Nevertheless, it is important to emphasize that the extent of weed control as a result of residual herbicides varies according to the soil type, precipitation level, and weed species (SILVA et al., 2012a; SCARIOT et al., 2013).

Other than for the Benghal dayflower, the level of control of the other weed species was more than satisfactory (> 80%) at 55 DAA (SBCPD, 1995) (Table 2). For Benghal dayflower species, herbicide combinations with clomazone presented greater performance than those with isoxaflutole. The residual control of horseweed by metribuzin was slightly inferior to ametryn and flumioxazin when used in combination with either clomazone or isoxaflutole. Nevertheless, in the present study, the treatments containing metribuzin reached levels greater than 80% of horseweed control. Similar results were also observed for amaranth.

Preeminent efficacy of different herbicide combinations applied in cassava pre-emergence was observed for both carpetweed and rooster crest species. These results are particularly important for cassava production system in the Northeast of Brazil due to the elevated occurrence of both these weed species in this region (CARDOSO et al., 2013). In addition, grasses were absent up to 55 DAA in plots that received clomazone application. A similar residual control by this herbicide has been observed for monocotyledons (SILVA et al., 2012b; SCARIOT et al., 2013).

In the evaluation performed at 91 DAA, the most significant results were observed for the control of horseweed in treatments containing ametryn and flumioxazin, regardless of whether they were combined with clomazone or isoxaflutole (Table 2). For amaranth, at 91 DAA, the level of control was reduced when compared to the evaluation at 55 DAA. Such diminishments in the level of control of amaranth indicate a decreased herbicide residual, where the remaining dosage in the soil was not able to effectively control this weed. For amaranth, the only treatments capable of maintaining control levels superior to 80% were those containing flumioxazin.

Treatments containing clomazone when compared to those in which isoxaflutole was incorporated performed better in controlling Benghal dayflower and grasses. Among species evaluated in this study, carpetweed exhibited greater sensitivity to all the herbicide treatments. To exemplify this fact, it was verified in the final control evaluation (91 DAA) that only herbicides containing both clomazone and metribuzin presented no effect in weed management. For the pre-emergence control of rooster crest, the preeminent treatment consisted of isoxaflutole + flumioxazin application. Combinations comprising of clomazone also stood out as being more effective.

To better understand the residual effect of each herbicide treatment, the average observed control for every weed was analyzed. The results are presented in Table 3. At 28 DAA, all the evaluated treatments exhibited elevated efficacy of more than 98%. At 55 DAA, although all the treatments showed some control, herbicide combinations containing clomazone showed slightly superior performance than treatments comprising isoxaflutole.

Table 3. Percentage control means of every weed species utilized in the experiment.

Treatments	Control (%)					
	28 DAA		55 DAA		91 DAA	
Clomazone + ametryn	99.9	a	99.1	a	91.3	a
Clomazone + metribuzin	100.0	a	95.5	b	77.7	b
Clomazone + flumioxazin	99.9	a	99.8	a	96.5	a
Isoxaflutole + ametryn	98.8	bc	92.7	bc	62.8	c
Isoxaflutole + metribuzin	99.1	ab	90.3	c	52.5	d
Isoxaflutole + flumioxazin	98.0	c	94.4	b	78.4	b
Weeded control	100.0	a	100.0	a	100.0	a
Nontreated control	0.0	d	0.0	d	0.0	e
CV (%)	0.9		2.5		9.1	
LSD	1.1		3.1		9.3	

DAA = days after application of herbicides. Means followed by same letters in the column do not differ among them by LSD Fisher test ($p \leq 0.05$).

In the assessment performed at 91 DAA, the superiority of combinations composed of clomazone to those containing isoxaflutole was evident as levels of control above 80% was observed only in the former. In contrast, it was verified that the poorest performance in the residual control of weeds was obtained for metribuzin in combination with clomazone and with isoxaflutole, and the observed average efficacy levels for these combinations with metribuzin was inferior to those with ametryn and flumioxazin.

Although the main commercialized products of cassava cultivation are the roots, the evaluation of the effect of weed management on the shoot system is important, since this is essential for production of photoassimilates, and consequently, for the development of cassava. Moreover, in certain cassava producing regions, the shoot part is used as fodder for animals, especially cattle and goats (FERNANDES et al., 2016).

Preeminent values of shoot mass in plots planted with Pretinha were verified in every treatment apart from those treated with clomazone + metribuzin (Table 4). This could be related to traits of this cassava variety, since Pretinha presents a more rapid development and attains larger sizes than Caravela.

Table 4. Shoot mass, starch content and roots productivity as a function of herbicide application in cassava crops pre-emergence.

Treatments	Shoot mass (Mg ha^{-1})		Starch content (%)	
	Caravela	Pretinha	Caravela	Pretinha
Clomazone + ametryn	15.83 Bab	24.37 Acd	31.50 Aab	30.28 Aab
Clomazone + metribuzin	17.80 Aab	22.92 Acd	31.68 Aa	31.40 Aa
Clomazone + flumioxazin	17.08 Bab	28.54 Abc	31.19 Aab	30.48 Aab
Isoxaflutole + ametryn	12.60 Bbc	23.53 Acd	31.47 Aab	30.41 Aab
Isoxaflutole + metribuzin	16.55 Bab	27.39 Abc	31.17 Aab	30.06 Ab
Isoxaflutole + flumioxazin	16.25 Bab	36.14 Aa	31.82 Aa	30.83 Aab
Weeded control	21.61 Ba	34.35 Aab	30.99 Aab	31.07 Aab
Nontreated control	7.39 Bc	19.15 Ad	30.34 Ab	30.18 Ab
CV (%)	24.52		3.15	
LSD – Plot	7.36		1.16	
LSD – Subplot	7.47		1.39	

Treatments	Roots productivity (Mg ha^{-1})	
	Caravela	Pretinha
Clomazone + ametryn	23.33 Ab	26.98 Aab
Clomazone + metribuzin	23.54 Ab	25.93 Aabc
Clomazone + flumioxazin	21.87 Ab	25.62 Aabc
Isoxaflutole + ametryn	18.33 Ab	25.00 Aabc
Isoxaflutole + metribuzin	21.66 Ab	23.12 Abc
Isoxaflutole + flumioxazin	23.85 Ab	30.72 Aa
Weeded control	32.65 Aa	28.13 Aab
Nontreated control	8.44 Bc	18.95 Ac
CV (%)	23.72	
LSD – Plot	7.10	
LSD – Subplot	8.08	

Means followed by distinct uppercase letters in the row and followed by lowercase letters in the column differ by Fisher LSD test ($p \leq 0.05$).

In both cassava varieties, the lower values of plants' green mass observed in the weeded controls demonstrate the negative effect exerted by weeds on vegetative growth (Table 4). Despite this similarity among the two cassava varieties, it could be noted that the decrease in Caravela (65%) was greater than that in Pretinha (44%) when comparing weeded control and non-treated control.

No discrepancy in the starch content was observed between the varieties (Table 4). The lowest starch content values were discerned in plots where weeds were not controlled. This proves the negative effect of weeds on both quantity and quality of roots produced, since starch content is an essential trait for the industrial processing of cassava.

The lowest productivity values of cassava roots yield were recorded in the non-treated control, recording a decrease of about 74 and 32% for Caravela and Pretinha varieties, respectively in comparison to the weeded control (Table 4). In addition, when comparing cassava varieties submitted to different treatments, discrepant values were observed only in the non-treated control, in which Pretinha productivity was superior to Caravela. These results provide important information for weed management in cassava crops, in that, the sensitivity to weed interference was different among varieties even though the productivity potential was similar among them as seen from the values recorded in the weeded control plots.

Differential sensitivity to weed community interference may be related to the traits of each cassava variety - Pretinha exhibits a more vigorous development than Caravela, a fact that benefits cultural control of weeds. When comparing treatments in which herbicides were applied with the non-treated control, regardless of the planted cassava variety, the plots without control demonstrated inferior productivity (Table 5).

Table 5. Estimation of contrast and significance level to consider the contrast as significant for cassava roots productivity variable.

Contrasts	Caravela		Pretinha	
	PValue	Estimation (Mg ha^{-1})	PValue	Estimation (Mg ha^{-1})
$\hat{C}1$ = clomazone and associations *versus* isoxaflutole and associations	0.41^{ns}	1.63	0.95^{ns}	-0.10
$\hat{C}2$ = clomazone and associations *versus* weeded control	0.00*	-9.74	0.49^{ns}	-1.95
$\hat{C}3$ = clomazone and associations *versus* nontreated control	0.00*	14.47	0.01*	7.22
$\hat{C}4$ = isoxaflutole and associations *versus* weeded control	0.00*	-11.37	0.51^{ns}	-1.85
$\hat{C}5$ = isoxaflutole and associations *versus* nontreated control	0.00*	12.84	0.01*	7.32

^{ns} – not significant at 5% and * - significant at 5% of probability.

For the Caravela variety, highest productivity was observed in the weeded control when compared to plots treated with herbicides. There was a reduction in cassava yield of about 9.74 and 11.37 Mg ha-1 for plots treated with herbicide combinations with clomazone and those with isoxaflutole, respectively. This decrease in cassava productivity was related to the absence of weed control for the entire period when weeds can potentially interfere with the crop growth (interference prevention period, PTPI), which, for cassava is about 135 days after planting (CARVALHO; ARAÚJO; AZEVEDO, 2004).

This diminishment in the control of weeds resulted from a decrease in herbicide residuals before the 135 days PTPI. It is noteworthy that the region where the experiment was performed includes an area with lower rainfall indexes, where cassava is produced - a fact that accentuates the competition for water between crops and weeds (SILVA et al., 2012a).

The above-described observation for Caravela was not perceived for Pretinha, a fact that enables the inference that cultural control of weeds benefits this crop. In this sense, the use of herbicides in cassava before the emergence of weeds, along with favorable developmental traits of the Pretinha variety, were sufficient to assure crop productivity, without exhibiting a significant difference from weeded control. Comparing the treatments with herbicides with the non-treated control showed that the plots in which no treatment was adopted presented inferior yield, regardless of the cassava variety (Table 5).

Selectivity

Phytointoxication levels resulted for all herbicide combinations, regardless of the period at which the evaluation was carried out, although the values did not exceed 13.75% (Table 6). These results demonstrate the tolerance of both cassava varieties to herbicidal application in pre-emergence, even with the use of elevated dosages and active principles in the combination.

In general, the results from the phytointoxication assessments indicate that, whether utilized in consonance with either clomazone or isoxaflutole, the flumioxazin presented the lowest intensity of injury to cassava plants in comparison to ametryn and metribuzin (Table 6). Similar observations were noted in both Caravela and Pretinha varieties when exposed to herbicidal residues in soil. No greater intoxication intensity was observed in none tested variety.

In the evaluation carried out at 132 DAA (data not shown), no injuries were noted in cassava plants from the action of the herbicides applied in pre-emergence. This shows the crop's potential to recover from the symptoms caused by exposure to herbicides. Moreover, the shoot mass of the cassava plants were not influenced by the application of the herbicide combinations, irrespective of the planted variety (Table 7). However, the shoot mass differed between the varieties, demonstrating higher values of shoot mass for Pretinha variety when compared to Caravela in approximately 43% of the evaluated herbicide treatments.

Starch content and cassava root yield were not influenced by pre-emergence herbicide treatments of cassava (Table 7). These results together with those documented for the shoot mass corroborate with phytointoxication evaluations, in which no intense symptoms of injuries caused by the pre-emergence application of herbicides to the cassava were found.

Table 6. Phytointoxication percentages of cassava as function of herbicide application in crop pre-emergence.

Treatments	Phytointoxication (%) – 28 DAA		Phytointoxication (%) – 55 DAA	
	Caravela	Pretinha	Caravela	Pretinha
Clomazone + ametryn	7.50 Aa	7.50 Ab	10.00 Aab	12.50 Aa
Clomazone + metribuzin	6.25 Aa	8.75 Aab	13.75 Aa	6.25 Babc
Clomazone + flumioxazin	5.00 Aa	5.00 Ab	3.75 Abc	3.75 Abc
Isoxaflutole + ametryn	6.25 Ba	12.50 Aa	13.75 Aa	10.00 Aab
Isoxaflutole + metribuzin	8.75 Aa	12.50 Aa	11.25 Aa	8.75 Aab
Isoxaflutole + flumioxazin	5.00 Aa	6.25 Ab	2.50 Ac	1.25 Ac
Weeded control	0.00 Ab	0.00 Ac	0.00 Ac	0.00 Ac
CV (%)	51.52		61.61	
LSD – Plot	3.80		7.03	
LSD – Subplot	4.84		6.18	

Treatments	Phytointoxication (%) – 91 DAA	
	Caravela	Pretinha
Clomazone + ametryn	7.50 Aa	3.75 Aab
Clomazone + metribuzin	2.50 Abc	5.00 Aa
Clomazone + flumioxazin	2.50 Abc	1.25 Aab
Isoxaflutole + ametryn	2.50 Abc	5.00 Aa
Isoxaflutole + metribuzin	5.00 Aab	3.75 Aab
Isoxaflutole + flumioxazin	1.25 Abc	0.00 Ab
Weeded control	0.00 Ac	0.00 Ab
CV (%)	101.08	
LSD – Plot	3.76	
LSD – Subplot	4.20	

Means followed by distinct uppercase letters in the row and followed by lowercase letters in the column differ by Fisher LSD test ($p \leq 0.05$).

Table 7. Shoot mass, starch content and cassava roots productivity in response to herbicides application in crop pre-emergence.

Treatments	Shoot mass (Mg ha^{-1})		Starch content (%)	
	Caravela	Pretinha	Caravela	Pretinha
Clomazone + ametryn	27.60 Aa	26.39 Aa	30.77 Aa	31.12 Aa
Clomazone + metribuzin	20.83 Aa	27.18 Aa	30.98 Aa	30.98 Aa
Clomazone + flumioxazin	26.25 Aa	32.81 Aa	30.98 Aa	29.90 Aa
Isoxaflutole + ametryn	20.41 Ba	31.45 Aa	31.19 Aa	30.63 Aa
Isoxaflutole + metribuzin	22.91 Ba	34.58 Aa	31.11 Aa	30.34 Aa
Isoxaflutole + flumioxazin	22.50 Aa	30.41 Aa	30.76 Aa	31.19 Aa
Weeded control	22.18 Ba	34.48 Aa	30.83 Aa	31.19 Aa
CV (%)	25.09		3.50	
LSD – Plot	9.44		1.31	
LSD – Subplot	9.76		1.56	

Treatments	Roots productivity (Mg ha^{-1})	
	Caravela	Pretinha
Clomazone + ametryn	35.21 Aa	30.83 Aa
Clomazone + metribuzin	34.16 Aa	32.39 Aa
Clomazone + flumioxazin	38.54 Aa	34.27 Aa
Isoxaflutole + ametryn	32.91 Aa	34.68 Aa
Isoxaflutole + metribuzin	34.58 Aa	35.00 Aa
Isoxaflutole + flumioxazin	38.54 Aa	31.45 Aa
Weeded control	33.22 Aa	28.44 Aa
CV (%)	22.78	
LSD – Plot	8.75	
LSD – Subplot	11.41	

Means followed by distinct uppercase letters in the row and followed by lowercase letters in the column differ according to Fisher LSD test ($p \leq 0.05$).

Every herbicide assessed in this study was selective for cassava, assuring the control of weeds without causing toxic effects to the crop even when applied in combinations. The results obtained in the present study corroborate those reported from earlier ones that demonstrated the selectivity of the herbicides clomazone, ametryn, metribuzin, flumioxazin, and isoxaflutole either when applied in isolation or in combinations (OLIVEIRA JR et al., 2001; BIFFE et al., 2010b; COSTA et al., 2013b).

CONCLUSIONS

Herbicide combinations containing clomazone showed greater residual control of weeds in cassava when compared to those that contain isoxaflutole. Among the herbicides tested, metribuzin in combination with clomazone and isoxaflutole portrayed the lowest spectrum of weed control (efficacy). Although the various herbicide combinations were selective for both Caravela and Pretinha varieties, these varieties responded differently in terms of tolerance to weed interference. Moreover, Pretinha can be considered less sensitive to competition with weeds than Caravela due to its more vigorous development.

ACKNOWLEDGMENTS

Acknowledgments to the Foundation for Research Support of the State of Alagoas (FAPEAL) for the financial contribution, which made feasible the present work development.

REFERENCES

ALBUQUERQUE, J. A. A. et al. Interferência de plantas daninhas sobre a produtividade da mandioca (*Manihot esculenta*). **Planta Daninha**, Viçosa, v. 26, n. 2, p. 279-289, 2008.

BIFFE, D. F. et al. Período de interferência de plantas daninhas em mandioca (*Manihot esculenta*) no Noroeste do Paraná. **Planta Daninha**, Viçosa, v. 28, n. 3, p. 471-478, 2010a.

BIFFE, D. F. et al. Avaliação de herbicidas para dois cultivares de mandioca. **Planta Daninha**, Viçosa, v. 28, n. 4, p. 807-816, 2010b.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. **Sistema de Agrotóxicos Fitossanitários/Agrofit**. Disponível em: <http://www.agricultura.gov.br/servicos-e-sistemas/sistemas/agrofitl>. Acesso em: 06 mar. 2017.

CARDOSO, A. D. et al. Levantamento fitossociológico de plantas daninhas na cultura da mandioca em Vitória da Conquista, Bahia. **Bioscience Journal**, Uberlândia, v. 29, n. 5, p. 1130-1140, 2013.

CARVALHO, J. E. B.; ARAÚJO, A. M. A.; AZEVEDO, C. L. L. **Período de controle de plantas infestantes na cultura da mandioca no Estado da Bahia**. Cruz das Almas: Embrapa, 2004. 7 p. (Technical announcement, 109).

COSTA, N. V. et al. Weed interference periods in the 'Fécula Branca' cassava. **Planta Daninha**, Viçosa, v. 31, n. 3, p. 533-542, 2013a.

COSTA, N. V. et al. Selectivity of clomazone and S-metolachlor applied after cassava pruning. **Planta Daninha**, Viçosa, v. 31, n. 4, p. 979-985, 2013b.

COSTA, N. V. et al. Sulfentrazone selectivity and efficiency in cassava crops in sandy and clayey soils. **Planta Daninha**, Viçosa, v. 33, n. 4, p. 787-793, 2015.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA — EMBRAPA. **Sistema Brasileiro de Classificação de Solos**. 3. ed. Brasília, DF: Embrapa Solos, 2013. 353 p.

FERNANDES, F. D. et al. Produtividade e valor nutricional da parte aérea e de raízes tuberosas de oito genótipos de mandioca de indústria. **Revista Brasileira de Saúde e Produção Animal**, Salvador, v. 17, n. 1, p. 1-12, 2016.

FERREIRA, D. F. Sisvar: a computer statistical analysis system. **Ciência e Agrotecnologia**, Lavras, v. 35, n. 6, p. 1039-1042, 2011.

GROSSMANN, J.; FREITAS, A. C. Determinação do teor de matéria seca pelo peso específico em mandioca. **Revista Agronômica**, Porto Alegre, v. 14, n. 160/162, p. 75-80, 1950.

MONQUERO, P. A. et al. Monitoramento do banco de sementes de plantas daninhas em áreas com cana-de-açúcar colhida mecanicamente. **Planta Daninha**, Viçosa, v. 29, n. 1, p. 107-119, 2011.

OLIVEIRA JR, R. S. et al. Tolerância de cinco cultivares de mandioca (*Manihot esculenta*) a herbicidas. **Planta Daninha**, Londrina, v. 19, n. 1, p. 119-125, 2001.

PERESSIN, V. A.; CARVALHO, J. E. B. Manejo integrado de plantas daninhas em mandioca. In: CEREDA, M. P. (Ed.). **Cultura de Tuberosas Amiláceas Latino Americanas**. São Paulo: Fundação Cargill, 2002. v. 2, p. 302-349.

SCARIOT, C. A. et al. Seletividade e eficiência de herbicidas aplicados em pré-emergência na cultura da mandioca. **Pesquisa Agropecuária Tropical**, Goiânia, v. 43, n. 3, p. 300-307, 2013.

SILVEIRA, H. M. et al. Sensibilidade de cultivares de mandioca ao herbicida mesotrione. **Revista Brasileira de Herbicidas**, Londrina, v. 11, n. 1, p. 24-31, 2012.

SILVA, D. V. et al. Manejo de plantas daninhas na cultura da mandioca. **Planta Daninha**, Viçosa, v. 30, n. 4, p. 901-910, 2012a.

SILVA, D. V. et al. Seletividade de herbicidas pós-emergentes na cultura da mandioca. **Planta Daninha**, Viçosa, v. 30, n. 4, p. 835-841, 2012b.

SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS - SBCPD. **Procedimentos para instalação, avaliação e análise de experimentos com herbicidas**. 1. ed. Londrina, PR: SBCPD, 1995. 42 p.

XAVIER, R. A.; DORNELLAS, P. C. Análise do comportamento das chuvas no município de Arapiraca, região Agreste de Alagoas. **Geografia**, Londrina, v. 14, n. 2, p. 49-64, 2005.