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Selectivity of pre-and post-emergent herbicides for cowpea (*Vigna unguiculata*)

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Historically, cowpea farming has been concentrated to the north and northeast of Brazil, and is usually cultivated with low level of technology. However, in recent years, there has been an increase in the area planted with the crop in the central west, using technology, and there is therefore now a need to study, among other factors, the chemical control of weeds. Two experiments were carried out with the aim of making a preliminary study during the vegetative phase of the cowpea, the first using pre-emergent herbicides and the second with post-emergent herbicides, in a greenhouse at the Federal University of Paraíba, in Areia, state of Paraiba, Brazil. The experimental design was completely randomized with four replications. The Relative Chlorophyll Content (SPAD index) was evaluated together with a visual evaluation of phytotoxicity. Promising results for selectivity in the cowpea were seen in relation to the herbicides under evaluation, whether applied prior to or after emergence of the crop. For weed control prior to crop emergence, the herbicides Diuron, S-metolachlor, Metribuzin, Diquat dibromide and Sulfentrazone gave promising results. In addition to these products, Clethodim and Haloxyfop-p-methyl should be noted as potential post-emergent herbicides.

Key words: Chemical control, phytotoxicity, tolerance, *Vigna unguiculata*, weed management.

INTRODUCTION

The cowpea (*Vigna unguiculata* (L.) Walp.) is among the most important species used for food in the human diet. Historically in Brazil, cowpea production has been concentrated in the north and northeast (55.8 million hectares and 1.2 thousand hectares, respectively), where it is cultivated mainly by small producers, generally using a low level of technology. However, the crop has been gaining ground in the central west, due to the development of erect and semi-erect cultivars, favouring mechanised cultivation (Freire Filho, 2011), and arousing

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Table 1. Mean values for chemistry, fertility and granulometry analysis of the soil.

pH (1:2.5)	P	K^+	Na^+	H+Al	Al^{+3}	Ca^{+2}	Mg^{+2}	OM
	mg dm^{-3}			$cmol_c kg^{-1}$				g kg^{-1}
5.2	1.9	0.22	0.07	6.6 [b]	0.4	1.1	0.7	25.0

Textural class			Dispersed clay	Degree of flocculation	Textural classification
Sand	Silt	Clay			
g kg^{-1}					
532	49	420	9	979	Sandy clay

the interest of large producers who practice a mechanised agriculture, and who plant the cowpea during the soybean off-season (Freitas et al., 2009).

The cowpea (*Vigna unguiculata*) is one of the most consumed and cultivated legumes in Brazil, especially in the north and northeast. However, in recent years, there has also been a great expansion of the cultivated area in the central west, where it is incorporated into such productive arrangements as the off-season harvest, after the soybean and rice crops, and in some places, as the main crop (Freire Filho, 2011).

The crop has become an excellent alternative as an off-season crop in the savannah of the northeast, especially in the areas, where soybeans and maize are cultivated in the south of the states of Maranhão and Piauí. It is estimated that there were approximately 50 thousand hectares under cultivation in these regions in the 2014 to 2015 season, with average yields greater than 1400 kg ha^{-1}.

Its rusticity, low production cost and economically viable productivity are the main characteristics that make this an ever-expanding crop. However, one of the major problems faced by producers in the region is the interference of weeds due to the lack of herbicides registered for the crop, and weed control by mechanical methods being impractical and impossible to use in large areas.

As they compete for light, nutrients and water, the interference of weeds is one of the factors that most influence growth, development and productivity in *Vigna unguiculata* (L.) Walp, which is directly reflected in a quantitative and qualitative reduction in production, in addition to increasing the operational costs of harvesting, drying and processing the grain, where weed control is considered one of the main components of the production costs. When uncontrolled, weeds may reduce grain yield by up to 90% (Freitas et al., 2009).

Chemical control using herbicides has several advantages, such as less dependence on labour, efficiency even during the rainy season, effectiveness in controlling weeds in the planting furrow and not affecting the root system of the crops, allowing for minimum cultivation or direct planting, and being efficient in controlling vegetative propagation in the weeds. However, the use of these methods in the cowpea is limited due to the scarcity of studies into the selectivity of herbicides for the crop (Silva et al., 2009; Souza et al., 2016). Most of the information on the use of herbicides is related to the common bean (*Phaseolus vulgaris* L.) or the soybean (*Glicyne maxima* (L.) Merr.) (Freitas et al., 2009).

Taking this information into consideration, the aim of the present work was to study the selectivity of herbicides for the cowpea crop when applied pre- and post-emergence during the initial phase of crop growth.

MATERIALS AND METHODS

Location of the experiments

Two experiments were carried out in a greenhouse at the Centre for Agrarian Sciences of the Federal University of Paraíba, Areia Campus, Brazil, during October and November 2014. Analysis of chemistry, fertility and granulometry of the soil used to fill out the cups is presented in Table 1.

Experimental design and statistical procedures

The experimental design was completely randomized with four replications, eight herbicides applied pre-emergence as treatments in the first experiment and 8 herbicides applied post-emergence as treatments in the second experiment (Table 2). The experimental units consisted of disposable 250 ml capacity cups with substrate. The cowpea cultivar used was IPA 207. Plants were irrigated every two days to maintain the soil at field capacity.

The herbicides were applied with a backpack spray at a constant pressure of 206.85 kPa, by compressed CO_2, using XR 110-02 flat fan spray tips. The equivalent of 200 L ha^{-1} of solution was applied. The operation was carried out soon after sowing the seeds. The application of the post-emergent herbicides was carried out in plants after 15 days of emergence and display of four to five distinct folioles. The following conditions were noted at the time of the applications, a wind speed of 1.6 km h^{-1}, ambient temperature of 34.3°C, and relative humidity of 47.6%.

The selectivity of the herbicides was evaluated visually at 07, 14 and 21 days after application of the herbicides (DAA) (in the first experiment), and at 07, 14, 21 and 28 days after application (in the second experiment). A percentage scale was adopted for the visual evaluation of phytotoxicity in the cowpea plants, where zero indicates the absence of symptoms, and 100% means death of the plant (Frans and Talbert, 1977). The Relative Chlorophyll Content (RCC) was determined by readings taken at 7, 14 and 21 days after

Table 2. Treatment (doses of herbicides in active ingredient – a.i.) applied pre and post-emergence.

Experiment 1: Pre-emergent	Experiment 2: Post-emergent
T1 - Flumioxazin (52.5 g a.i. ha^{-1})	T1 -Fluazifop-p-butyl (187.5 g a.i. ha^{-1})
T2 - Diuron (1.6 kg a.i. ha^{-1})	T2 -Quizalofop-p-ethyl (80 g a.i. ha^{-1})
T3 - S-metolachlor (1.2 kg a.i. ha^{-1})	T3 -Fenoxaprop-p-ethyl (44 g a.i. ha^{-1})
T4 - Metribuzin (422.4 g a.i. ha^{-1})	T4 - Sethoxydim (276 g a.i. ha^{-1})
T5 - Clomazone (1.64 kg a.i. ha^{-1})	T5 - Clorimuron-ethyl (17 g a.i. ha^{-1})
T6 - Diquat dibromide (350 g a.i. ha^{-1})	T6 – Clethodim (96 g a.i. ha^{-1})
T7 - Sulfentrazone (600 g a.i. ha^{-1})	T7 - Haloxifop-p-methyl (43.75 g a.i. ha^{-1})
T8 - Lactofen (180 g a.i. ha^{-1})	T8 – Bentazon (720 g a.i. ha^{-1})

Table 3. Summary of the analysis of variance (mean squares) for relative chlorophyll content and phytotoxicity in cowpea seedlings verified at intervals of seven days after application (DAA) of pre-emergent herbicides.

SOV	d.f	7 DAA	14 DAA	21 DAA
		Relative chlorophyll content		
Herbicides	6	239.419**	36.99**	28.87^{ns}
Residual	28	7.587	9.33	12.89
CV (%)	-	8.82	9.39	12.76
		Phytotoxicity		
Herbicides	7	46.376**	56.923**	29.35**
Residual	32	0.8802	0.6137	1.213
CV (%)	-	22.42	19.85	23.38

SOV: Sources of variation; d.f: degrees of freedom; CV: coefficient of variation; **Significant 1% probability. ^{ns}Not significant.

application of the treatments, using the Minolta SPAD-502 chlorophyll meter.

The data were evaluated for variance and error normality. Variance analysis was used to analyse the data, and mean values were compared by Tukey's test at 5% probability.

RESULTS

In the first experiment, selectivity of cowpea to pre-emergent herbicides was evaluated. The treatments were significantly different ($p < 0.01$) among them for all RCC and phytoxicity evaluations, with the only exception for this first one at 21 DAE (Table 3). Furthermore, the fair to good value obtained for the coefficient of variation indicated good experimental procedure.

Multiple comparison tests were applied to the mean values for RCC and phytotoxicity visual evaluation, carried out 7, 14 and 21 days after application of the herbicides (Table 4). At seven days after application of the herbicides, the highest values for RCC were found for the herbicides sulfentrazone (350 g a.i. ha^{-1}) and lactofen (180 g a.i. ha^{-1}).

Fourteen days after application of the treatments, death of the lots occurred with the herbicide Flumioxazin (T1). From this point, then statistical analysis considered only seven treatments, with this product excluded from the analysis.

The highest values for RCC were seen using the herbicides Lactofen (36.16) and Clomazone (34.85) when analyzed at 14 days after treatment application. However, when analysed at 21 days after application of the herbicides, no significant differences were found by Tukey's test at 5% probability.

According to phytotoxicity visual evaluation, cowpea was more selective to the herbicide Metribuzin, having the lowest value (0.1%), followed by the herbicides Diuron (0.7%), Diquate Dibromide (1.6%) and S-metolachlor (7.4%). Similar behaviour was seen when evaluating phytotoxicity after 14 days of application, where the herbicide Diquat dibromide had the lowest evaluation (0.4%), followed by the herbicides Metribuzin (0.5%), Diuron (0.7%) and S-metolachlor (3.9%), with no statistical difference at 5% probability by Tukey's test. Twenty-one days after application, the crop was seen to be more selective to the herbicide Diuron (5.3%), with levels of toxicity significantly lower than those for

Table 4. Relative chlorophyll content and phytotoxicity in cowpea seedlings verified at intervals of seven days after application (DAA) of pre-emergent herbicides.

Herbicide	7 DAE	14 DAE	21 DAE
	Relative chlorophyll content		
Flumioxazin (52.5 g a.i. ha^{-1})	16.19^{d}	NE	NE
Diuron (1.6 kg a.i. ha^{-1})	29.60^{bc}	28.29^{b}	28.81^{a}
S-metolachlor (1.2 kg a.i. ha^{-1})	34.06^{ab}	33.61^{ab}	24.72^{a}
Metribuzin (422.4 g a.i. ha^{-1})	27.86^{c}	30.31^{ab}	30.96^{a}
Clomazone (1.64 kg a.i. ha^{-1})	34.59^{ab}	34.85^{a}	29.13^{a}
Diquat dibromide (350 g a.i. ha^{-1})	33.08^{abc}	31.32^{ab}	26.53^{a}
Sulfentrazone (600 g a.i. ha^{-1})	37.31^{a}	33.09^{ab}	30.75^{a}
Lactofen (180 g a.i. ha^{-1})	37.17^{a}	36.16^{a}	26.11^{a}
	Phytotoxicity (%)		
Flumioxazin (52.5 g a.i. ha^{-1})	61.3 (7.86)^{a}	100 (10.03)^{a}	100 (10.03)^{a}
Diuron (1.6 kg a.i. ha^{-1})	0.7 (1.07)^{b}	0.7 (1.04)^{d}	5.3 (2.39)^{d}
S-metolachlor (1.2 kg a.i. ha^{-1})	7.4 (2.54)^{b}	3.9 (1.91)^{d}	17.7 (4.14)^{bcd}
Metribuzin (422.4 g a.i. ha^{-1})	0.1 (0.78)^{b}	0.5 (0.90)^{d}	31.6 (5.19)^{bc}
Clomazone (1.64 kg a.i. ha^{-1})	39.3 (6.27)^{a}	35.7 (5.96)^{b}	18.1 (4.26)^{bcd}
Diquat dibromide (350 g a.i. ha^{-1})	1.6 (1.29)^{b}	0.4 (0.88)^{d}	9.3 (3.07)^{cd}
Sulfentrazone (600 g a.i. ha^{-1})	55.7 (7.44)^{a}	44.3 (6.66)^{b}	8.3 (2.95)^{cd}
Lactofen (180 g a.i. ha^{-1})	40.3 (6.21)^{a}	18.7 (4.19)^{c}	32.1 (5.66)^{b}

Mean values followed by the same letter in a column do not differ by Tukey's test at 5% probability. NE: Not evaluated. Original data in parentheses; transformed data (Root x + 0.5).

Table 5. Summary of the analysis of variance (mean squares) for relative chlorophyll content and phytotoxicity in cowpea seedlings verified at intervals of seven days after application (DAA) of post-emergent herbicides.

SOV	d.f	7 DAA	14 DAA	21 DAA	28 DAA
		Relative chlorophyll content			
Herbicides	7	45.968^{ns}	122.668**	118.918**	NE
Residual	24	30.192	17.164	16.117	NE
CV (%)	-	26.99	18.56	19.30	NE-
		Phytotoxicity			
Herbicides	7	0.3972^{ns}	1.9502**	2.0709**	4.1489**
Residual	24	0.4537	0.5556	0.2982	0.4088
CV (%)	-	15.47	15.59	10.64	10.84

SOV: Sources of variation; d.f: degrees of freedom; CV: coefficient of variation; **Significant 1% probability. ^{Ns}not significant; NE: not evaluated.

Metribuzin (31.6%), Lactofen (32.1%) and Flumioxazin (100%).

In the second experiment, eight herbicides applied in post-emergence of cowpea crop were evaluated. Table 5 presents the data for RCC and phytotoxicity at 7, 14 and 21 days after application of the post-emergent herbicides. No significant difference was found among treatments for RCC in the first evaluation (7 DAE), but in the remaining evaluations (14 and 21 DAA) significant effect of treatments on both variables were observed.

For visual evaluations of phytotoxicity, it was observed that only in the first evaluation, there was no significant effect for treatments (Table 5). Hence, these products influenced significantly (p <0.01) this variable, according to evaluations carried out at 14, 21 and 28 DAA.

Statistical difference among treatments for RCC values at the first evaluation (7 DAA) was not noticed, but higher values of this variable were obtained for the treatment with Quizalofop-p-ethyl (80 g a.i. ha^{-1}) throughout other evaluations (Table 6). On the other hand, the treatment

Table 6. Relative chlorophyll content and phytotoxicity in cowpea seedlings verified at intervals of seven days after application (DAA) of post-emergent herbicides.

Herbicide	7 DAA	14 DAA	21 DAA	28 DAA
	Relative chlorophyll content			
Fluazifop-p-butyl (187.5 g a.i. ha^{-1})	21.18^{a}	26.78^{ab}	25.00^{ab}	NE
Quizalofop-p-ethyl (80 g a.i. ha^{-1})	21.79^{a}	29.79^{a}	27.88^{a}	NE
Fenoxaprop-p-ethyl (44 g a.i. ha^{-1})	21.18^{a}	17.38^{bc}	16.04^{bcd}	NE
Sethoxydim (276 g a.i. ha^{-1})	20.40^{a}	17.23^{bc}	15.35^{cd}	NE
Clorimuron-ethyl (17 g a.i. ha^{-1})	21.59^{a}	24.76^{ab}	23.10^{abc}	NE
Clethodim (96 g a.i. ha^{-1})	12.23^{a}	14.53^{c}	13.09^{d}	NE
Haloxifop-p-methyl (43.75 g a.i. ha^{-1})	21.23^{a}	21.24^{abc}	20.34^{abcd}	NE
Bentazon (720 g a.i. ha^{-1})	23.30^{a}	26.88^{ab}	25.60^{a}	NE
	Phytotoxicity (%)			
Fluazifop-p-butyl (187.5 g a.i. ha^{-1})	18.8 (4.38)^{a}	19.4 (4.41)^{b}	42.5 (6.50)^{a}	57.5 (7.60)^{a}
Quizalofop-p-ethyl (80 g a.i. ha^{-1})	17.9 (4.27)^{a}	15.8 (4.00)^{b}	22.9 (4.83)^{bc}	32.5 (5.72)^{bc}
Fenoxaprop-p-ethyl (44 g a.i. ha^{-1})	15.4 (3.99)^{a}	18.3 (4.30)^{b}	20.8 (4.61)^{bc}	5.84 (33.8)^{bc}
Sethoxydim (276 g a.i. ha^{-1})	24.2 (4.92)^{a}	24.2 (4.94)^{ab}	23.8 (4.91)^{bc}	36.3 (6.04)^{bc}
Clorimuron-ethyl (17 g a.i. ha^{-1})	17.3 (4.18)^{a}	25.0 (5.03)^{ab}	30.4 (5.54)^{ab}	47.5 (6.88)^{ab}
Clethodim (96 g a.i. ha^{-1})	22.1 (4.69)^{a}	39.2 (6.24)^{a}	30.8 (5.58)^{ab}	27.5 (5.26)^{cd}
Haloxifop-p-methyl (43.75 g a.i. ha^{-1})	16.3 (4.05)^{a}	24.6 (4.96)^{ab}	23.8 (4.88)^{bc}	4.22 (17.50)^{d}
Bentazon (720 g a.i. ha^{-1})	19.2 (4.35)^{a}	19.2 (4.35)^{b}	17.1 (4.18)^{c}	31.3 (5.6)^{bcd}

Mean values followed by the same letter in a column do not differ by Tukey's test at 5% probability. NE: Not evaluated. Original data in parentheses; transformed data (Root x + 0.5).

with Clethodim (96 g a.i. ha^{-1}) resulted in statistically lower values than the other treatments at those evaluation periods.

It was found that as visual analysis of phytotoxicity symptoms continued, different behaviours were observed when the mean values were tested at 5% probability, as can be seen in Table 6. In the first evaluation, 7 days after herbicide application, there was no difference found among treatments. However, in the evaluation at 14 DAA, it was found that the herbicide Clethodim did the most damage to the crop, followed by the herbicides Chlorimuron-ethyl (17 g a.i. ha^{-1}), Sethoxydim (276 g a.i. ha^{-1}) and Haloxifope-p-methyl (43.75 g a.i. ha^{-1}), where there was no difference. When carrying out the evaluation at 21 DAA, it was found that Fluazifop-p-butyl (187.5 g a.i. ha^{-1}) resulted in the greatest phytotoxicity among the herbicides used. Similar behaviour occurred when the visual evaluation was carried out at 28 DAA, where the herbicides that displayed the most phytotoxicity were Fluazifop-p-butyl (187.5 g a.i. ha^{-1}) and Chlorimuron-ethyl (17 g a.i. ha^{-1}), whereas the herbicides that produced the least phytotoxicity were Haloxyfop-p-methyl (43.75 g a.i. ha^{-1}) and Clethodim (96 g a.i. ha^{-1}).

DISCUSSION

In the present study, Diuron, S-metolachlor, Metribuzin, Diquat dibromide and Sulfentrazone showed promising results as pre-emergent herbicides for cowpea crop. Some studies has been done to evaluate the use of herbicides in the cowpea, where the following herbicides were noteworthy for selectivity: Imazamox + Bentazon (Linhares et al., 2014; Mesquita, 2011); Imazamox (Silva et al., 2003; Mesquita, 2011); Bentazon, Fluazifop-p-butyl, Imazethapyr, Trifluralin, S-metolachlor (Mesquita, 2011) and Fenoxaprop-p-ethyl (Silva et al., 2003). Severe intoxication with a reduction in productivity was found in the cowpea with applying the herbicides Fomesafen (Linhares et al., 2014) and Lactofen, while the mixtures of Metribuzin and Chlorimuron-ethyl + Fluazifop-p-butyl caused death of the crop (Mesquita, 2011).

The cause of the reduction in the RCC seen with some of the herbicides studied may be related to the active ingredient of the molecules, since most of the substances act by inhibiting the synthesis of photosynthetic pigments. Thus, the applied herbicides cause injury to the leaves, reducing the reflectance of the green colouration, which directly or indirectly represents the presence of chlorophyll (Arantes et al., 2013).

Symptoms of phytotoxicity in plants of the cowpea, as well as a great variability in the tolerance of the cowpea genotypes to different herbicides, are commonly seen after herbicide application (Silva et al., 2003; Ishaya et al., 2008; Souza et al., 2016). A number of factors could be related to this, such as soil type, precipitation, irrigation management, temperature and the cultivar used (Kunkel et al., 1996; Silva et al., 2003). In this way, Silva et al. (2003) confirmed the selectivity of Fenoxaprop-p-ethyl to cowpea, which exclusively controls grasses, and Imazamox, which has an effect on dicotyledonous plants; nevertheless, these authors did not find the latter herbicide to be effective on *Chamaesyce hirta* or *Euphorbia heterophylla*.

In a study evaluating the selectivity of herbicides applied post-emergence, Freitas et al. (2009) found that the herbicide Bentazon and the mixture Imazamox + Bentazon did not cause intoxication in the cowpea, whereas Fomesafen, both alone and in a mixture with Bentazon, caused severe and moderate injury to the crop, respectively. Souza et al. (2016) also observed that a mixture of the herbicides glyphosate + imazethapyr + flumioxazin caused phytotoxicity in the cowpea crop, placing limitations on the production components. Evaluating the herbicides Fomesafen and Lactofen, both protoporphyrinogen oxidase (Protox) inhibitors, Correa and Alves (2009), found symptoms of severe intoxication in the cowpea, with later recovery of the plants at 14 DAA, and moderate symptoms of intoxication at 30 DAA. These results corroborate with the results observed here with respect to these herbicides.

In the first experiment, it was observed that 14 days after application of Flumioxazin, there were massive elimination of plants from this treatment. Silva et al. (2014), also working in a greenhouse experiment evaluating the selectivity of pre- and post-emergent herbicides, found that application of the herbicide Metribuzin resulted in death of the cowpea plants. Lactofen and Fomesafen, applied alone or mixed with other herbicides, also caused injury to the cowpea plants, which resulted in reduced production.

The use of Fluazifop-p-butyl (187.5 g a.i. ha^{-1}) as a pre-emergent herbicide resulted in higher RCC and lower phytotoxicity percentages. Similarly, Silva et al. (2014) verified that Fluazifop-p-butyl caused mild intoxication in this crop, without affecting grain production. Furthermore, Silva et al. (2003) did not note any visual symptoms characteristic of toxicity in the cowpea plants when evaluating the selectivity of the herbicides Imazamox and Fenoxaprop-p-ethyl. Apparently, those herbicides can be used for chemical management of weeds in cowpea without major issues regarding crop phytotoxicity.

S-metolachlor (1.2 kg a.i. ha^{-1}) applied as a pre-emergent herbicide in cowpea showed good results in this work. Minimal damages caused by this product through the visual evaluations were observed. Divergent results were found by Deuber and Novo (2006), reporting inhibition of root development by the action of Trifluralin that has the same mechanism of action as the herbicide S-metolachlor, both inhibitors of tubulin polymerisation in main root growth and in secondary root emission.

According to our results, the use of Fomesafen is not totally safe for weed control in areas with this crop, once this product caused moderate phytotoxity in seedlings. These results agree with those of Linhares et al. (2014), who found that Fomesafen caused severe intoxication in the crop, delaying its cycle, and leading to a delay of 7 days in flowering and harvesting. In addition, Fontes et al. (2013) observed intoxication of cowpea plants when applying Fomesafen alone or together with Fluazifop-p-butyl post-emergence.

Other literature works also corroborate with our results regarding phytoxical effects of Lactofen on cowpea seedlings. Silva et al. (2014), also working in a greenhouse experiment evaluating the selectivity of pre- and post-emergent herbicides, verified that the herbicides. Lactofen and Fomesafen, both alone and when mixed together, caused severe intoxication in the plants. According to these authors, Fomesafen delayed flowering and harvesting by 13 days in relation to the control with no application, although the cowpea plants did recover from the injuries caused by the herbicide. Nevertheless, according to Mancosi et al. (2016), Fomesafen during early establishment of the crop gives greater weed control and, despite noting phytotoxicity at the end of the trial, the treatment resulted in similar productivity to the control treatment with weed control.

Treatment with applying Bentazon (720 g a.i. ha^{-1}) showed an increase in phytotoxicity levels throughout the time. Harrison Jr. and Fery (1993), in an experiment to evaluate the tolerance of cowpea germplasm to the herbicide Bentazon, found both susceptible and highly tolerant genotypes, demonstrating the need for studies on the selectivity of herbicides for different varieties. Mancuso et al. (2016), studying selectivity and weed control, concluded that the herbicide Bentazon resulted in the lowest levels of intoxication in the cowpea. They also stated that mixture of the herbicides Bentazon + Imazamox did not affect characteristics related to the growth of the plants nor the production components.

Although, the relatively low RCC and moderate phytotoxicity in seedlings in which was applied Clethodim and Haloxyfop-p-methyl were verified, these ones recover well throughout the time. Thereafter, those treatments presented increased RCC values, as well as decreased phytotoxycity percentages by the end of the experiment. Thus, these herbicides should be noted as potential post-emergent herbicides for cowpea crop.

According to Linhares et al. (2014), environmental conditions of high temperatures and high rainfall can favour vegetative growth in the crop and result in a high leaf area index, leading to self-shading and consequently reducing the photosynthetic efficiency of the plant, which may reflect negatively on productivity. This fact may have favoured plants treated with Clethodim and Haloxyfop-p-methyl in the second research, which, with the moderate intoxication, acted as a growth regulator, reducing the rate of vegetative growth and increasing the RCC. However, under suitable environmental conditions for the crop, the intoxication caused by this herbicide is not expected to be beneficial.

Despite being a preliminary study in the evaluation of selectivity to herbicides, their potential for use in the cowpea was noted. However, in the present work a need was found to take these studies further, especially under field conditions, using different types of soils and different doses of herbicides, since selectivity can be achieved through various types of crop managements. Nonetheless, some herbicides were preliminarily identified for use with the crop in question.

Conclusion

There were promising results regarding the selectivity of the cowpea in relation to the herbicides applied in both pre-emergence and post-emergence. It is also possible to highlight the pre-emergent herbicides Diuron (1.6 kg a.i. ha^{-1}), S-metolachlor (1.2 kg a.i. ha^{-1}), Metribuzin (422.4 g a.i. ha^{-1}), Diquat dibromide (600 g a.i. ha^{-1}) and Sulfentrazone (600 g a.i. ha^{-1}). A potential use of the herbicides applied post-emergence to this crop was noted for Clethodim (96 g a.i. ha^{-1}) and Haloxyfop-p-methyl (43.75 g a.i. ha^{-1}).

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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