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Studies on effectiveness of post-emergent herbicides for cowpea (*Vigna unguiculata* L.)

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Abstract
Cowpea farming has been concentrated to the north India, 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. Therefore, now 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, using the post-emergent herbicides in a field condition at the Rani Lakshmi Bai Central Agricultural University, Jhansi, India. 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 imazethapyr should be noted as potential post-emergent herbicides.

Keywords: Chemical control, phytotoxicity, tolerance, *Vigna unguiculate* L., post emergent, weed management

Introduction
The cowpea (*Vigna unguiculata* (L.) Walp.) is among the most important species used for food in the human diet. Historically in India, cowpea production has been concentrated in the north and northeast where it is cultivated mainly by small producers, generally using a low level of technology. Poor seed yield remains a great challenge for cowpea production in India and continuous evaluation of available genetic resource to develop high and stable yielding varieties is the panacea to the food security crisis(Singh *et al*. 2022) [2]. 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) [7], and arousing the interest of large producers who practice a mechanised agriculture and who plant the cowpea during the soybean off-season (Freitas *et al*., 2009) [6]. The cowpea (*Vigna unguiculate* L.) is one of the most consumed and cultivated legumes in India, 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) [7]. The crop has become an excellent alternative as an offseason crop in the south and west, especially in the areas where soybeans and maize are cultivated. In India 50 thousand hectares area under cultivation with 4.8 lakh tonnes production and productivity is 8.44 t/ha. 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) [6]. 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) [15, 19]. Most of the information on the use of herbicides is related to the common bean (*Phaseolus vulgaris* L.) or the soybean (*Glycine maxima* (L.) Merr.) (Freitas *et al*., 2009) [6]. Taking this information into consideration, the aim of the present work was to study the selectivity of herbicides for the cowpea crop when applied post-emergent during the initial phase of crop growth.

Materials and Methods

Location of the experiments

Experiment was carried out in University seed and research farm at the RLBCAU, Jhansi, during August 2020. 100 varieties and germplasm lines were planted for the screening in Kharif 2019 and 2020. Seeds of varieties and germplasm accessions were obtained from ICAR-NBPGR, New Delhi, ICAR-IIPR Kanpur, ICAR-IIVR Varanasi, ICAR-IGFRI Jhansi and GBPUA&T, Pantnagar.

Experimental design and statistical procedures

The experimental design was completely randomized with four replications, three herbicides applied post-emergent as treatments in the experiment (Table 1). The experimental units consisted of disposable 250 ml capacity cups with substrate. The cowpea 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 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, 21 and 28 days after application. 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) [5]. The Relative Chlorophyll Content (RCC) was determined by readings taken at 7, 14 and 21 days after 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.

Table 1: Treatment (doses of herbicides in active ingredient – a.i.) applied post-emergence.

S.N.	Post-emergent herbicides
1	T_1 - Imezathyper (150.0 g a.i. ha^{-1})
2	T_2 - Quizalofop-p-ethyl (0.1 g a.i. ha^{-1})
3	T_3 - Metribuzin (500 g a.i. ha^{-1})

Results

Three herbicides applied in post-emergent of cowpea crop were evaluated. (Table 2) 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 2). 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 imazethapyr (150.0 g a.i. ha^{-1}) throughout other evaluations (Table 3). On the other hand, the treatment with Metribuzin (500 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 3). 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 Metribuzin did the most damage to the crop. When carrying out the evaluation at 21 DAA, it was found that imazethapyr (150.0 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 Imazethapyr (150.0 g a.i. ha^{-1}) and Quizalofop-p-ethyl (0.1 g a.i. ha^{-1}), whereas the herbicides that produced the least phytotoxicity were Metribuzin (500 g a.i. ha^{-1}).

Table 2: 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			
Imezathyper (150.0 g a.i. ha^{-1})	21.97a	24.16ab	23.24ab	NE
Quizalofop-p-ethyl (0.1 g a.i. ha^{-1})	21.19a	27.44a	27.19a	NE
Metribuzin (500 g a.i. ha^{-1})	19.25a	15.96bc	16.12bcd	NE
	Phytotoxicity (%)			
Imezathyper (150.0 g a.i. ha^{-1})	16.9 (5.56)a	16.9 (4.52)b	40.5 (6.22)a	55.9 (7.15)a
Quizalofop-p-ethyl (0.1 g a.i. ha^{-1})	16.2 (4.62)a	14.5 (3.03)b	22.3 (5.21)bc	29.5(4.56)bc
Metribuzin (500 g a.i. ha^{-1})	14.7 (3.29)a	17.6 (3.19)b	20.9 (4.46)bc	5.33(30.2)bc

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 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 post-emergent herbicides.

		7 DAA	14 DAA	21 DAA	28DAA
SOV	**d.f**	**Relative chlorophyll content**			
Herbicides	2	21.624ns	5.546**	49.244**	NE
Residual	12	14.171	7.345	8.255	NE
CV (%)	-	11.87	7.17	8.98	NE
		Phytotoxicity			
Herbicides	2	0.1725ns	0.9962**	1.1509**	2.3497**
Residual	12	0.4223	0.2635	0.1482	0.2028
CV (%)	-	6.76	6.81	4.69	5.24

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

Discussion

Some studies has been done to evaluate the use of herbicides in the cowpea, where the following herbicides were noteworthy for selectivity: Severe intoxication with a reduction in productivity was found in the cowpea with applying the herbicides while the mixtures of Metribuzin caused death of the crop (Mesquita, 2011) [14]. 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) [1]. 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) [15, 19]. 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) [15]. In this way, Silva *et al*. (2003) [15] confirmed the selectivity of imazethapyr to cowpea, which exclusively controls grasses, 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*. Evaluating the herbicides imazethapyr and Quizalofop-p-ethyl, both protoporphyrinogen oxidase (Protox) inhibitors, Correa and Alves (2009) [9], 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 imazethapyr, there were massive elimination of plants from this treatment. Silva *et al*. (2014) [17], 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. The use of Quizalofop-p-ethyl (0.1 g a.i. ha^{-1}) as a post-emergent herbicide resulted in higher RCC and lower phytotoxicity percentages. Similarly, Silva *et al*. (2014) [17] verified that Quizalofop-p-ethyl caused mild intoxication in this crop, without affecting grain production. Furthermore, Silva *et al*. (2003) [15] did not note any visual symptoms characteristic of toxicity in the cowpea plants when evaluating the selectivity of the herbicides imazethapyr and Quizalofop-p-ethyl. Apparently, those herbicides can be used for chemical management of weeds in cowpea without major issues regarding crop phytotoxicity. Other literature works also corroborate with our results regarding phytoxical effects of Lactofen on cowpea seedlings. Silva *et al*. (2014) [17], also working in a greenhouse experiment evaluating the selectivity of pre and post-emergent herbicides, verified that the herbicides. According to Linhares *et al*. (2014) [12], 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 Metribuzin (500 g a.i. ha^{-1}) 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 post-emergent. A potential use of the herbicides applied post emergence to this crop was noted for imazethapyr (150.0 g a.i. ha^{-1}).Total 11 accessions and varieties were found highly tolerant towards post emergence herbicide, Imazethapyr (with herbicide tolerance score of 1-2) out of which accessions EC390219, EC390226, EC390266, EC390269, GC 6 and GC 5 showed herbicide score of 1. *Mullago* was found to be the major weed followed by *Commelina*. Imazethapyr effectively controlled the weed population from average 4 to 9 weeds per m^2 taken at 10 different locations in the treatment.

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