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Weed interference periods in cowpea crop

Períodos de interferência de plantas daninhas na cultura do feijão-caupi

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ABSTRACT - Cowpea is one of the pulse crops that present the highest potential for growing in the Semiarid region of Brazil. Low-cost vegetable protein source, it has resilience to adverse conditions, however, in competition with weeds, its productivity can be strongly compromised. To overcoming this situation, it is essential for integrated management programs to determine the critical period for preventing interference. Thus, the objective of this work was to determine weed interference periods and the effect of coexistence periods on cowpea grain yield in the Semiarid region of the state of Minas Gerais, Brazil. The treatments were arranged in a 2×9 factorial scheme, as follows: cultivation in coexistence with weeds and cultivation under weed control, for nine crescent periods (0-7, 0-14, 0-21, 0-28, 0-35, 0-42, 0-49, 0-56 and 0-63 days after crop emergence), in a randomized experimental block design with four replications. The weed community was studied through phytosociological survey and evaluation of dry matter production and cowpea was evaluated for dry matter production, 100-grain mass and grain yield. The interference periods were determined using a non-linear logistic regression model. The weed community found was composed of 70% dicotyledonous and 30% monocotyledon plants, distributed in seven families and ten species. The coexistence with weeds results in losses of up to 90% in cowpea grain yield. The critical period of weed control in cowpea crop in the Semiarid region of the state of Minas Gerais, Brazil, is 11 to 36 days after crop emergence.

Keywords: *Vigna unguiculata* (L.) Walp. Critical period. Weed management.

RESUMO - O feijão-caupi é uma das culturas de pulses com maior potencial de cultivo no semiárido brasileiro. Fonte de proteína vegetal de baixo custo, apresenta resiliência a condições adversas, entretanto, em competição com plantas daninhas, pode ter sua produtividade fortemente comprometida. Para superar essa situação, é indispensável aos programas de manejo integrado determinar o período crítico de prevenção à interferência. Assim, objetivou-se com este trabalho determinar os períodos de interferência de plantas daninhas e o efeito dos períodos de convivência sobre a produtividade do feijão-caupi no semiárido mineiro. Os tratamentos foram arranjados em esquema fatorial 2×9, da seguinte forma: cultivo em convivência com plantas daninhas e cultivo sob controle de plantas daninhas, por nove períodos crescentes (0-7, 0-14, 0-21, 0-28, 0-35, 0-42, 0-49, 0-56 e 0-63 dias após a emergência da cultura), em delineamento experimental de blocos casualizados com quatro repetições. A comunidade infestante foi estudada por meio de levantamento fitossociológico e avaliação da produção de matéria seca e o feijão-caupi foi avaliado quanto à produção de matéria seca, massa de 100 grãos e rendimento de grãos. Os períodos de interferência foram determinados adotando um modelo de equação não linear logístico. A comunidade infestante foi composta por 70% de plantas eudicotiledôneas e 30% de monocotiledôneas, distribuídas em sete famílias e dez espécies. A convivência com plantas daninhas resulta em até 90% de perdas na produtividade do feijão-caupi. O período crítico de controle de plantas daninhas no feijão-caupi no semiárido mineiro é de 11 a 36 dias após a emergência da cultura.

Palavras-chave: *Vigna unguiculata* (L.) Walp. Período crítico. Manejo de Plantas daninhas.

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INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) is a globally widespread leguminous species and one of the most important pulse crops, mainly in developing countries. It stands out in these countries as a low-cost protein-rich alternative food, and as a resilient crop under adverse climate conditions, such as those in the Semiarid region of Brazil (SILVA et al., 2018; LONARDI et al., 2019; MELO et al., 2022).

In Brazil, cowpea is predominantly grown under rainfed conditions by family farmers in the North and Northeast regions (SOUZA et al., 2020). However, its cultivation is expanding to the Central-West and Southeast regions of Brazil as an option for winter crops after summer soybean, maize, and rice crops, reaching yields higher than 1,000 kg ha^{-1} (ALMEIDA et al., 2017; FREIRE FILHO et al., 2017). This expansion can be attributed mainly to the development of modern cultivars, with compact and erect traits that favor mechanization.

According to the Brazilian National Food Supply Company, it is estimated that in the 2020/2021 harvest the country had a production of 623,800 Mg of cowpea, grown in an area of approximate 1,349,600 ha^{-1}, with a mean yield lower than 500 kg ha^{-1} (CONAB, 2022). This low mean yield can be explained by, among other factors, the presence of weeds, which compete with the crop for water, light, and nutrients, are hosts of pests and diseases, and produce allelopathic substances that compromise the expected productions (LACERDA et al., 2020). These dynamics include direct and indirect factors that characterize the weed interference (SHIRGAPURE; GHOSH, 2020).

The weed interference level depends on factors related to characteristics of the weed community (specific composition, density, and distribution); the crop (cultivar, spacing, and planting density), the time the competition is established between them; and the duration of coexistence (CASTRO et al., 2019; FREITAS et al., 2021). In addition, it can be affected by agronomic and environmental variables, as soil, climate, and management conditions, generating negative effects on the crop yield (SCAVO; MAUROMICALE, 2020).

From this knowledge, it becomes possible to determine the interference periods, which, according to Pitelli and Durigan (1984) are called: Period Previous to Interference; Total Period of Interference Prevention; and Critical Period of Interference Prevention. When these parameters are correctly determined, they provide guidelines for decision making regarding the time the weed control should be effectively carried out.

Therefore, there is a specific threshold for prevention of weed interference to optimize crop yields. In this sense, the objective of this work was to determine weed interference periods and the effect of coexistence periods on cowpea grain yield in the Semiarid region of the state of Minas Gerais, Brazil, focused on technification and expansion of cowpea crop in semiarid regions.

MATERIAL AND METHODS

Characterization of the experiment

The experiment was conducted at the Experimental Farm of the State University of Montes Claros, in Janaúba, Minas Gerais, Brazil (15°48'13"S, 43°19'3"W, and altitude of 510 m). The climate of the region is Aw, tropical, with rainy summer and dry winter, according to the Köppen-Geiger classification (PEEL; FINLAYSON; MCMAHON, 2007).

The soil of area experimental was classified as *Latossolo Vermelho eutrófico* (Oxisol) (SANTOS et al., 2018); the chemical analysis of the soil 0-20 cm layer showed: pH in water of 5.2; 30.7 mg dm^{-3} of P; 43.3 mg dm^{-3} of P-rem; 189 mg dm^{-3} of K; 2.3 $cmol_c$ dm^{-3} of Ca^{2+}; 0.9 $cmol_c$ dm^{-3} of Mg^{2+}; 0 $cmol_c$ dm^{-3} of Al^{3+}; 1.8 $cmol_c$ dm^{-3} of H+Al; sum of bases of 3.8 $cmol_c$ dm^{-3}; 3.8 $cmol_c$ dm^{-3} of effective cation exchange capacity (CEC); 5.6 $cmol_c$ dm^{-3} of CEC; aluminum saturation of 0%; base saturation of 68%; and 1.7 dag kg^{-1} of organic matter.

Experimental design and treatments

A randomized block experimental design was used, with four replications. The treatments were arranged in a 2×9 factorial scheme, as follows: cultivation in coexistence with weeds and cultivation under weed control, for nine crescent periods (0-7, 0-14, 0-21, 0-28, 0 - 35, 0 -42, 0-49, 0-56 and 0-63 days after emergence of the crop - DAE).

In the coexistence treatments, the crop was maintained with the presence of weeds for the periods described, from which they were controlled by manual weeding. In the weed control treatments, the crop was kept free of weeds by hand weeding for the same periods and the weeds that appeared after these intervals were no longer controlled until the cowpea harvest, at 63 DAE.

Treatments in which the crop remained with presence of weeds in crescent periods were used to determine the possible extension of the initial coexistence period, or the Period Previous to Interference. The treatments in which the crop remained with absence of weeds in crescent periods were used to determine the possible final coexistence period, or the Total Period of Interference Prevention. The limits between them were used to determine the period that the control should be carried out, or the Critical Period of Interference Prevention.

Implementation and conduction of the experiment

Cowpea seeds were planted in the summer-autumn crop season (February 2017), considering a population density of 300,000 plants ha^{-1}. The soil was prepared under conventional system with one plowing and two harrowing. A seeder-fertilizer machine was used for planting the seeds and distribute soil fertilizer in the rows. Fertilization was performed according to the soil analysis and the crop demand (MELO; CARDOSO; SALVIANO, 2005), with 250 kg ha^{-1} of the NPK 04-30-10 formulation being applied at planting and 40 kg ha^{-1} of N in topdressing, at the crop V4 stage, using urea as source of nitrogen.

The experimental plots consisted of six 4-meter rows spaced 0.5 m apart, resulting in a total area of 12 m^2; the evaluation area consisted of the two central rows, totaling 4 m^2.

The cowpea cultivar used (BRS Itaim) has determined growth habit, erect growth, and high resistance to lodging. It presents typical, well-formed grains, with excellent visual characteristics, cycle of 60 to 65 days, and is recommended mainly for rainfed crops (EMBRAPA, 2009).

A conventional sprinkler irrigation system was used, according to the crop water demand, until the physiological maturity of the crop.

Characteristics evaluated

A phytosociological surveying of the weed community was carried out at the end of each coexistence period or weed control and the dry matter production of weeds and cowpea plants were evaluated.

The weed samples were obtained following the standard inventory frame method proposed by Braun-Blanquet (1979), by randomly launching a 0.5 × 0.5 m

(0.25 m²) frame to the evaluation area of each plot. Initially, the identification, classification and quantification of the weed species were carried out.

The determination of the number of plants of each species in each plot and total number of plants in each collection was used to calculate the following phytosociological variables: a) weed density per m², i.e., quantification of plants of each species per unit of area; b) occurrence index, i.e., individual percentage in relation to the total during the whole cycle.

After the identification procedures, weeds collected at the end of each coexistence or weed control period were placed in paper bags and dried in a forced air-circulation oven at 70 °C until constant mass, to determine the dry matter production. Four cowpea plants were collected at the end of each coexistence or weed control period and subjected to the same process to determine the cowpea dry matter production.

After harvesting, the cowpea 100-grain mass and grain yield were determined.

The 100-grain mass was obtained considering the mean of weight of three sub-samples of 100 grains randomly collected from grains harvested of each plot, and the results were expressed in grams.

The cowpea grain yield was estimated by weighing the grains harvested in the evaluation area of each plot, correcting the values to 13% moisture, and transforming it to kg ha^{-1}.

Statistical analyses

Data from the phytosociological survey and dry matter production were compared and presented using descriptive statistics.

The 100-grain mass and grain yield data were submitted to analysis of variance, when significant, the effect of coexistence or weed control was studied by the F test at 5% significance ($p < 0.05$).

Coexistence and weed control periods were analyzed through regression analysis, using a non-linear logistic model to describe the biological dynamics of the interference periods: $y = y0 + a/(1 + (x/x0)^b$, in which y = cowpea grain yield as a function of coexistence or control periods; $y0$ = minimum yield during the coexistence or control period; a = difference between the maximum and minimum yields; x = days after emergence; $x0$ = number of days for the occurrence of 50% decrease in maximum yield; and b = curve slope. The limits of the interference periods were determined tolerating losses of up to 5% in relation to maximum grain yield obtained in the equations.

RESULTS AND DISCUSSION

More than 1,300 weed specimens, distributed in seven families and ten species, were found during the crop cycle. The weed community was composed of 70% dicotyledon and 30% monocotyledon species (Table 1). Considering dicotyledon species, the family Fabaceae stood out by presenting two species. Considering monocotyledon species, the family Poaceae stood out by presenting three species. The other families presented only one species each (Table 1).

Table 1. Family, scientific name, common name in Brazil, class, photosynthetic metabolism, and occurrence index of weed species in cowpea crop (cultivar BRS Itaim) in the Semiarid region of the state of Minas Gerais, Brazil.

Family	Species				Occurrence index (%)
	Scientific name	Common name	Class	Metabolism	
Amaranthaceae	*Amaranthus viridis*	Caruru	Magnoliopsida	C4	6.2
Asteraceae	*Acanthospermum hispidum*	Carrapicho-de-carneiro	Magnoliopsida	C3	4.3
Convolvulaceae	*Ipomoea grandifolia*	Corda-de-viola	Magnoliopsida	C3	5.0
Fabaceae	*Senna obtusifolia*	Mata-pasto	Magnoliopsida	C3	10.4
	Neonotonia wightii	Soja-Perene	Magnoliopsida	C3	8.3
Malvaceae	*Sida* sp.	Guanxuma	Magnoliopsida	C3	2.4
Poaceae	*Cenchrus echinatus*	Capim-carrapicho	Liliopsida	C4	3.6
	Dactyloctenium aegyptium	Capim-mão-de sapo	Liliopsida	C4	1.7
	Sorghum bicolor	Sorgo	Liliopsida	C4	13.4
Portulacaceae	*Portulaca oleracea*	Beldroega	Magnoliopsida	C4	44.7

These results assist in understanding the level of importance of weed populations present in cowpea crop and can be used to subsidize the development of integrated weed management programs (CONCENÇO et al., 2017). According to Lacerda et al. (2021), the higher occurrence of dicotyledon weed species found may be connected to their class, which is the same of cowpea, presenting similarities that make them more difficult to control. In addition, species that have C4 photosynthetic metabolism, as those from the families Poaceae, Portulacaceae, and Amaranthaceae (Table 1), may have some competitive advantages when they occur in crops with C3 photosynthetic metabolism plants (SANTOS et al., 2017), such as cowpea. This information raises the attention for the choice of effective control measures for these species in integrated weed management programs.

Variations in weed populations within crops may occur due to edaphoclimatic differences, previous crops, and weed seed banks of each region (BATISTA et al., 2017; LACERDA et al., 2020). It reinforces the importance of information on weed community and its distribution throughout the crop cycle, for the adoption of efficient integrated weed management programs, according to specificities of each environment, reducing production costs and yield losses.

The highest weed density was found at 21 DAE, with more than 640 plants m^{-2}, denoting a high degree of competition. Subsequently, it decreased up to 35 DAE and there was an increase in the shoot dry matter production of weeds up to 63 DAE (Figures 1 and 2).

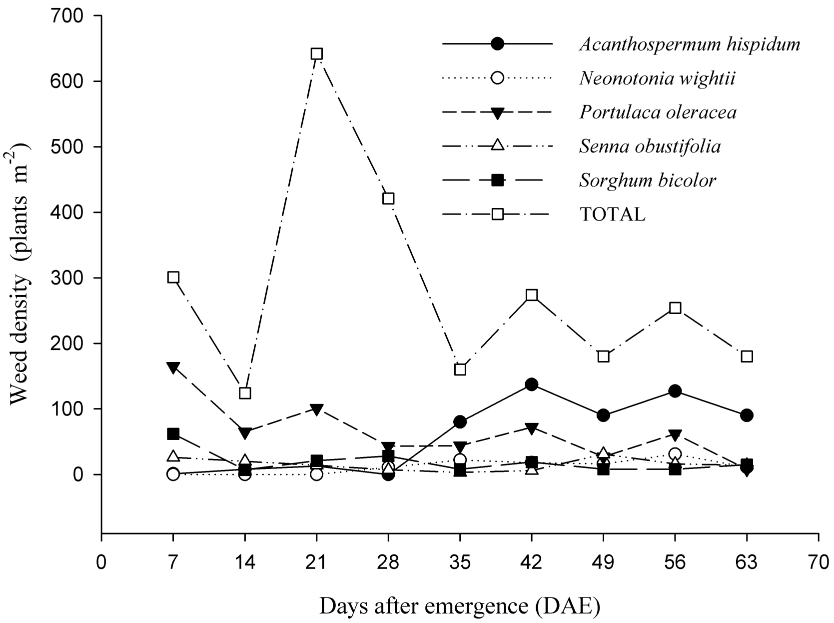

Figure 1. Density of the main weed species found in different interference periods in cowpea crop (cultivar BRS Itaim) in the Semiarid region of the state of Minas Gerais, Brazil.

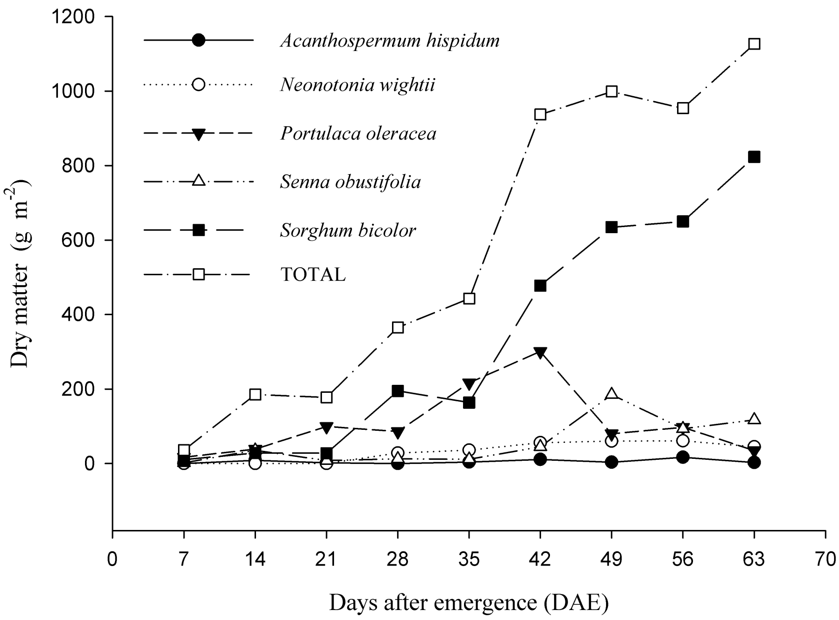

Figure 2. Dry matter accumulation of the main weed species found in different interference periods in cowpea crop (cultivar BRS Itaim) in the Semiarid region of the state of Minas Gerais, Brazil.

The decreases in number of weeds and the higher shoot dry matter accumulation of weeds at the end of the cowpea cycle can be attributed to the occupation of space by the dominant weed species, suppressing the less competitive ones. Intra and interspecific competitions increase as the plants grow, decreasing the availability of resources, remaining only plants with higher initial growth rates and dominant, taller, and well-developed plants, in detriment of smaller and less developed plants (REGINALDO et al., 2021).

The species *Portulaca oleracea* presented the highest occurrence index in the surveying (Table 1), standing out for the number of individuals in the area. Therefore, it also presented higher density than the others in initial interference periods and, consequently, significant dry matter production, which denoted their high importance in the area (Figures 1 and 2). Focusing on weed interference at initial development stages is of paramount importance, as weeds can be more competitive than the crop in this period.

P. oleracea is a common plant in the Semiarid region of Brazil (LINS et al., 2019) and has been shown in phytosociological surveys of weeds in the North region of the state of Minas Gerais as one of the species that present the highest importance index in cowpea cultivars (BATISTA et al., 2017). It denotes the special attention required with this species for the adoption of efficient measures to control weeds, avoiding their interference in grain yield of cowpea crop.

In addition to reproducing by seeds, *P. oleracea* propagates vegetatively from propagules of stem cuts in contact with the soil, which makes mechanical control inefficient (PROCTOR; GAUSSOIN; REICHER, 2011; KHAKZAD et al., 2019). It denotes the importance of studies and approvals of selective herbicides for cowpea crop, focused on optimizing weed control efficiency and reduce costs with labor and time required for these operations. Since, the labor costs for manual weeding and time spent in the operations are relatively high compared to the use of herbicides, in addition, manual weeding is not efficient for some crops that reproduce vegetatively (OSIPITAN; YAHAYA; ADIGUN, 2018). However, developing an integrated weed management program for cowpea crop is needed, which should be efficient, economically viable, and environmentally secure (OSIPITAN, 2017).

The species *Acanthospermum hispidum* presented higher density than the others from 35 DAE onwards (Figure 1), which was worry due to the proximity to the harvest period (63 DAE). This species, in addition to competing directly with the crop, can make harvesting operations difficult, as it has sharp thorns in the diaspores, posing a risk to workers, especially when they manually harvest cowpea pods.

Cowpea dry matter accumulation was higher in treatments with weed control from 21 DAE onwards. The highest dry matter accumulation was found at 56 DAE (181.89 g), decreasing at 63 DAE (148.98 g), when the plants were already at senescence, signaling the end of the crop cycle (Figure 3).

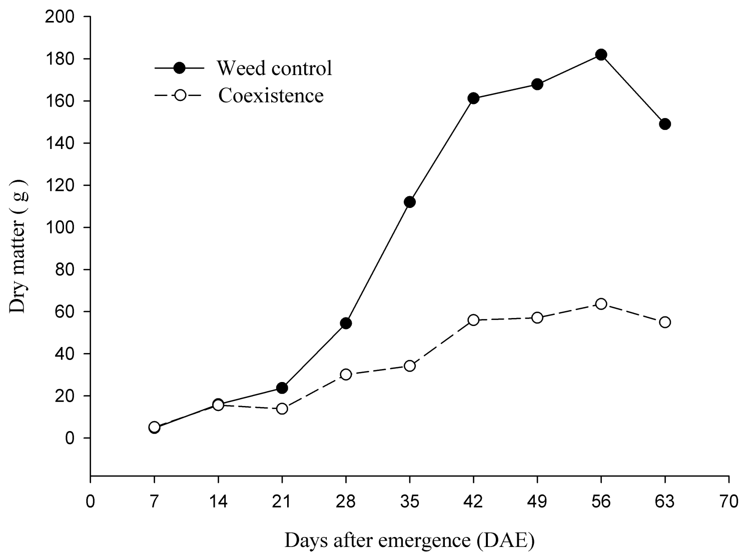

Figure 3. Dry matter accumulation of plants of cowpea crop (cultivar BRS Itaim) in weed control (without weeds) and coexistence (with weeds) periods in the Semiarid region of the state of Minas Gerais, Brazil.

The dry matter accumulation in cowpea plants was lower when grown under coexistence with the weed community (Figure 3). It can be explained by the competition exerted by weeds on cowpea plants for environmental resources. Cowpea plants presented lower development, with occurrence of etiolation, lower branching, and consequently, smaller leaf area, which resulted in a lower dry matter production.

The effect of the interaction between the factors was not significant for 100-grain mass. When analyzing the isolated effects, it was verified that the 100-grain mass of cowpea was higher when subjected to weed control, to the detriment of those in coexistence with weeds (Table 2).

Table 2. 100-grain mass of cowpea crop (cultivar BRS Itaim) as a function of weed control (without weeds) and coexistence (with weeds) periods in the Semiarid region of the state of Minas Gerais, Brazil.

Treatments	Periods (Days after emergence)								Mean
	0-7	0-14	0-21	0-35	0-42	0-49	0-53	0-63	
	g								
Weed control	25.37	23.44	22.78	22.48	23.83	22.74	22.79	23.15	23.48 A
Coexistence	21.40	22.09	22.62	20.61	22.71	23.24	21.68	22.60	22.28 B

Means followed by the same letter are not different from each other by the F test at 5% significance (p<0.05).

The lower grain mass found for plants under coexistence with weeds can be attributed to interspecific competition for environmental resources, limiting the accumulation of reserves in grains (MORSY et al., 2020).

The grain yield of cowpea crop grown under weed control (without weeds) and coexistence (with weeds) periods was used to determine the Period Previous to Interference and the Total Period of Interference Prevention, considering possible yield losses. Acceptable losses in cowpea grain yield due to weed interference vary according to control costs, yield gains due to the control, and market value. More thoroughly studies may enable to establish a damage level of the economic yield for the start of weed control.
Considering an acceptable loss level of 5% in relation to the maximum yield, the interference is tolerable up to 11 DAE (Period Previous to Interference). In this period, the competition is not still well established and the crop can coexist with weeds. After this period, the competition starts to negatively affect the crop and the control of weed interference should be carried out up to 36 DAE (Total Period of Interference Prevention) (Figure 4).

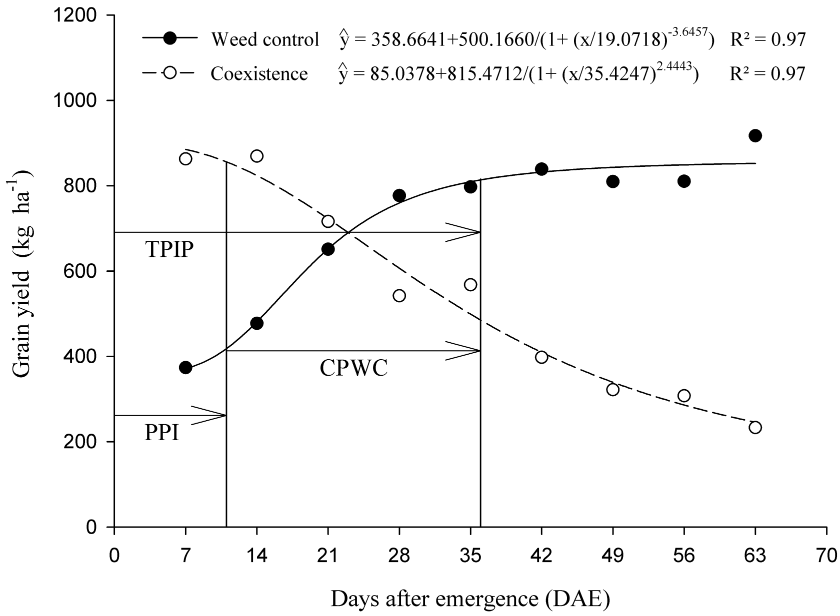

Figure 4. Grain yield (kg ha^{-1}) of cowpea crop (cultivar BRS Itaim) as a function of weed control (without weeds) and coexistence (with weeds) periods in the Semiarid region of the state of Minas Gerais, Brazil.

In this interval (11-36 DAE), it is essential to carry out weed control, being understood as the Critical Period of Interference Prevention or Critical Period of Weed Control (Figure 4). The Critical Period of Weed Control is agronomically used to define the interval for weeding or residual action of herbicides for suppressing the weed community, stopping the interference and decreasing significant losses in crop yield (GALON et al., 2019; KNEZEVIC et al., 2019; LINS et al., 2019; BEIERMANN et al., 2022). Thus, knowing this information is essential for establishing integrated weed management programs for crops and optimizing production costs.

Theoretically, after the Total Period of Interference Prevention, weeds that emerge will not result in significant interference. Since, adequate weed control in the Critical Period of Interference Prevention allows for cowpea growth and canopy closure, resulting in a greater competitiveness, mainly in relation to late-emergence weeds (OSIPITAN et al., 2021).

The comparison between the maximum estimated yield of plants under weed control (815.89 kg ha^{-1}) and the minimum in coexistence periods (85.04 kg ha^{-1}), allowed to verify a decrease of 90% in cowpea grain yield when the control was not performed. It denotes the importance of an effective weed control and studies involving interference periods for maximizing crop yields and minimize losses caused by competition. In the conditions of the present study, the maximum yield of the crop under weed control exceeds the Brazilian national mean (462 kg ha^{-1}) and the Minas Gerais state mean (549 kg ha^{-1}) in the 2020/2021 crop season (CONAB, 2022). This demonstrates that special attention should be paid to weed control in cowpea crops to obtain satisfactory yields and reach higher production levels.

Similarly, Freitas et al. (2009) found a Critical Period of Weed Control of 11-35 DAE, in addition to a decrease in final plant stand, number of pods per plant and up to 90% losses in grain yield of cowpea crop grown without weed control. These results, combined with the understanding of the weed community dynamics, can optimize management practices (LACERDA et al., 2020). Therefore, the application of this information can increase productive indexes of cowpea crop grown under the edaphoclimatic conditions of the Semiarid region of Brazil.

However, the Critical Period of Weed Control may vary from one region to another due to edaphoclimatic conditions, composition of the weed community, weed infestation level and history of the area. In addition, the use of cultivars with higher competitive capacity can reduce the Critical Period of Interference Prevention in the crop. Therefore, improving the decision making related to the time of weed control and adopting cultivars with high weed suppression capacity can be an alternative for increasing the prevention and reduce the use and costs with other weed control methods (CASTRO et al., 2019; LINS et al., 2019; MEDEIROS et al., 2021; WERLE et al., 2022).

The information generated through this study are important for directing the planning and decision making of integrated weed management programs for cowpea crop grown in the Semiarid region of Brazil. The results found establish the period of 11 to 36 DAE for an effective weed control in cowpea crop, minimizing the negative impacts of weed interference on cowpea grain yield.

CONCLUSIONS

The coexistence with weeds results in up to 90% losses in cowpea grain yield in the Semiarid region of the state of Minas Gerais, Brazil.

The critical period of weed control in cowpea crop in the Semiarid region of the state of Minas Gerais, Brazil, is 11 to 36 days after crop emergence.

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