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Weed Dynamics and Yield of Cowpea Inoculated in Mulching (Crushed Capoeira)

Tácila Rayene dos Santos Marinho

Programa de Pós-Graduação da Universidade Estadual do Maranhão

São Luís, Maranhão, Brazil

Régilla Martins Feitosa dos Reis

Programa de Pós-Graduação da Universidade Estadual do Maranhão

São Luís, Maranhão, Brazil

Luiz Júnior Pereira Marques

Instituto Federal do Maranhão, São Luis, Maranhão, Brazil

Maria José Pinheiro Corrêa

Universidade Estadual do Maranhão, São Luis, Maranhão, Brazil

Denise Lima Cavalcante Marinho (Corresponding author)

Universidade Estadual da Região Tocantina do Maranhão

Imperatriz, Maranhão, Brazil. E-mail: deniselcaval@gmail.com

Antonio Carlos Reis de Freitas

Empresa Brasileira de Pesquisa Agropecuaria

São Luís, Maranhão, Brazil

Maria Rosângela Malheiros Silva

Universidade Estadual do Maranhão, São Luis, Maranhão, Brazil

E-mail: romalheir@gmail.com

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Abstract

Mulching (crushing capoeira) is an alternative system for the use of fire for cultivation in the Northern region of Brazil. Cowpea is considered an important food crop in this region; however, weeds might limit its productivity. This study aimed to evaluate the population dynamics of weeds and the productivity of cowpea with different habit of growth inoculated with *Bradyrhizobium* sp in mulching. The experiment was carried out in randomized blocks with the cultivars BRS Guariba and BR 17 Gurgueia, with and without inoculation of *Bradyrhizobium* sp and nitrogen fertilization as a control. Twenty-seven species and three genera of weeds were identified, distributed into 12 botanical families in the BRS Guariba cultivar and 25 species in ten families in BR 17 Gurgueia cultivar. The results revealed that the significative species were *Vismia guianensis* (Aubl.) Pers, *Cyperus* sp, *Scleria melaleuca* Rchb. ex Schltdl. & Cham, and *Spermacoce verticillata* L. Inoculation with *Bradyrhizobium* sp reduced the infestation of the most important species and presented higher productivity (1965.09 kg ha^{-1}) than the treatment without inoculation (987.14 kg ha^{-1}). The growth habit of cowpea cultivars in mulching (crushing capoeira) system did not affect crop yield, but longer studies are needed to validate the information obtained.

Keywords: *Bradyrhizobium* sp, weed community, mulching, phytosociology, *Vigna unguiculata* L. Walp.

1. Introduction

Cowpea (*Vigna unguiculata* L. Walp.), also known as Macassar bean or string bean, is considered a staple food item for the population of the North and Northeastern regions of Brazil, especially for the population in the poorest rural areas (Calvet et al., 2013).

In the Northern region of Brazil, family farmers generally cultivate cowpea in a “slash and burn” system that does not negatively affect crop productivity in the first year of cultivation. However, the implementation of this practice in consecutive years leads to the abandonment of the area (Marques et al., 2010). As an alternative for this practice, Embrapa Amazônia Oriental introduced direct planting in mulching (crushing capoeira), which consists of cutting and crushing the aerial part of the fallow vegetation.

Weeds are among the biological factors limiting cowpea yield and can reduce from 46% (Correa et al., 2015) to 73.5% (Lacerda et al., 2020) in grain yield when not properly managed. In crushed capoeira, these species show high diversity and rapid changes in the composition of the weed community in the cowpea crop (Marques et al., 2010).

The rapid changes in the population dynamics of weeds in the cowpea crop in mulching justify the importance of the update of phytosociological surveys, the inclusion of inoculation of symbiotic diazotrophic bacteria such as *Bradyrhizobium* and prostrate cultivar are preferred

by many family farmers because they provide more than one harvest (Batista et al., 2017).

The bacteria inoculation in the cowpea crop has increased the grain yield and changed the floristic composition of the weed community when cultivated in cover crops straws (Pereira et al., 2020). Meanwhile, the growth habit of the crop can alter the interaction with weeds, as erect plants may produce less shadowed environments than prostrate plants (Batista et al., 2017) increasing the richness of weed species in cowpea crop as observed by Corrêa et al. (2015), Lima et al. (2016) and Bandeira et al. (2018) in a conventional cultivation system. In crushed capoeira, Marques et al. (2010) also observed high weed diversity in a semi-erect growth cowpea cultivar.

Concerning no-tillage in crushed capoeira, there is still little information about the dynamics of weeds in the cowpea crop when inoculated with symbiotic diazotrophic bacteria and prostrate cultivar. The variability of factors that affect weed dynamics makes the phytosociological survey a relevant tool in the analysis of the impact that management systems and agricultural practices have on the dynamics of weed growth and occupation in the agroecosystem (Concenço et al., 2013; Ferreira et al., 2014).

In conventional cultivation of cowpea, Corrêa et al. (2015) in northern Maranhão verified *Alternanthera tenella*, *Cyperus rotundus*, *Digitaria ciliaris*, *Eleusine indica* and *Mollugo verticillata* with the highest densities in the infesting community. Batista et al. (2017) in northern Minas Gerais observed *Portulaca oleraceae* followed by *Amaranthus viridis* and *Amaranthus deflexus*. Bandeira et al. (2018) in southwestern Bahia observed *Digitaria horizontalis*, *Panicum maximum* and *Portulaca mucronata* as the most relevant. However, in crushed capoeira Marques et al. (2010) evidenced *Cyperus diffusus*, *Fimbristylis dichotoma*, *Spermacoce verticillata*, *Cyperus* sp., *Digitaria horizontalis* and *Pavonia cancellata* as the most important of the infesting community. Results that show the edaphoclimatic conditions of each region, as well as the cultivation systems influence the dynamics of the weed community and that phyto-sociological surveys for each site are necessary to adapt to the management of these species.

Further studies about the introduction of inoculants in cowpea crops and prostrate cultivar in a mulching system may allow evaluating strategies to enhance the performance of the culture. Based on that, the objective of the present investigation was to evaluate the effects of inoculation of symbiotic diazotrophic bacteria such as *Bradyrhizobium* in cowpea cultivars with different growth habits systems on weeds and crop yield in mulching (crushing capoeira).

2. Method

2.1 Study Site

The study was conducted in the period of May to July of 2017 in an area of family farmers in Cristina Alves Settlement Project, located in the municipality of Itapecuru Mirim – MA, which belongs to the Mesoregion Norte Maranhense, Latitude: 3º 23'34" S and Longitude: 44º 21' 32" W. The soil in the experimental area was classified as a typical Dystrophic Yellow Latosol, with a sandy clay loam texture and slightly wavy relief.

The climate of the region, according to Köppen's classification, is Aw type (tropical warm and wet) with a rainy-summer and a dry-winter characteristics. Climatological data during the crop cycle were obtained from the Brazilian National Institute of Meteorology and Statistics (INMET), as shown in Figure 1.

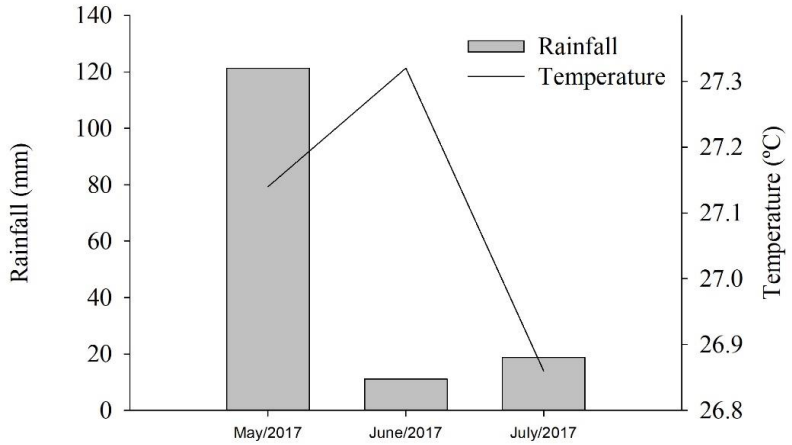

Figure 1. Average temperature and rainfall during the cowpea crop cycle in the municipality of Itapecuru Mirim – MA, 2017

2.2 Cultural Practices

The experimental area, unmanaged for approximately eight years, was prepared by crushing the mulching (capoeira) with the Ecotritus – Himev forest crusher to plant corn intercropped with sun hemp (*Crotalaria juncea*). After corn harvesting, manual hoeing was carried out followed by demarcation and opening of holes for sowing cowpea.

The sown cowpea cultivars were BRS Guariba and BR 17 Gurgueia. The first cultivar is characterized by semi-erect growth, the average cycle of 65 - 70 days, an average of 12 seeds per pod, the average weight of 100 seeds of 19.5 g, indeterminate growth, relatively short branches, and resistance to lodging. The second cultivar, BR 17 Gurgueia is characterized by its indeterminate growth habit, semi-prostrate, the average cycle of 75 days (for rainfed cultivation), an average of 15 seeds per pod, and the average weight of 100 seeds of 12.5 g.

About microbiological treatments, the *Bradyrhizobium* strains BR 3262 were used in the proportions of 10 g of inoculant in 100 ml of sugar solution (1%) for 1 kg of seed, kept under constant temperature.

2.3 Experimental Design and Application of Treatments

The experimental design adopted was in randomized blocks with four replications. The treatments were arranged in a 2 x 2 + 2T factorial scheme: cowpea cultivars (BRS Guariba and BR 17 Gurgueia), microbiological treatments (with and without bacterial inoculation of the genus *Rhizobium*), and additional controls of the two cultivars with nitrogen fertilization.

The plots consisted of six lines of 10.0 m spaced 0.5 m between rows and 0.25 m between

plants. The useful area for weed evaluation was composed of four central and harvest rows and two central rows without 0.50 m from the ends.

2.4 Dados Collection

For the weed's survey, samples collections were carried out every ten days after emergence (DAE) of the crop, that is, at 10, 20, 30, 40, 50, and 60 DAE, by the random release of a 0, 25 m^2 four times in the useful area of each plot. The aerial parts of the plants were collected, identified, and placed in a greenhouse with forced air ventilation at 65-70 °C to obtain dry matter.

Weed density and dry matter data were extrapolated to the number of plants (m^{-2}) and grams (m^{-2}), respectively. These data were used to determine the phytosociological parameters, relative density, absolute and relative frequency, relative dominance, and the importance value index (Pitelli, 2000).

Nodulation assessment was carried out at 40 DAE in four plants in the useful area of the plots per treatment. The plants were carefully removed from the ground, cut at the base of the stem, separating the aerial part from the roots, and the nodules detached and counted. The harvest was manual at 70 DAE, followed by estimations of the number of pods $plant^{-1}$ (obtained by counting all pods of eight sample plants per plot); the number of grains per pod^{-1} (average of 20 pods per plot), and average mass per grain unit (average of 100 grains).

The moisture content of 100 dry seeds at 13% was corrected and yield was obtained in kg ha^{-1} by the equation: $R = {}^{P.Vp.Gv.M}/_{1000}$, where P = population (plant ha^{-1}); Vp = average number of plant $pods^{-1}$; Gv = mean number of pod $grains^{-1}$; and M= average mass per unit of grain.

2.5 Data Analysis

Crop data were submitted to analysis of variance using the Agroestat 1.1 software (Barbosa & Maldonado Junior, 2015) for each variable, and the means, when significant, were compared by the Tukey test at 5% probability.

3. Results and Discussion

In the survey of the weed community, 27 species and three genera, distributed in 12 botanical families were identified into the experimental area. In BRS Guariba cultivar, 27 species and 12 families were found, and in BR 17Gurgueia cultivar, 25 species and ten families were identified. The botanical family with the highest species in cowpea cultivars was Cyperaceae, with eight species followed by Poaceae with five (Table 1).

Marques et al. (2010), investigating mulching, identified 46 species and five genera in two years of BRS Guariba cultivation. Corrêa et al. (2015), in conventional system in the North mesoregion of Maranhão state, found 32 species of weeds. Batista et al. (2017) in the north of Minas Gerais identified 14 weed species in erect cultivars and 11 species in prostrate cultivars. Bandeira et al. (2018) in southwestern Bahia observed 43 weed species and Teixeira Júnior et al. (2020) in Roraima observed 29 species in a semi-prostrate cultivar. The high

variation in the number of species of the weed community shows the importance of phytosociological survey in each region due to differences in climate, soil, cultivation system and the growth habit of the culture.

The predominance of weeds of the families Cyperaceae and Poaceae are consistent with research conducted in the studied region (Marques et al. 2010; Corrêa et al. 2015; Silva et al. 2017; Marinho et al., 2020).

Among the studied cultivars, it was noted that BR 17 Gurgueia suppressed species from two botanical families, Molluginaceae and Solanaceae, possibly due to its indeterminate growth habit and semi-prostrate, which interfered in the development of species in these families.

Table 1. Floristic composition of weeds in cowpea cultivars BRS Guariba and BR 17Gurgueia in mulching (crushing capoeira), in the municipality of Itapecuru Mirim-MA, 2017

Families	Species	BRS Guariba	BR17Gurgueia
	Monocotyledons		
CYPERACEAE	*Cyperus diffuses* Vahl	X	X
	Cyperus ferax Rich	X	X
	Cyperus iria L.	X	X
	Cyperus rotundus L.	X	X
	Cyperus sp.	X	X
	Fimbristylis miliacea (L.) Vahl	0	X
	Bulbostylis capilares (L.) C. B. Clarke	X	0
	Scleria melaleuca Rchb. ex Schltdl. & Cham	X	X
	Kyllinga odorata Vahl	X	X
POACEAE	*Digitaria ciliares (*Retz.) Koeler	X	X
	Chloris barbata (L.) Sw.	0	X

	Echinochloa colona (L.) Link	X	0
	Panicum maximum Jacq.	X	X
	Urochloa mutica (Forssk.)	X	X
	Urochloa sp.	X	X
	Eudicotyledons		
AMARANTHACEAE	*Alternanthera tenella* Colla	X	X
ASTERACEAE	*Elephantopu smollis* Kunth	X	X
	Emilia coccinea (Sims) G. Dom	X	X
	Erechtites hieracifolius (L.) Raf. Ex DC	X	0
FABACEAE	*Bauhinia sp.*	X	X
	Calopogonium muconoides Deves	X	X
HYPERICACEAE	*Vismia guianensis* (Aubl.) Choisy	X	X
MALVACEAE	*Sida cordifolia* L.	X	X
	Sida rhombifolia L.	0	X
MOLLUGINACEAE	*Molugo verticillata* L.	X	0
PLANTAGINACEAE	*Lindernia crustacea* (L.) I. V. Müell	X	X
ONAGRACEAE	*Ludwigia leptocarpa* (Nutt) H. Raven	X	X
RUBIACEAE	*Spermacoce latifolia* Aubl.	X	X
	Spermacoce verticillata L.	X	X
SOLANACEAE	*Physalis angulata* L.	X	0

The results showed that in treatments without inoculation and nitrogen fertilization of the cultivars, the weeds with the highest importance value index (IVI) in BRS Guariba were

Cyperus sp. (116.58%) at 10 DAE; *Urochloa* sp. (133.59%) at 20 DAE; V. *guianensis* (81.38 to 109.99%) from 30 to 50 DAE; and S. *melaleuca* (117.28%) at 60 DAE. While in BR 17Gurgueia cultivar, these species presented IVI below 90%, with a predominance of V. *guianensis* from 10 to 50 DAE, and higher IVI (88.33%) at 30 DAE (Figure 2A and 2B).

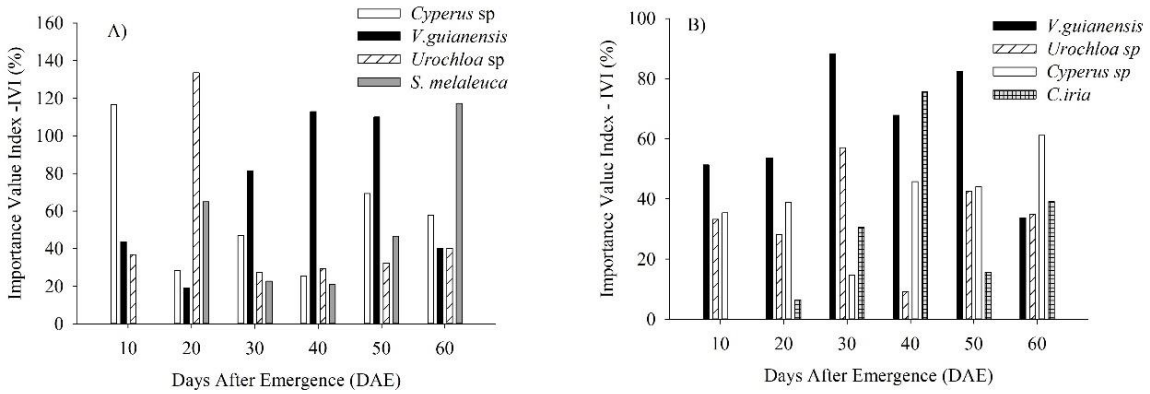

Figure 2. A) Importance value index of the main species in the treatment without inoculation of the cowpea cultivars BRS Guariba, and B) BR 17-Gurgueia, in mulching (crushing capoeira), in the municipality of Itapecuru Mirim – MA, 2017

The highest IVI of the species in the BR Guariba cultivar indicates that the semi-erect growth and relatively short branches facilitated the facilitate the light penetration, which allowed the development of weeds. Meanwhile, the semi-prostrate growth of the BR 17Gurgueia covered the soil better, inhibiting the growth of these species.

Castro et al. (2019), studying weed interference in cowpea cultivars, verified a higher accumulation of total dry matter of weeds in BR Guariba compared to the cultivar Aracê (semi-prostrate growth), which had occupied the area better. Meanwhile, Batista et al. (2017) observed that the greater distance between rows of prostrate cultivars increased dry matter and number of weeds compared to erect cultivars.

It is noteworthy that *Vismia guianensis*, a pioneer species typical of deforestation areas in the Amazon region and the Northeast coast of the country (Lorenzi, 2008), showed significant participation in the weed community of cultivars, which is explained by root system of mulching when crushed.

In treatments with inoculation, the most relevant species in BRS Guariba cultivar at 10 DAE was *V. guianensis* (95.25%), which at 30 DAE was supplanted by *S. melaleuca* (81.62%), and at 40 DAE by *Cyperus* sp (77.11%). At 50 DAE, this species increased its IVI (74.57%), but at 60 DAE, it was surpassed by *S. melaleuca* (114.42%). In BR17 Gurgueia cultivar, the main species were *Cyperus* sp. and *V. guianensis*, with IVI below 90% (Figure 3A and 3B).

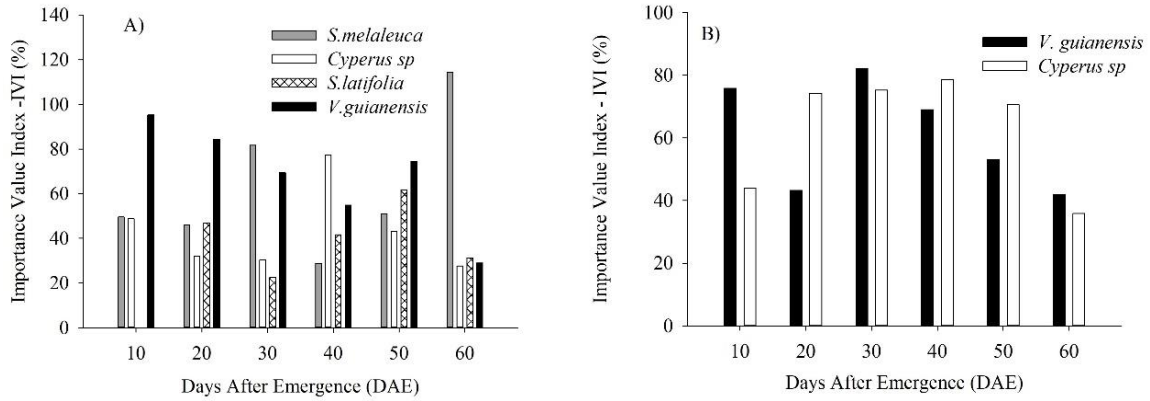

Figure 3. A) Importance value index of the main species in the inoculation treatment of the cowpea cultivars BRS Guariba, and B) BR 17Gurgueia, in mulching (crushing capoeira), in the municipality of Itapecuru Mirim – MA, 2017

The results demonstrated those weeds reduced their IVI in treatments inoculated with both cultivars compared to the absence of them. From these results, it is clear that the effect of *Bradyrhizobium* sp on the growth of cultivars, especially in BR 17 Gurgueia, induced greater suppression on weeds due to its semi-prostrate growth habit.

Castro et al. (2019) also observed that the semi-prosted growing cowpea cultivar BRS Aracê was less susceptible to the weed community when compared to the BRS Guariba cultivar.

The presence of *Cyperus* sp and *V. guianensis* in the weed community of inoculated cowpea cultivars suggests a high adaptation to the mulching system. Likewise, Marques et al. (2010) also identified *Cyperus* sp and *Vismia guianensis* in the weeding community of the cultivar BRS Guariba in mulching. Marinho et al. (2020) in rice cultivation under similar ecological conditions also observed the presence of several species of the genus *Cyperus* that were suppressed by mulching of the babassu straw.

In the treatment with nitrogen fertilization of the cultivars it was observed in BRS Guariba predominance of *V. guianensis* from 10 to 30 DAE (59.84 to 117.66%) and at 50 DAE (115.66%). While in BR 17 Gurgueia, *V. guianensis* surpassed the other species from 10 to 50 DAE with IVI from 53.43 to 97.54% (Figure 4A and 4B).

The high IVI of *V. guianensis* in the weed community of cultivars indicated that nitrogen fertilization provided the growth of this species of much. Therefore, the use of Nitrogen mineral in mulching suggests an increase in plants from secondary forests (capoeira).

Marque et al. (2010), after two consecutive years of cultivation of the cultivar BRS Guariba without Nitrogen mineral application in mulching, concluded that there was a reduction in infestation of plants from secondary forests (capoeira) and an increase in the density of herbaceous weeds.

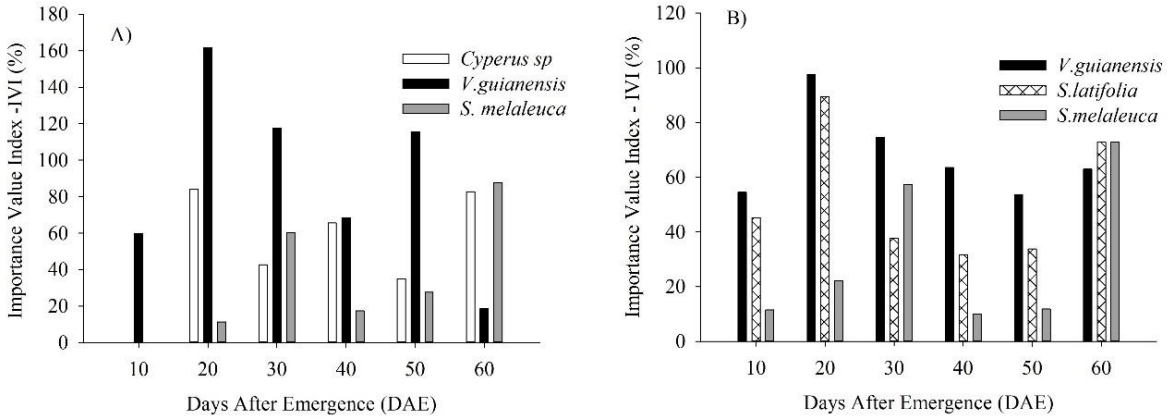

Figure 4. A) Importance value index of the main species in N-fertilizer treatments of cowpea cultivars BRS Guariba and B) BR 17Gurgueia, in mulching (crushing capoeira), in the municipality of Itapecuru Mirim – MA, 2017

To estimate the species richness, areas were further analyzed using the Shannon-Wiener diversity index (H'). The results revealed that the weed community of cultivar BR 17 Gurgueia had higher H' values than BRS Guariba in all treatments, except for N-fertilization. The smallest diversity of cultivars occurred in the inoculated treatment (Figure 5).

The growth of cultivars provided by inoculation with *Bradyrhizobium* sp reduced weed diversity. On the other hand, nitrogen fertilization promoted the growth of plants from secondary forests (capoeira) such as *V. guianensis*, with higher IVI in BRS Guariba cultivar.

The diversity's values of the weed community of cowpea cultivars in crushed poultry were low compared to those obtained in the study by Marques et al. (2010) in the same planting system. These authors found diversity's values ranging from 1.95 to 2.72, probably due to low rainfall during the conduct of the experiment.

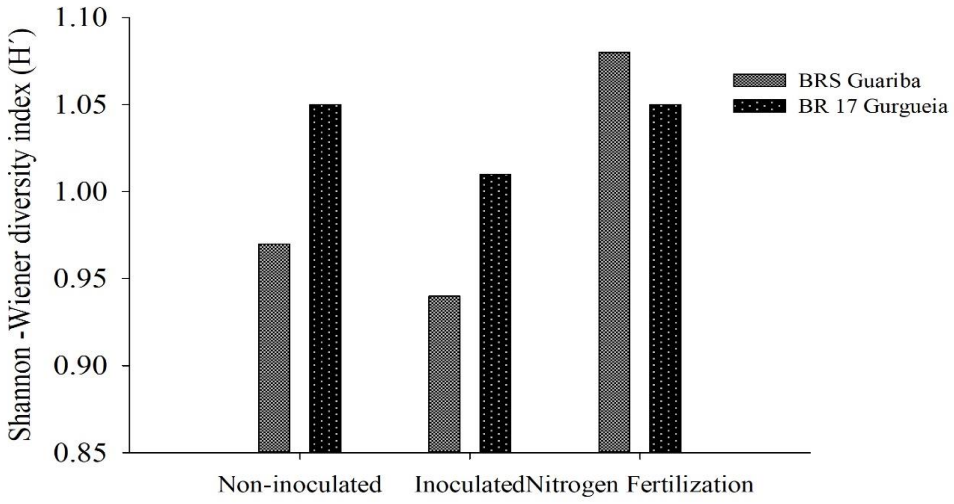

Figure 5. Shannon diversity index (H') of weeds in cowpea cultivars BRS Guariba and BR 17 Gurgueia, in mulching (crushing capoeira), in the municipality of Itapecuru Mirim – MA, 2017

The measurement of the degree of similarity in floristic composition among weed communities by the Jaccard similarity index (J) showed a low J between cowpea cultivars. It also revealed a higher J between treatments of cultivar BR 17 Gurgueia, without inoculation and nitrogen fertilization (Figure 6).

The lack of weed similarity between cultivars confirms that the growth habit and size of the cultivars influenced the floristic composition of the weed community in mulching. The greater similarity between treatments without inoculant and nitrogen fertilization of BR 17 Gurgueia was consistent with the high IVI of the main weeds. However, Batista et al., (2017) in conventional cultivation in Northern Minas Gerais, found high floristic similarity among weeds in the cultivars of erect and prostrate cowpea cultivars.

It is emphasized that there was only a phytosociological evaluation and there is a need for long-term studies to better validate the population dynamics of weeds in the cowpea crops and its interactions with local environmental conditions.

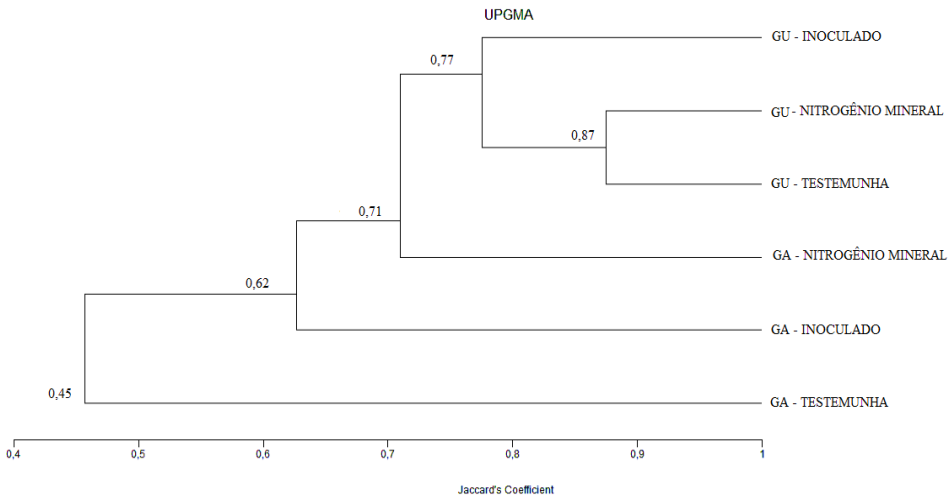

Figure 6. Dendrogram of floristic similarity of weeds by Jaccard index between cowpea cultivars, BRS Guariba and BR 17 Gurgueia, in mulching (crushing capoeira), in the municipality of Itapecuru Mirim – MA 2017

*UPGMA (Unweighted Pair-Group Method using Arithmetic Averages).

The cultivars differed significantly from each other about the number of nodules. The largest quantities were observed in BR 17 Gurgueia cultivar. For plant dry matter accumulation, there were no significant differences. The plant average was 30.47 g (Figure 7A and 7B). The greater nodulation of the cultivar BR 17 Gurgueia probably resulted from more affinities with the introduced bacteria than BRS Guariba in the mulching system; however, it did not reflect in higher dry matter accumulation.

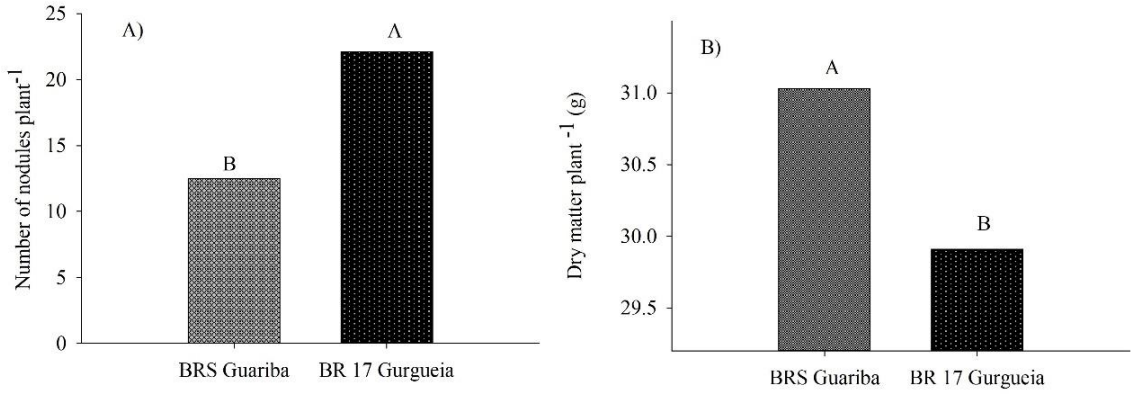

Figure 7. A) Number of nodules and B) dry matter accumulation of the cowpea cultivars BRS Guariba and BR 17 Gurgueia in a mulching (crushing capoeira) system, Itapecuru Mirim – MA, 2017. *Averages followed by different letters differ from each other by Tukey's test at the 5% probability level

Microbiological treatments differed from each other for the number of nodules and dry matter of the cowpea plants. The highest values were observed for treatments with inoculation, while treatments with nitrogen fertilization exhibited the lowest responses (Table 2).

The cowpea inoculation in a mulching system indicates that the number of nodules increased, favoring the dry matter accumulation in the plants. The results also showed that nitrogen fertilization inhibited the native population of cowpea nodulous soil and leading to a significant reduction in dry matter of cultivar BR 17 Gurgueia than in BRS Guariba.

Almeida et al. (2010), working in a conventional cowpea cropping system, did not notice a reduction in nodulation in the cultivar BR 17 Gurgueia by nitrogen fertilization, opposing the results obtained in mulching system. However, Chagas Junior et al. (2014), also investigating the conventional system, obtained higher nodulation in inoculated treatments compared to those with nitrogen fertilization.

Table 2. Number of nodules and dry matter accumulation of cowpea cultivars BRS Guariba and BR 17 Gurgueia, in mulching (crushing capoeira) system, in Itapecuru Mirim – MA, 2017

Microbiological treatments	Number of nodules plant^{-1}	Dry matter plant $^{-1}$ (g)
Non-inoculated	10.31 b	27.78 b
Inoculated	24.35 a	32.16 a
Nitrogen Fertilization (BRS Guariba)	1.73 c	27.65 b

Nitrogen Fertilization (BR 17 Gurgueia)	1.50 c	20.73 c
CV (%)	44.44	12.01

*CV: Coefficient of Variation

The cultivars did not differ for the number of pods plant^{-1} (NPP) and grain yield (GY). Only significant differences were observed for the number of grains per pod (NGP) and grain mass (GM). The BR 17 Gurgueia showed a greater number of grains per pod, while BRS Guariba had a higher grain mass (Figure 8A, 8B, 8C, and 8D).

The highest number of grains per pod of BR 17 Gurgueia cultivar did not result in higher productivity, as BRS Guariba cultivar presented high grain mass equaling its productivity. In a conventional system, Corrêa et al. (2015) found that the weight of 100 grains of the BRS Guariba cultivar was not affected by weed interference and proposed to be an inherent characteristic of the cultivar.

Regarding yield, the BRS Guariba cultivar had a lower average compared to that mentioned by Gonçalves et al. (2009) of 1508 kg ha^{-1} for the State of Maranhao. However, BR 17 Gurgueia cultivar was an above-average yield of 976 kg ha^{-1} in rainfed cultivation (Freire Filho et al., 1994).

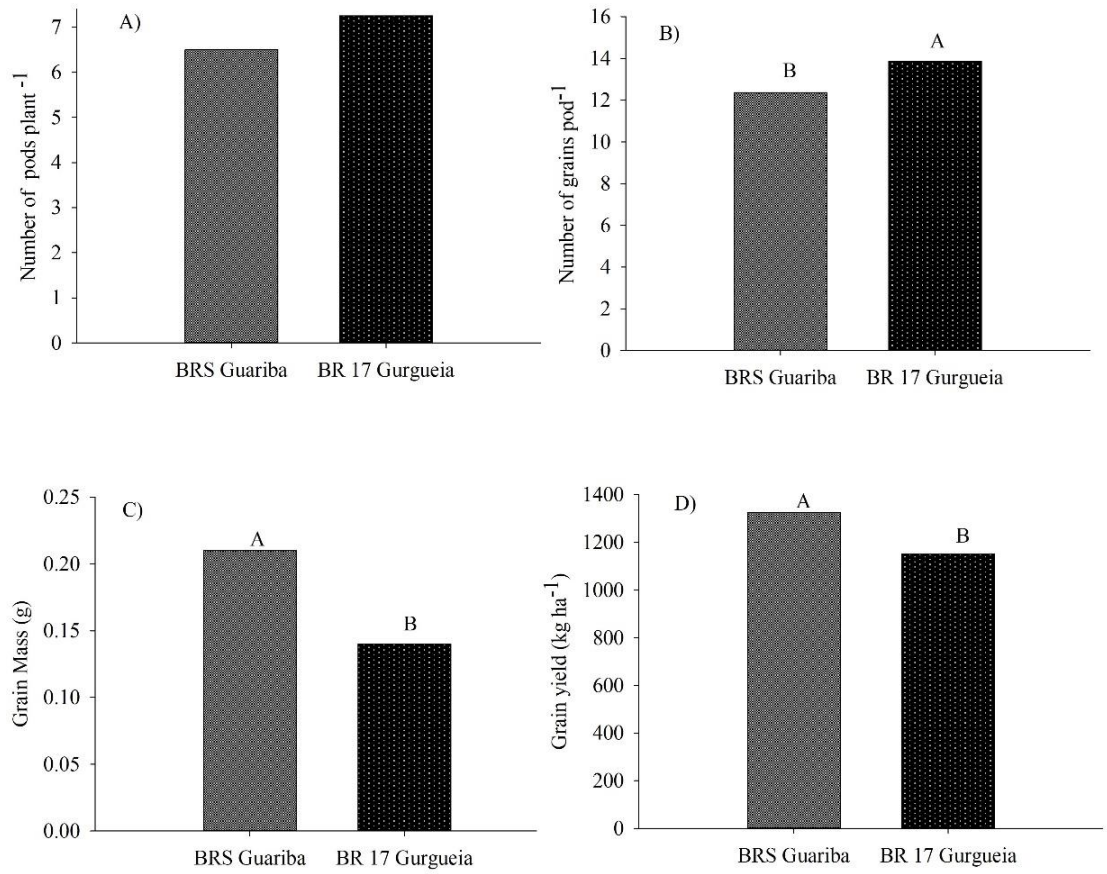

Figure 8. A) Number of pods plant^{-1}, B) Number of grains pod^{-1} C) Grain mass (g), and D) Grain yield (kg ha^{-1}) of cowpea cultivars BRS Guariba and BR 17 Gurgueia, in mulching (crushing capoeira) system, in Itapecuru Mirim – MA, 2017. *Averages followed by different letters differ by Tukey's test at the 5% probability level

The result suggests that the moisture retention and nutrients availability in mulching favored the symbiotic relationship between bacteria and cowpea, thus, promoting crop development with reduced weed infestation and increased grain yield. Additionally, nitrogen fertilization provided greater productivity in BRS Guariba cultivar.

Microbiological treatments differed for all cowpea yield parameters. The number of pods plant^{-1} (NPP) and the number of grains pod^{-1} (NGP) were higher with inoculation and nitrogen fertilization. Whereas the grain mass (MG) and grain yield (GY) were superior in the treatment with nitrogen fertilization of BRS Guariba cultivar (Table 3).

Table 3. Number of pods plant^{-1}(NPP), number of grains pod^{-1} (NGP), grain mass (GM), and grain yield (GY) of cowpea in mulching (crushing capoeira) system. Itapecuru Mirim – MA, 2017

Microbiological treatments	NPP	NGP	GM	GY (kg ha $^{-1}$)

Non-inoculated	6.12 b	12.25 b	0.17 bc	987.14 d
Inoculated	7.62 a	14.00 a	0.18 b	1490.95 b
Nitrogen Fertilization (BRS Guariba)	8.0 a	14.25 a	0.24 a	1965.09 a
Nitrogen Fertilization (BR 17 Gurgueia)	7.75 a	12.75 a	0.15 c	1288.92 c
CV (%)	11.94	9.77	9.19	19.02

*CV: Coefficient of Variation

4. Conclusions

Mulching (crushing capoeira) system promotes a weeds diversity in the cowpea cultivars BRS Guariba and BR 17 Gurgueia, leading to a greater development of the species *Vismia guianensis*, *Cyperus* sp., *Scleria melaleuca*, and *Spermacoce verticillata*. The inoculation of the cultivars with *Bradyrhizobium* sp reduced the infestation of these species in mulching, regardless of cowpea growth habit, but long-term studies are needed to better validate weed dynamics in this management system.

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