Growth and production of cowpea cultivated with liming and nitrogen fertilization in the Eastern Amazon[1]

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ABSTRACT

In the northeastern of Pará, cowpea is one of the main protein sources of the population. This study aimed to evaluate the effects of liming, the P and K mineral fertilization, and the combination of seed inoculation with *Rhizobium* associated with mineral N supplementation in the growth and production of cowpea cultivars. Two experiments were carried out in two consecutive years at the Federal Rural University of Amazonia (Capitão Poço-PA). A randomized block experimental design with subdivided plots was used with four replications, two cowpea cultivars (BRS Tapaihum and BRS Marataoã) and six fertilization and liming treatments: i) without fertilization and without liming; ii) P and K mineral fertilization, liming and seed inoculation with *Rhizobium*; iii) P and K mineral fertilization and seed inoculation with *Rhizobium*; iv) N, P and K mineral fertilization and liming; v) P and K mineral fertilization and liming; and vi) N, P and K mineral fertilization, liming and seed inoculation with *Rhizobium*. Cowpea responded to liming and P and K mineral fertilization, but not N fertilization. There was no difference between the supply of N through seed inoculation or mineral fertilization. Thus, it is suggested to inoculate seeds with Rhizobium in order to maintain the soil N reserve.

Keywords: acidity correction; biological nitrogen fixation; *Rhizobium*; leguminous crops; amazon soils.

INTRODUCTION

Cowpea [*Vigna unguiculata* (L.) walp.] (Fabaceae) is a legume consumed as a high quality plant protein source worldwide, especially in Brazil, in which it is important for economy and food security, especially for small farmers in northeastern Pará (Silva *et al.*, 2012). Despite its socioeconomic importance, productivity of cowpea is still low in Brazil, with an average of 476 kg ha^{-1} (CONAB, 2020).

Biological nitrogen fixation (BNF) is a technology capable of increasing cowpea productivity (Gualter *et al.*, 2011). The association of cowpea cultivation with N-fixing bacteria guarantees the supply of N, reducing production costs due to the lower use of N-mineral fertilizers (Soares *et al.*, 2014; Chakirwa *et al.*, 2019). The practice of inoculating seeds with rhizobacteria causes increases in the population of rhizobia as well as the efficiency of BNF (Gualter *et al.*, 2011). On the other hand, BNF might be compromised in conditions of low technological input, mainly due to the lack of correction of soil acidity, fertilization, irrigation and adequate crop management (Melo & Zilli, 2009). Attributes related to soil such as pH, Al^{3+} and nutritional deficiency are capable of altering the symbiotic efficiency and development of beans (Soares *et al.*, 2014; Farias *et al.*, 2016).

Weathered soils are characteristic of tropical regions and present chemical restrictions to agriculture, especially considering Fabaceae plants, through soil acidity, which decreases the efficiency of BNF (Farias *et al.*, 2016). Thus, soil acidity correction in the cultivation of cowpea is essential not only regarding the efficiency of BNF but also related to higher crop yields (Farias *et al.*, 2016).

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The combination of seed inoculation with rhizobia and the application of mineral N is a strategy commonly used in the cultivation of beans (*Phaseolus vulgaris* L.) (Brito *et al.,* 2015). However, for the success of the combination of biological and mineral fertilization, it is important to know the dose of mineral N capable to meet the nutritional demands of the plant so there is not a reduction or inhibition of NBF (Brito *et al.,* 2011).

This study aimed to evaluate the effects soil acidity correction, the P and K mineral fertilization, and the combination of seed inoculation with rhizobia associated with supplementation of mineral N on the growth and production of two cowpea cultivars.

MATERIAL AND METHODS

The study was carried out at the Campus of the Federal Rural University of the Amazon (UFRA-CCP) (01º44'47'' S and 47º03'34'' W), in Capitão Poço, state of Pará, Brazil, in two consecutive years (July to October of 2018 and July to September 2019). The areas of the experiments (2018 and 2019) were arranged in parallel and spaced approximately 20 m apart.

According to the Köppen classification, the region has a tropical altitude climate (Am) with an average temperature of 26.2 ºC, average annual precipitation of 2,500 mm and relative humidity between 75 and 89% (INMET, 2020). During the experimental period, data on temperature and precipitation (Figure 1) were obtained from the Automatic Surface Observation Meteorological Station of the National Institute of Meteorology (INMET), located at UFRA (CCP).

Prior to the installation of the experiment in 2018, 15 simple samples (0 - 0.20 m) were randomly collected with Dutch auger to form a composite sample of the soil in the area. This soil sample was sent to the laboratory to determine its granulometry: 834 g kg^{-1} of total sand, 46 g kg^{-1} of silt and 120 g kg^{-1} of clay, which is characteristic of soft sandy soils. The results of the chemical characterization of the soil in the experimental areas are shown in Table 1. All soil analyzes were performed in the Soil Laboratory of Embrapa Amazônia Oriental (Belém-PA).

The experiment was conducted in a randomized block design (RBD) with four replications, using a split plot scheme. Two cowpea cultivars, BRS Tapaihum (C1) and BRS Marataoã (C2), were cultivated in the main plots and six fertilization and liming treatments were applied in each experimental subplots: i) without fertilization and without liming (T1); ii) P and K mineral fertilization, liming and seed inoculation with *Rhizobium* (T2); iii) P and K mineral fertilization and seed inoculation with *Rhizobium* (T3); iv) N, P and K mineral fertilization and liming (T4); v) P and K mineral fertilization and liming (T5); and vi) N, P and K mineral fertilization, liming and seed inoculation with *Rhizobium* (T6).

In both experiments, soil preparation was carried out at 44 days before sowing at the end of the rainy season in the Amazon region and consisted of two harrows and liming. Dolomitic limestone (total neutralization power = 92%) was incorporated in the 0-0.20 m layer in the plots T2, T4, T5 and T6, in order to reduce the saturation by Al^{3+} to 20% (Cravo & Souza, 2007). Three seeds were sowed per hole at 0.2 x 0.6 m spacing. After emergence, two plants were left per hole (166,667 plants ha^{-1}). The experimental plots were composed of six sowing lines of 5 m each and the two central lines were selected for the evaluations, excluding 1 m at the ends of each line.

Seeds were inoculated one hour before sowing, with inoculant "TotalNitro Bean-cowpea" (*Bradyrhizobium* sp.), registered with MAPA (PR 93923 10060-1), which was provided by Total Biotecnologia. A dose of 2 mL kg^{-1} of

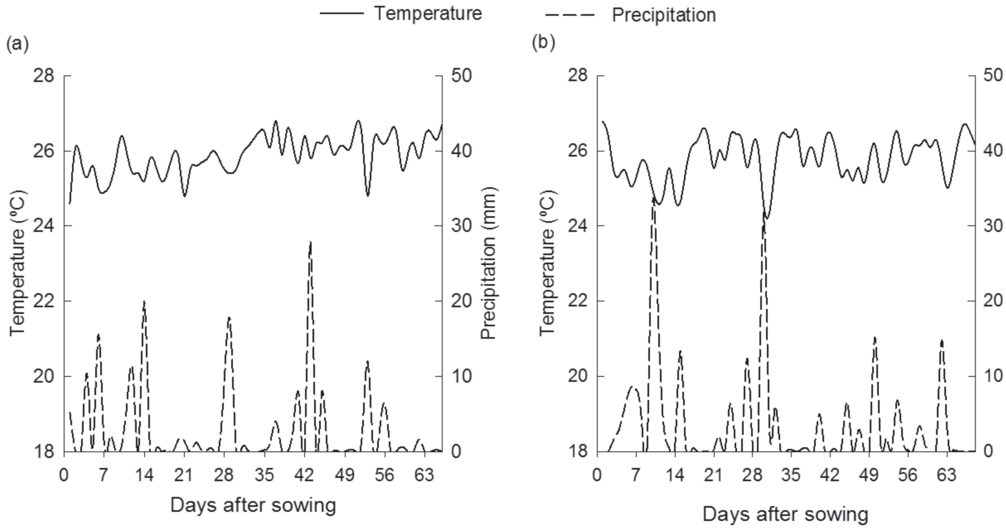

Figure 1: Average air temperature (ºC) and precipitation (mm) in Capitão Poço (PA) during the first (A) and second year (B) of cowpea cultivation. Source: INMET, 2020.

seeds was used following the manufacturer's recommendation. For treatments T4 and T6, 20 kg ha^{-1} of N (urea) were applied as top dressing at 27 days after sowing (Cravo & Souza, 2007), performing the incorporation of the fertilizer in the soil (0.05 m) at the beginning of the day period at lower temperature and, subsequently, irrigated. For the mineral fertilization of P (exception T1), 70 kg ha^{-1} of P_2O_5 were applied as simple superphosphate on the day of sowing. For mineral fertilization of K (exception T1), a dose of 60 kg ha^{-1} of K_2O was applied as potassium chloride, which was divided in two equal applications; the first application at day of planting (along with P application) and the second one at 27 days after planting (along with N application). The mineral fertilization of N, P and K followed the recommendation of the culture in the state of Pará (Cravo & Souza, 2007), performing all fertilizations in each pit of the plants. All mineral fertilizers were applied manually to the seeding line at a depth of approximately 0.05 m from the soil surface. During the experiments, due to the oscillation of precipitation observed in the region (Figure 1), on days when there was no rain the plants were irrigated (localized micro sprinkler irrigation) on alternate days at an average flow of 18.8 mm h^{-1}.

Weed control was carried out 14 days before sowing, using the herbicide N- (phosphonomethyl) grycine (glyphosate isopropylamine salt) (480 g L^{-1}) at a dose of 1 L ha^{-1}. Weeding was also necessary at the end of the vegetative phase of the plants. To prevent the attack of fungi, Carbendazim (500 g L^{-1}) was applied at a dose of 0.5 L ha^{-1}. There were no outbreaks of insect pests in the experiments and, therefore, control was not necessary.

At 46 days after sowing (beginning of the reproductive period), the growth of cowpea was evaluated by plant height (PH), stem diameter (SD), number of leaves (NL) and the ration PH/SD. Plant height was obtained with the aid of a graduated ruler, SD with the aid of a digital caliper, NL by simple counting. The production of cowpea was evaluated at the end of the experiments (68 days after sowing) by the number of pods per plant (NP), pod length (PL), pod weight (PW), number of grains (NG), grain weight (GW) and grain yield (GY). To measure NP and NG, a simple count was performed. As for PW and GW, a semi-analytical balance was used. For the PL, a graduated ruler was used and GY was estimated from GW and the number of plants per plot, in which the values were extrapolated to t ha^{-1}.

After meeting the assumptions of normality and homoscedasticity, the data were submitted to Analysis of Variance (ANOVA). Regarding the significance of the F test, the means were compared using the Tukey test. Analyzes were performed using Agroestat software (Barbosa & Maldonato Junior, 2015) and tested at 5% probability level.

RESULTS AND DISCUSSION

The plant height (PH) in 2018 was higher for BRS Marataoã (C2) (Figure 2a) and, in 2019, PH did not differ between cultivars (Figure 2b). For both cultivation years, plants grew less in height when cultivated in the absence of liming and fertilization (T1) (Figures 2a and 2b). This fact highlights the importance of correcting the acidity of the soil in order to neutralize Al^{3+} and increase the availability of nutrients (Cravo *et al.*, 2012), with consequent plant growth. In 2018, the absence of lime application (T3) also promoted low PH (Figure 2a), indicating that for the greater efficiency of rhizobia the correction of soil acidity is essential. Studies carried out with nitrogen fertilization on cowpea have shown plant height of approximately 0.4 m (Monteiro *et al.*, 2010). Silva *et al.* (2019), by evaluating the efficiency of rhizobia strains on BRS Marataoã cultivar found values close to 0.35 m of PH. The average values for PH were 0.31 and 0.24 m, for 2018 and 2019, respectively (Figures 2a and 2b).

The combined supply of mineral and biological N fertilization (T6) did not decrease PH in both years of cultivation, since it was used a low dose of mineral N (20 kg ha^{-1}) and it was applied at 27 days after the inoculation of the seeds with rhizobacteria. A study carried out with cowpea indicated that the excessive use of mineral N fertilization in supplementation has reduced the efficiency of NBF (Brito *et al.*, 2011). There were similar values of PH when N was supplied via mineral fertilization (T4) or inoculation of seeds with rhizobia (T2).

In 2018 and 2019, stem diameter (SD) presented higher values for the cultivar BRS Tapaihum (C1) and there were lower values only when liming and fertilization was not applied (Figures 2c and 2d). The SD of cowpea in both cultivation years also did not differ between the treatments with mineral and/or biological nitrogen fertilization, indicating the capacity of the rhizobia to supply the demand of N of the plants. Nitrogen directly interferes with the metabolism of vegetables because it is a constituent of amino acids and proteins capable of increasing the vegetative growth of plants (Dechen & Nachtigall, 2007; Souza & Fernandes, 2018). The supply of N was able to promote greater vegetative growth of cowpea both by mineral and biological fertilization in both cultivation years. Studies with rhizobia in cowpea indicated their capacity to supply the N demand of plants, similarly replacing mineral fertilizers (Brito *et al.*, 2011).

For the ratio between plant height and stem diameter (PH/SD) cultivar C2 showed higher values and there were no differences between fertilization and liming treatments for that variable in both evaluated years (Figures 3a and 3b). The values of PH/SD in both cultivations were higher than 3.5 and without prejudice to the development of the plants. Roza & Rosa (2016) stated that cowpea is a rustic species capable of adapting under adverse conditions. However, it requires liming and fertilization practices to obtain satisfactory grain production. Plant growth studies have determined the ideal PH/SD range of 3.5 to 4 and lower values are indicative of low growth (Marana *et al.*, 2008). In this sense, it is essential to establish a growing balance between the PH and SD for great plant development. The cultivar with the lowest PH (C1) (Figure 2a) was precisely the one that obtained the lowest PH/SD quotient (Figure 3a).

Regarding the number of leaves (NL), there were no differences between cultivars in the first year of the experiment and, in 2019, NL was higher in cultivar C1 (Figures 3c and 3d). The NL of the studied cultivars were lower in plots that did not receive fertilization and liming (T1), both in 2018 and 2019. In 2018, for C2, there was also less NL in the absence of liming, but with the inoculation of seeds with rhizobia (T3), this is an indication of the importance of correcting soil acidity to increase the efficiency of NBF. The increase in soil pH by liming increases the activity of bacteria (Soares *et al.*, 2014). In 2019, a lower NL was also observed in the treatment without application

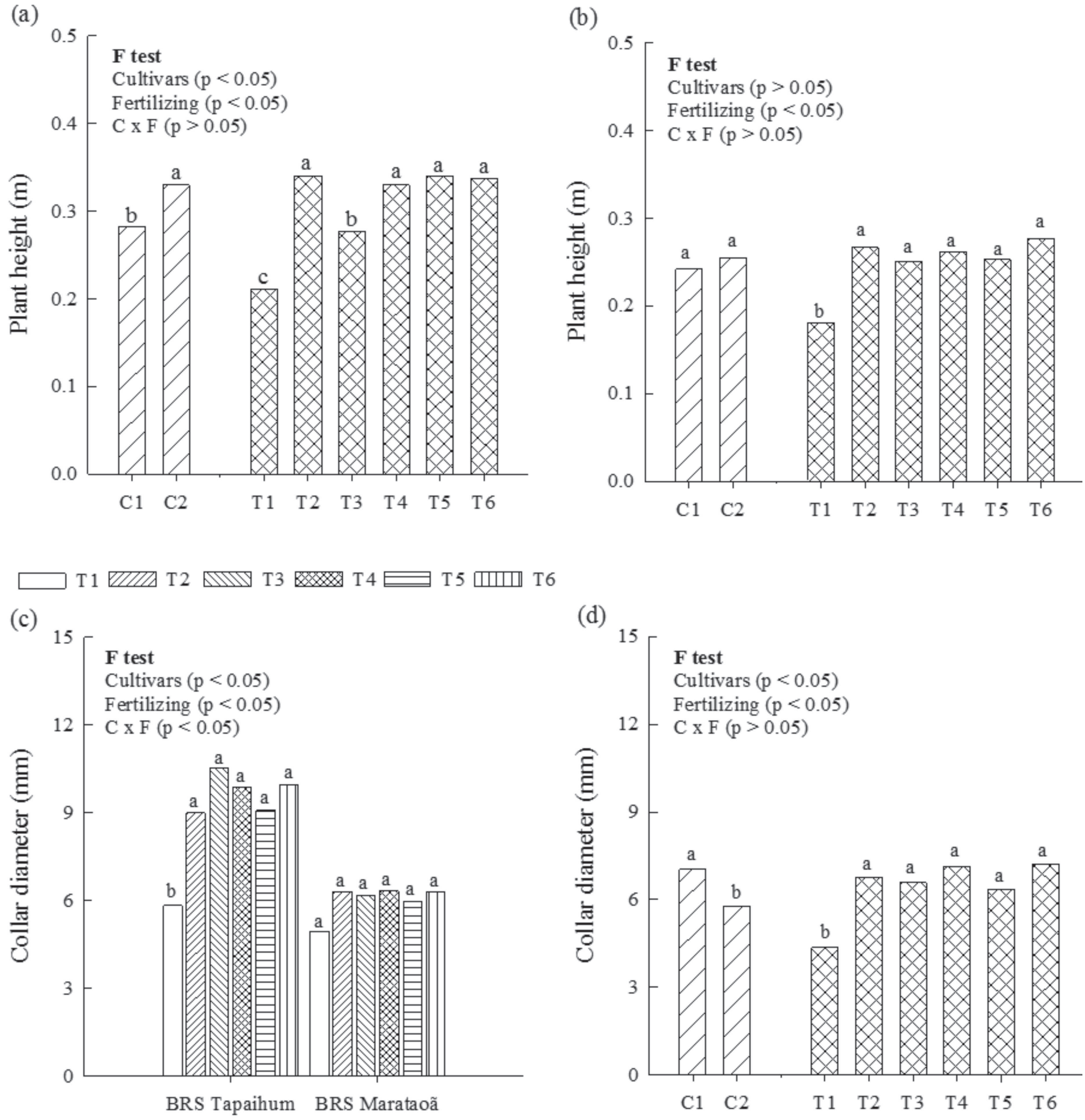

Figure 2: Plant height in 2018 (A) and 2019 (B) and stem diameter in 2018 (C) and 2019 (D) for cowpea cultivars (BRS Tapaihum - C1 and BRS Marataoã - C2) as a function of fertilization and soil correction (Treatments - T). Means comparing cultivars and fertilization treatments followed by the same letter do not differ from each other by the Tukey test (p > 0.05).

of N (T5) when compared with treatments with the presence of N (T2, T3, T4 and T6) (Figure 3d). This indicates the effect of this nutrient in increasing leaf growth. The absorbed N is incorporated into plants as amino acids and, later, transformed into proteins capable of promoting leaf growth and increasing the photosynthetic area in vegetables (Dechen & Nachtigall, 2007).

For the variables number of pods (NP) and pods weight (PW) there were no differences between cultivars in both evaluated years. However, for the treatments, there were lower values for the lack of liming and fertilization (Figures 4a, 4b, 4c and 4d).

Studies carried out with nitrogen fertilization (mineral or biological) in cowpea suggested that variables such as NP and PW did not suffer interference from N sources (Martins *et al.*, 2013). The supply of N in plants is related to vegetative growth, but its excess can stimulate the overgrowth of plants at the expense of grain production (Martins *et al.*, 2013). In this sense, the supply of N via mineral and/or biological fertilization did not directly influence the characteristics of NP and PW in both cultivation years (Figures 4a, 4b, 4c and 4d).

Regarding pod length (PL), there were no differences between cultivars in both evaluated years (Figures 4e and

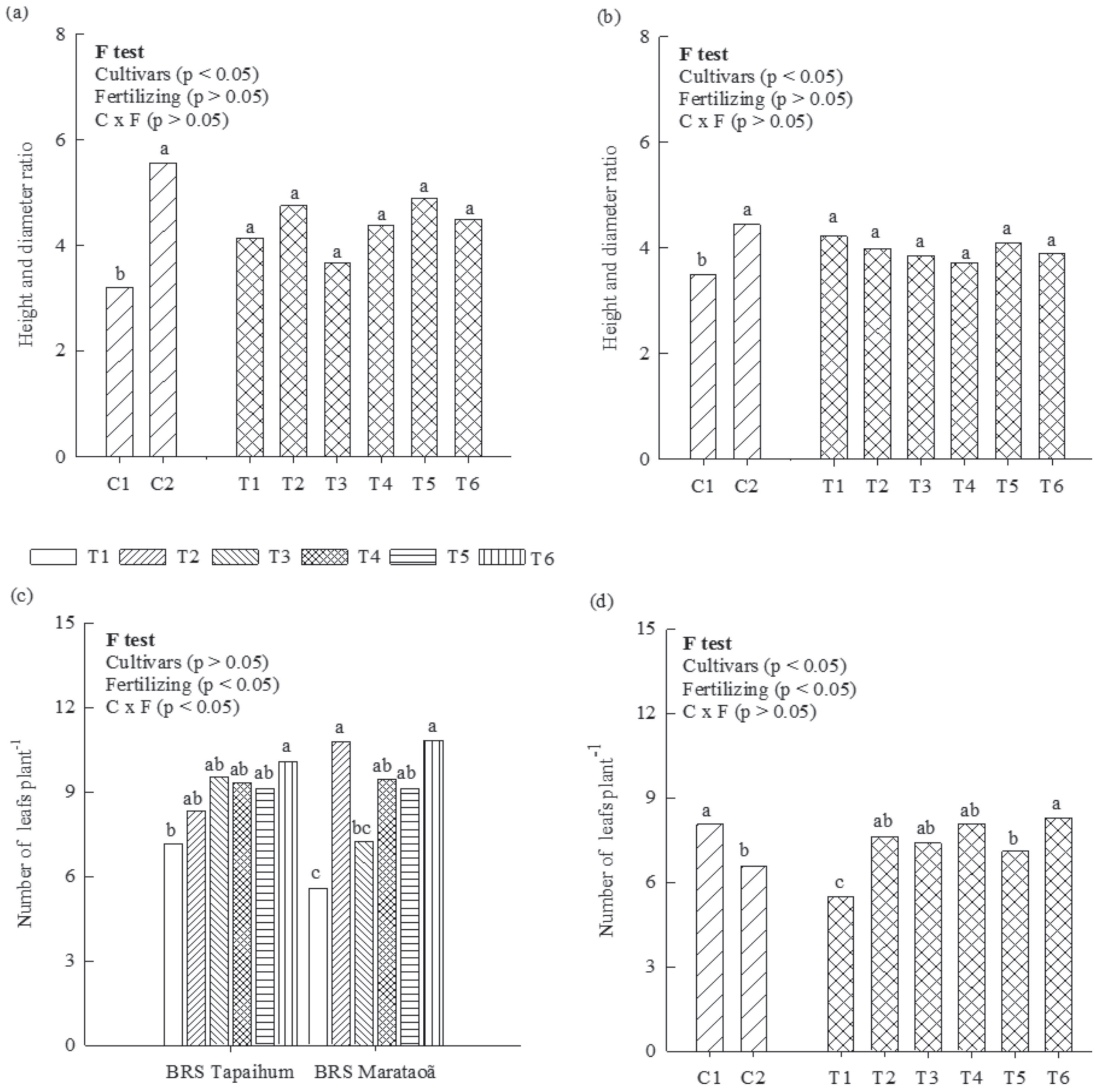

Figure 3: Relationship of height and stem diameter in 2018 (A) and 2019 (B) and number of leaves in 2018 (C) and 2019 (D) for cowpea cultivars (BRS Tapaihum - C1 and BRS Marataoã - C2) as a function of fertilization and soil correction (Treatments - T). Means comparing cultivars and fertilization treatments followed by the same letter do not differ from each other by the Tukey test (p > 0.05).

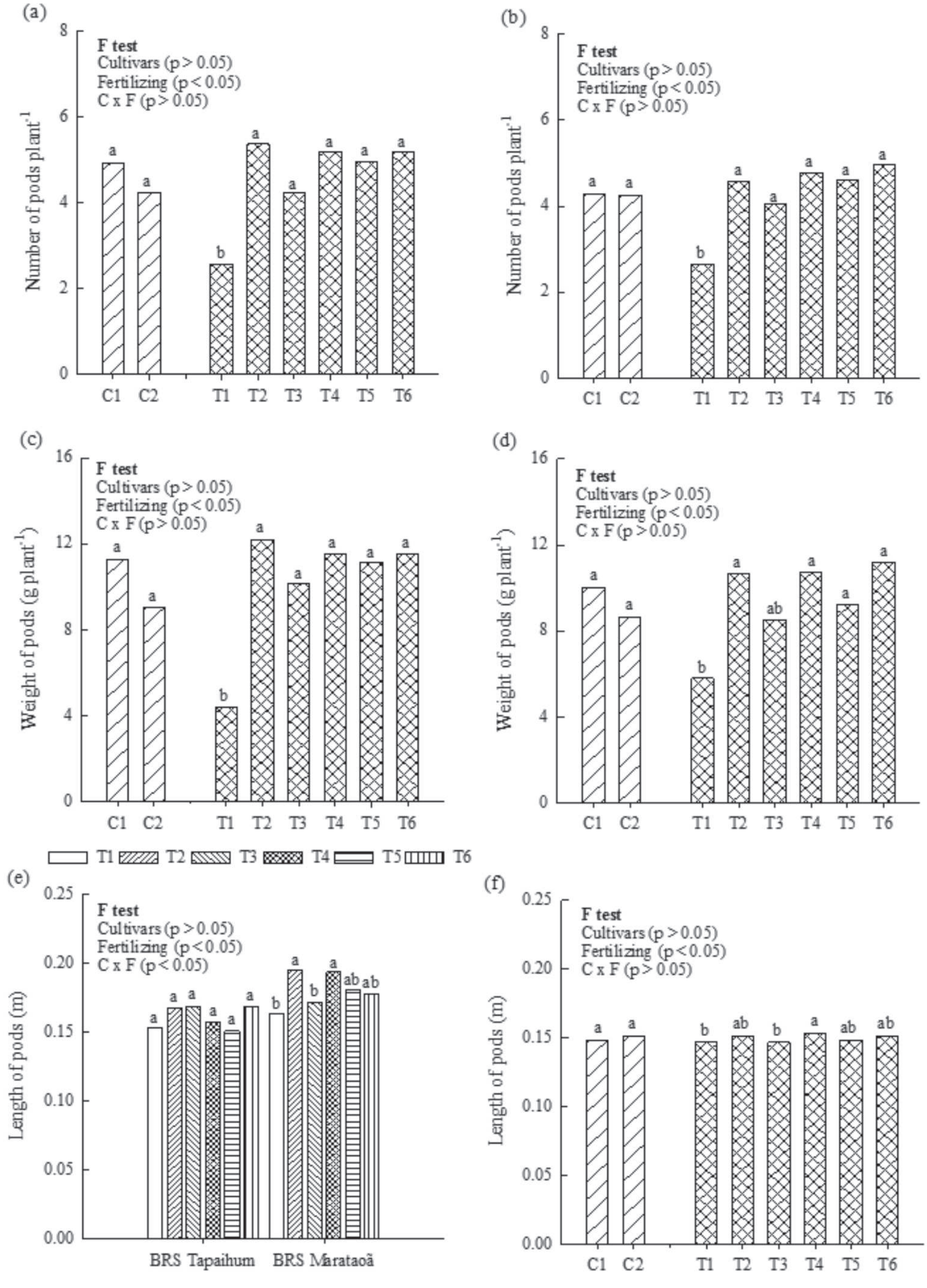

Figure 4: Number of pods in 2018 (A) and 2019 (B), weight of pods in 2018 (C) and 2019 (D), and length of pods in 2018 (E) and 2019 (F) for cowpea cultivars (BRS Tapaihum - C1 and BRS Marataoã - C2) as a function of fertilization and soil correction (Treatments - T). Means comparing cultivars and fertilization treatments followed by the same letter do not differ from each other by the Tukey test (p > 0.05).

4f). In the first year, cultivar C2 showed higher PL when cultivated in treatments that received liming and/or nitrogen fertilization (mineral and/or biological) (Figure 4e). In 2019, PL was also higher in plants that received liming and/or nitrogen fertilization (T2, T4, T5 and T6) (Figure 4f).

The number of grains (NG), grains weight (GW) and grains yield (GY) did not differ between cultivars for both evaluated years (Figures 5a, 5b, 5c, 5d, 5e and 5f). However, in both periods of evaluation, there was a tendency for a higher GY of cultivar C1 when compared with cultivar C2 (Figures 5e and 5f). In 2019, cultivar C1 also had presented higher NL (Figures 3d), which is an indicative of a direct relationship between GY and NL. Higher NL might represent greater leaf area, with consequently higher photosynthetic rates, carbon assimilation and greater plant production. Nitrogen is essential to the physiological activities of beans, present in the chlorophyll molecule, a pigment responsible for the photosynthetic process and for the transformation of nutrients into photoassimilates and grains, with a reflection on the productivity gain (Sorrato *et al.*, 2006). In 2018, there was lower NG, GW and GY in the plants grown in T1 treatment (Figures 5a, 5c and 5e), while in the second year there were lower values of these variables in T1 and T3 (Figures 5b, 5d and 5f).

In 2018, GY was negatively influenced by the absence of liming and fertilization with P and K (T1) (Figure 5e) and, in 2019, also by the lack of soil acidity correction (T3) (Figure 5f). It is important to highlight that when the seeds were inoculated with rhizobia and it was not applied lime (T3), the condition of lower soil pH and greater Al^{+3} concentration at second year (Table 1) was most limiting to production of cowpea (Figure 5f). Such observation indicates the importance of liming and the supply of macronutrients (P, K, Ca and Mg) to enhance the efficiency of rhizobia to supply N for cowpea. It is also interesting to note that when comparing T2 and T3 treatments in 2019, there was a decrease in GY in the latter treatment (Figure 5f). This fact indicates the benefit of correcting the acidity of the soil in increasing the pH and thus NBF, with a contribution in increasing GY in T2 when compared with T3. Strategies for increasing NBF in agricultural ecosystems include, among other factors, the use of liming and fertilization (Furtini Neto *et al.*, 2000).

Liming ensures the correction of soil acidity, increases the availability of nutrients to plants, promotes greater efficiency of fertilizers and, finally, results in optimal conditions for crop development (Caires & Joris, 2016), even for those considered tolerant to relatively high levels of acidity such as cowpea (Furtini Neto *et al.*, 2000).

When liming was performed, there were no differences in the production variables in relation to the supply of N via seed inoculation (T2), via mineral fertilization (T4) or both (T6) (Figure 5). In both cultivation years, the treatment inoculated with rhizobacteria (T2) and the treatment fertilized with mineral N (T4) obtained the same GY (Figures 5e and 5f). Thus, it is interesting to supply N via inoculation of cowpea seeds in relation to the application of mineral N, given the relatively lower cost of inoculation. In 2019, the average price of urea (44.4 kg), equivalent to 20 kg ha^{-1} of N (recommendation for cowpea; Cravo & Souza, 2007) in the country was R$ 69.30 (CONAB, 2020), whereas, depending on the region, the cost to the producer of the inoculant (100 mL) sufficient for 50 kg of seeds was only around R$ 5.50 (Total Biotechnology). Unfortunately, the inoculation of beans with rhizobacteria is a practice still not commonly used by farmers in Brazil, mainly in the northeast region of Pará, especially by the lack of positive results in field conditions (Chagas Junior *et al.,* 2010), making the present work a practical tool for producers in the region. Moreover, despite the application of mineral N being the main source of supply of this nutrient to cultivated plants, when in high doses, part of the supply is lost due to leaching and volatilization in tropical regions (Sorrato *et al.*, 2006; Martins *et al.*, 2013), which increases contamination mainly in sandy soil and in a region with high rainfall. In addition, the use of urea as a mineral source of N must be done with correct management, such as at lower temperatures, incorporation and/or irrigation, otherwise losses of volatile N can reach 80% of the total applied (Sangoi *et al.*, 2003), mainly in the region with higher temperatures (Figure 1).

Considering the contribution of NBF by rhizobia to the cowpea culture, seed inoculation was able to supply the N demand of the plants in a similar way to the supply through mineral fertilization, providing similar responses in grain yield (Zilli *et al.*, 2009; Chaves *et al.,* 2018). Thus, these studies prove that the supply of N via mineral fertilization or inoculation with rhizobia is able to meet the nutritional demand without difference in GY of cowpea.

There was no response from the production variables to the application of N (Figures 4 and 5). Similar values were observed between its omission (T5) and its supply (T2, T4 and T6), which cannot be interpreted as a no indication of nitrogen fertilization, since there might be a decrease in the N reserve in the soil in subsequent crops. Practical observations in the region have indicated a higher frequency of responses to nitrogen fertilization in soils with intensive use and that are cultivated for several years without organic fertilization or green fertilizers (Brasil & Cravo, 2009), which is not the case of areas of the present study (Table 1). Furthermore, it is necessary to consider replacement fertilization (Cantarella, 2007), which

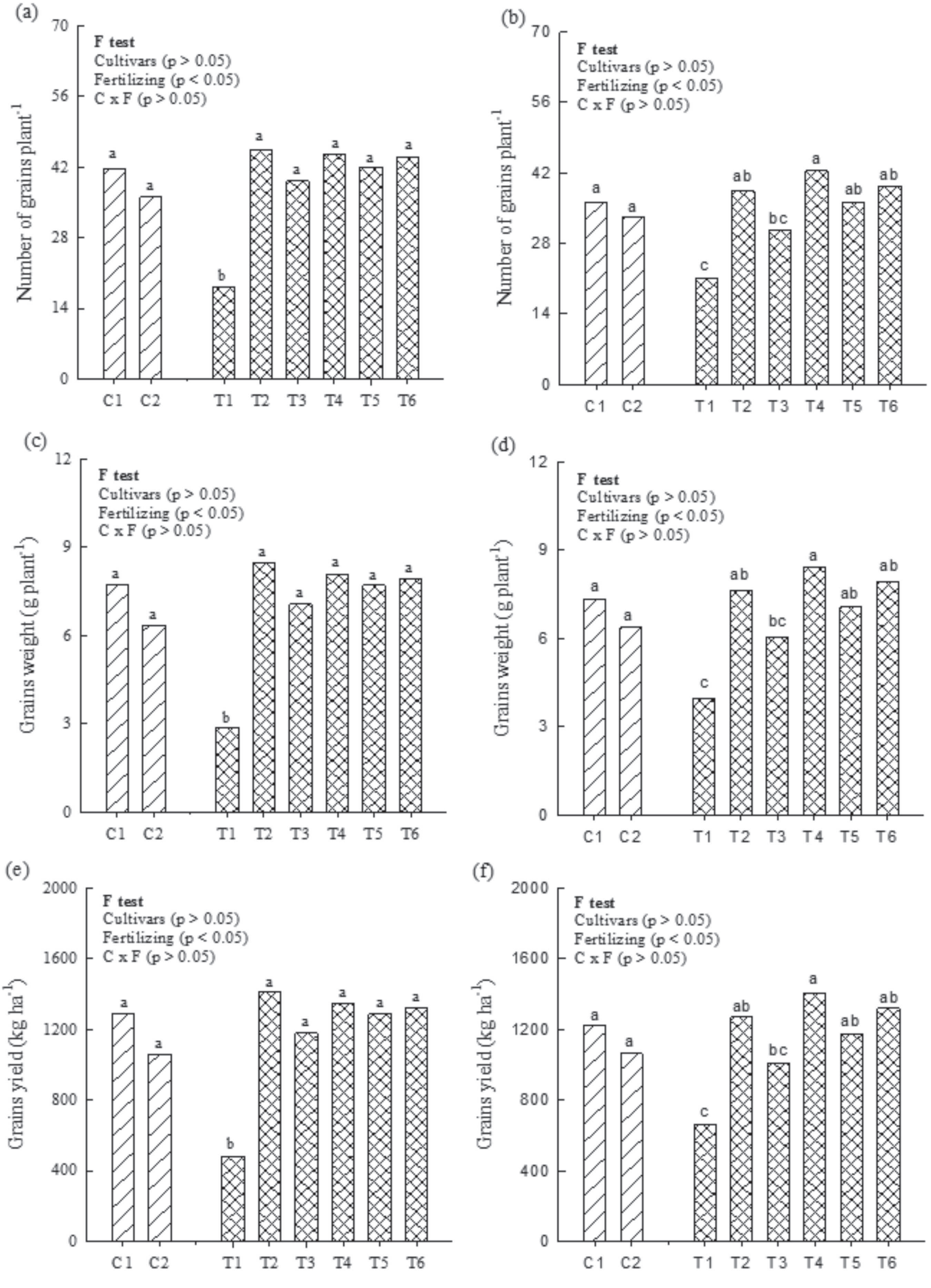

Figure 5: Number of grains in 2018 (A) and 2019 (B), weight of grains in 2018 (C) and 2019 (D), and grain yield in 2018 (E) and 2019 (F) for cowpea cultivars (BRS Tapaihum - C1 and BRS Marataoã - C2) as a function of fertilization and soil correction (Treatments - T). Means comparing cultivars and fertilization treatments followed by the same letter do not differ from each other by the Tukey test ($p > 0.05$).

aims to supply the amount of N exported by the crops. For cowpea, this value is in the order of 30 kg ha^{-1} (Randall *et al.*, 2006). Thus, for maintaining the reserve of N in the soil and due to the environmental aspects already mentioned, it is recommended the inoculation of seeds with rhizobia aiming at the supply of N to cowpea. Gualter *et al.*, (2008) also found no difference in productivity between inoculated and non-inoculated treatments caused by the ability of native bacteria to perform symbiosis with cowpea. The culture has low specificity of nodulation, being able to obtain different responses of the rhizobia from the conditions of cultivation, cultivars and region (Chagas Junior *et al.*, 2010; Borges *et al.*, 2012). Cowpea BNF fully meets the demand for N via seed inoculation with rhizobia, being able to replace nitrogenous mineral fertilizers (Brito *et al.*, 2011).

Soil organic matter (SOM) is the main source of N in the soil for plants and it can represent up to 95% of the total N of the soil (Silva & Mendonça, 2007). Thus, the lack of response of cowpea in production to nitrogen fertilization can be partly explained by the contribution of SOM due to its mineralization, although in soil with low content of SOM (Table 1; Alvarez *et al.*, 1999) and region with high temperatures and rainfall (Figure 1). In newly deforested areas, the organic carbon content might be a good indicator of the N stock in the soil, allowing its gradual release in the first years of agricultural exploration (Wadt & Cravo, 2005). About 2 to 3% of the organic N in the soil is mineralized annually (Foth & Ellis, 1996), which represents an annual release of 16 to 180 kg ha^{-1} of inorganic N for different types of Brazilian soils (Cantarella, 2007). The demand for N from cowpea is in the order of 106 kg ha^{-1} (Neves *et al.*, 2009). Estimates of the potentially mineralizable N in Oxisols and Neossols in the state of Goiás indicate that this fraction represents less than 2% of the total N of the soils (Silva & Mendonça, 2007), although management practices such as liming can increase the mineralization rate of the N of SOM (Silva *et al.*, 1999), meeting the demand for crops regarding the nutrient. In addition, liming can contribute to increasing the content of N and NBF (Fonseca *et al.*, 2010), thus in soils with low SOM content the N mineralized is not sufficient to supply the demand for cowpea (Table 1). In this sense, liming provided greater grain production to cowpea (Figure 5), which can be explained by the increases the levels of soil N by correcting the soil acidity (Fonseca *et al.*, 2010) because of the pH increase and acceleration of the mineralization process of SOM.

In addition, wetting the dry soil can stimulate mineralization and cause a peak release of available N (Foth & Ellis, 1996). This fact might have occurred in the present study once the areas were irrigated. Additionally, the mineralization of organic N is stimulated by the addition of nitrogen fertilizers (priming effect), which increases the availability of N in the soil from SOM, in addition to the revolving of the soil reducing the stock of organic N over time (Cantarella, 2007). However, the immobilization of N carried out by microorganisms occurs concomitantly with its mineralization. There is a condition of balance between these two processes when the C/N ratio of the substrate is in the range of 20 to 30, this fact influences the availability of N for the crops and the way, season and dose of fertilizer applied (Cantarella, 2007). In 2018 and 2019, the C/N ratio in the soil was 10/1 and 12/1 (Table 1), respectively, which favored mineralization rather than immobilization, which must have increased the release of N from SOM for plant absorption and decreased dependence on N added via fertilizer.

Finally, it is noteworthy that even though there was no significant response in GY to the application of N in both cultivation years (Figures 5e and 5f), there was a numerical difference in GY when comparing the treatment without supply of N (T5) to the treatments with its application (T2, T4 and T6). This difference can be practical order for the producer. For example, in 2019, there was GY of 1,177 kg ha-1 in T5 and 1,270 kg ha^{-1} in the treatment with seed inoculation with rhizobia (T2), difference of 93 kg ha^{-1} for the farmer, with emphasis again for the importance of nitrogen fertilization for the cultivation of cowpea in the region (Cravo & Souza, 2007). Moreover, high grain yields were verified in the present study, mainly in the treatments with fertilization and liming (T2, T4, T5 and T6) (Figures 5e and 5f), when compared with the averages of the municipality of Capitão Poço (585 kg ha^{-1}), Pará (776 kg ha^{-1}) and Brazil (493 kg ha^{-1}) (IBGE, 2017). Unfortunately, liming and fertilizing practices

Table 1: Chemical characterization of the soil (0 to 0.20 m) of the area immediately before the installation of the experiments in 2018 and 2019

<u>Year</u>	pH	P	K	Ca^{+2}	Mg^{+2}	Al^{+3}	H+Al	SOC	N	V	m
	(H_2O)	mg dm^{-3}		cmol$_c$ dm^{-3}				%			
2018	5.11	2	21	0.34	0.11	0.55	3.97	0.62	0.06	12.36	49.53
2019	4.60	3	13	0.47	0.20	0.61	4.39	0.87	0.07	14.07	45.93

pH in water (ratio 1:2.5). P and K extraction by Mehlich-1. Ca^{+2}, Mg^{+2} and Al^{+3}, extraction by KCl (1 mol L^{-1}). H+Al extraction by buffered calcium acetate at pH 7,0. Soil organic carbon (SOC) - extraction by sodium dichromate and sulfuric acid. Total nitrogen (N) - sulfuric digestion / method Kjeldahl. V- Bases saturation. m – Aluminum saturation.

are still rarely used in the region, only 18.8% of rural establishments use these practices in the state of Pará (IBGE, 2017). In both cultivation years of cowpea there was an average of 1320 kg ha^{-1} of GY for treatments with fertilization and liming (T2, T4, T5 and T6) (Figures 5e and 5f), which represents 70% more in relation to the average GY of Pará (IBGE, 2017). This fact proves the importance of adopting soil management practices, such as fertilization and liming, in increasing the productivity of the crop in the region, with a consequent gain for producers.

CONCLUSIONS

The lack of soil acidity correction and mineral fertilization with P and K proved to be limiting to the growth and production of cowpea.

There was no plant response to nitrogen fertilization. However, it is suggested to inoculate the seeds with rhizobia due to less environmental impact and lower cost in order to maintain the N reserve in the soil over time.

In general, the cultivars Tapaihum and Marataoã differed in growth, but not in the production variables.

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