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Effects of copper on the development and yield of cowpea bean grains in Oxisol

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ABSTRACT

This study aimed to evaluate the effects of Cu doses on the development and yield of cowpea bean grains, cultivars BR3 Tracuateua and Canapu, in terms of fertility in a medium texture Oxisol in the eastern Amazon, Brazil. The experiment was carried out in a greenhouse at the Universidade Federal Rural (UFRA), on the Capanema Campus, Pará. The experimental design was a completely randomized arrangement of 5x2 factorial, with five repetitions, where the first factor is the use of five doses (0, 10, 20, 30 and 60 mg dm^{-3} of Cu) having copper sulfate as a source, while the second factor is the use of cultivars BR3 Tracuateua and Canapu. Cowpea bean cultivars have different behaviors in terms of Cu requirement and cultivar BR3 Tracuateua, in general, is more responsive to Cu supply than Canapu. The estimated dose of 32.5 g kg^{-1} of Cu provided the maximum production of TDM of cultivar BR3 Tracuateua at in 60 days after planting.

Keywords: *Vigna unguiculata (L.),* Growth, Micronutrient, Grains.

Efeitos do cobre no desenvolvimento e produção de grãos de feijão-caupi em Latossolo Amarelo

RESUMO

Este trabalho teve como objetivo avaliar os efeitos de doses de Cu no desenvolvimento e produtividade de grãos de feijão-caupi, cultivares BR3 Tracuateua e Canapu, em termos de fertilidade em Latossolo de textura média na Amazônia oriental, Brasil. O experimento foi conduzido em casa de vegetação da Universidade Federal Rural (UFRA), Campus Capanema, Pará. O delineamento experimental foi inteiramente casualizado em esquema fatorial 5x2, com cinco repetições, onde o primeiro fator é a utilização de cinco doses (0, 10, 20, 30 e 60 mg dm-3 de Cu) tendo como fonte sulfato de cobre, enquanto o segundo fator é o uso das cultivares BR3 Tracuateua e Canapu. As cultivares de feijão-caupi apresentam comportamentos diferenciados quanto à exigência de Cu e a cultivar BR3 Tracuateua, em geral, é mais responsiva à oferta de Cu do que a Canapu. A dose estimada de 32,5 g kg-1 de Cu proporcionou a máxima produção de TDM da cultivar BR3 Tracuateua aos 60 dias após o plantio.

Palavras-chave: *Vigna unguiculata* (L.), Crescimento, Micronutriente, Grãos.

1. Introduction

Micronutrients play a crucial role in cowpea crops; nevertheless, few studies have investigated their importance to the crop. Some works have assessed the doses of zinc (Zn) and manganese (Mn) tested alone or in conjunction with macronutrients on variables, such as grain yield and crude protein (CP) contents in cowpea grains (Melo, 2016). Fertilization in cowpea crops is needs accurate quantification, as excess or lack of nutrients can change plant metabolism, causing nutrient toxicity or deficiency. Inadequate amounts of soil nutrients lead to changes in the rates of nutrient absorption and translocation, which can reduce crop yield, among other factors (Fontes, 2016), highlighting the importance of micronutrients and their performance in the plant.

The Bragantina region in Pará State, Brazil, is a prominent site of cowpea plantations with intense use of technologies for crop production. However, the most used cowpea cultivar (BR3 Tracuateua) was released over 20 years ago, which is a natural cross of local varieties of cowpea crops. BR3 Tracuateua contains a grain pattern, with white color and rough integument. Therefore, the cultivar has remained genetically stable due to manual selection of the its seeds by producers (Freire Filho et al, 2009). Micronutrients are required at low doses; however, they are as important as macronutrients for an adequate development and yield of plants (Leite et al., 2009). Malavolta (2006) reports that all essential elements need to be present in plants; nevertheless, not all elements present are essential.

Copper (Cu) is absorbed by plants in the form of Cu2+ and high concentrations of phosphorous (P), molybdenum (Mo), and Zn decrease Cu absorption (Malavolta, 2006). Several Cu-containing enzymes catalyze oxidation-reduction reactions, which are crucial to plant photosynthesis and respiration (Malavolta, 2006). In addition, Cu is essential for leguminous plants, as it helps the symbiotic fixation of N2 and is required in root nodules for the full operation of this process. Cu-deficient plants have wilted and curled young leaves that become brittle.

In addition, leaves show undulations, face downwards, and protruding veins on the underside, which leads to the drooping of petioles and stalks. Finally, chlorosis result in pale or yellowed leaves. (Neto-Bezerra et al., 2015). On the other hand, plants with adequate Cu content are well developed with good structure and growth and have higher yield and quality. Nutrient absorption in plants refers to nutrient concentration in different parts of the plant tissue, resulting in its nutritional status, which is kept by factors related to genetics and the environment. Information on the amounts of nutrients absorbed, accumulated, and exported is necessary to understand plant nutrient demand. Thus, diagnosis of soil nutrients is important for an adequate supply of nutrients to plants (Sampaio and Brasil, 2009). It is important to understand the effects of Cu in cowpea crops for the appropriate supply to each cultivar analyzed, since Cu needs to be supplied to the crop, even at relatively small amounts (Salimpour et al., 2010).

Furthermore, few studies have investigated Cu supply in cowpea, while many works have addressed the topic in other crops, such as wheat, corn, rice, oats, and barley. This study aimed to evaluate the effects of Cu doses on the development and yield of cowpea bean grains, cultivars BR3 Tracuateua and Canapu, in terms of fertility in a medium texture Oxisol in the eastern Amazon, Brazil.

2. Material and Methods

The experiment was carried out in a greenhouse at the Universidade Federal Rural (UFRA), on the Capanema Campus (Lat. 01°11'45"S and Long. 47°10'50” W). The predominant climate of the region is humid or sub-humid Am-tropical, according to the Köppen and Geiger classification (1928), with an average annual rainfall of 2,495 mm and mean temperature around 26.4 °C. The experimental design was a completely randomized arrangement of 5x2 factorial, with five repetitions, where the first factor is the use of five doses (0, 10, 20, 30 and 60 mg dm^{-3} of Cu) having copper sulfate as a source, while the second factor is the use of cultivars BR3 Tracuateua and Canapu.

Fertilization with macronutrients and micronutrients, except for Cu, was carried out based on the soil analysis and on the recommendations of Brasil *et al*. (2020). The nutrient doses and sources applied in the treatments were as follows: 50 mg dm^{-3} of soil with urea, 80 mg dm^{-3} of soil with monosodium phosphate, 150 mg dm^{-3} with potassium chloride, 50 mg dm^{-3} of soil with calcium sulfate, 60 mg dm^{-3} of soil with magnesium sulfate, 30 mg dm^{-3} of soil with sodium sulfate, 2 mg dm^{-3} of soil with manganese sulfate, 3 mg dm^{-3} of soil with zinc sulfate, and 0.7 mg dm^{-3} of soil with the use of acid boric.

Sowing was carried out manually, with 6 seeds placed at 5 cm depth in each pot with a capacity of 8 kg, using 5 kg of Oxisol substrate of medium texture. After sowing, the pots were placed in a greenhouse, receiving daily irrigation of 200 ml per pot. Thinning was performed at 15 days, leaving two plants per pot, the most vigorous ones, and in a standardized shape. Before the experiment, the soil chemical analysis was carried out, with the following results: OM 32 g kg^{-1}, pH in water 4.1, P 1.2 mg dm^{-3}, K 0.03 mg dm^{-3}, Na 0.4 mg dm^{-3}, Mg 0.2 cmol dm^{-3}, Ca 0.3 cmol dm^{-3}, H+Al 6 cmol dm^{-3}, CEC 6.57, V% 9, m% 6.7, and SB 0.57.

The variables analyzed were: Leaf width (LW), Leaf length (LL), Pod number (PN), Pod diameter (PD), Pod length (PL), Leaf dry matter content (LDMC), Pod husk dry matter (PHDM), Grain dry matter (GDM) and Total dry matter (TDM). The assessments were conducted every 15 days. After collecting the biometric and reproductive variables of cowpea cultivars BR3 Tracuateua and Canapu, the samples were sanitized, packed in kraft bags, and dried in an oven at 65ºC until constant weight. Soon after, the biomasses of the parts of the cultivars. The analysis of variance of the data was performed and significance was obtained by the F test at 5% of probability, using the regression equations to express the behavior of variables. We used the Minitab 19 Statistical Software for the data normality test.

3. Results and Discussion

Plant height (PH) showed no difference between Cu doses, while the doses 30 and 60 mg kg^{-1} displayed symptoms of toxicity, where the leaves showed chlorosis with a burnt appearance on the edges in Canapu variety. BR3 Tracuateua showed no damage or visible disability; therefore, Cu did not influence plant height of common bean, but it had a significant influence on the direct production of grains. This result is similar to reports of Rosolem and Marubayashi (1994) where Cu application had greater effect on pod production, but with no influence on the growth rate of the bean plant. On the other hand, Pontes et al. (2017) reported the influence of Cu fertilization on PH.

Leaf number (LN) also showed no significant difference between Cu doses for both cultivars. This is possibly explained because the Cu content in the soil (Table 2) was sufficient to meet the demand for the production of plant leaves, which is directly related to the presence of nitrogen (N). N indirectly depends on the performance of Cu2+, as it induces iron (Fe) to produce leghemoglobin that increases nodulation roots, consequently increasing N_2 fixation. Thus, low Cu doses are well assimilated by cowpea crops; however, high Cu doses (30 and 60 mg kg^{-1}) drastically reduce the N2 symbiosis, when do not lead to plant death (Malavolta et al., 1997).

The cowpea cultivars showed different behavior regarding Cu application, as expected. Cultivar BR3 Tracuateua was more tolerant to Cu doses showing little demand for the nutrient, while Canapu responded positively to Cu application in terms of grain yield. Cu absorption by cultivar BR3 Tracuateua is higher than that of soybean in which the amount of Cu considered sufficient was between 10-30 mg kg^{-1} (EMBRAPA, 1999). Root dry matter (RDM) values showed no significant difference between treatments, possibly because the amount of Cu in the soil was adequate for root development. Higher Cu amounts allowed the plants metabolize the nutrient, avoiding toxicity, as occurred with BR3-Tracuateua.

The roots of some species use mechanisms of release of organic compounds capable of complexing Cu in the plant rhizosphere, preventing its absorption and consequent toxicity in this region (Treeby et al., 1989; Mench, 1990). Leaf width (LW) presented a similar result to that obtained with the leaf length (LL) for cultivar Canapu, that is, a reduction with increasing Cu doses (Figure 1A). On the other hand, cultivar BR3 Tracuateua was more demanding for Cu, as the model that most adjusted to explain the effect of Cu nutrient doses on LW was the equation of the second degree (Figure 1A). The estimated optimal dose was 22.3 mg kg of Cu, which corresponded to 5.5 cm of LW of cultivar BR3 Tracuateua.

For cultivar Canapu, leaf length (LL) decreased linearly with increasing Cu doses (Figure 2A). This result demonstrates that cultivar Canapu can be less demanding for Cu, since the concentration of 0.2 mg kg in the soil (Table 2) provided higher LL. Cu excess can compromise the performance of cultivated plants affecting their biomass and consequently crop yield. On the other hand, LL in cultivar BR3 Tracuateua was more demanding for Cu, with the maximum estimated dose of 36.7 mg kg^{-1} of Cu for an estimated LL of 11.2 cm (Figure 2B). Depending on the Cu doses, which vary according to its mobility, the cowpea cultivars had different behaviors regarding fertilization with Cu, as reported for *Vigna mungo* L. Hepper (Jongruaysup et al., 1994). This is a species of legume that produces small beans, known as Chinese beans and black beans.

The pod number (PN) also showed a significant difference between the Cu doses for Canapu, as explained by a quadratic equation (Figure 3A). The dose estimated was 20.4 mg kg^{-1} of Cu which provided a mean PN of 1.2. In cultivar BR3 Tracuateua decreased with the increase of the Cu doses applied, with greater value of PN as a function of the amount of Cu in the soil (Figure 3B). Bedin (2018) found no significant difference for PN in soybean plants with Cu application. Fageria et al. (2014) reported an increase in PN in common bean with Cu application in comparison to the control.

Cu doses showed no beneficial effect on the number of flowers in both cultivars BR3 Tracuateua and Canapu. The pod diameter (PD), pod length (PL), and NP in Canapu responded to the application of Cu doses. The estimated optimal Cu dose that provided the greatest PD was 6.8 mg kg^{-1} reflecting 1.39 cm of PD. For BRS3 Tracuateua, the estimated optimal dose was 7.8 mg kg^{-1} of Cu, which provided the maximum PD for 3.2 cm (Figure 4 B).

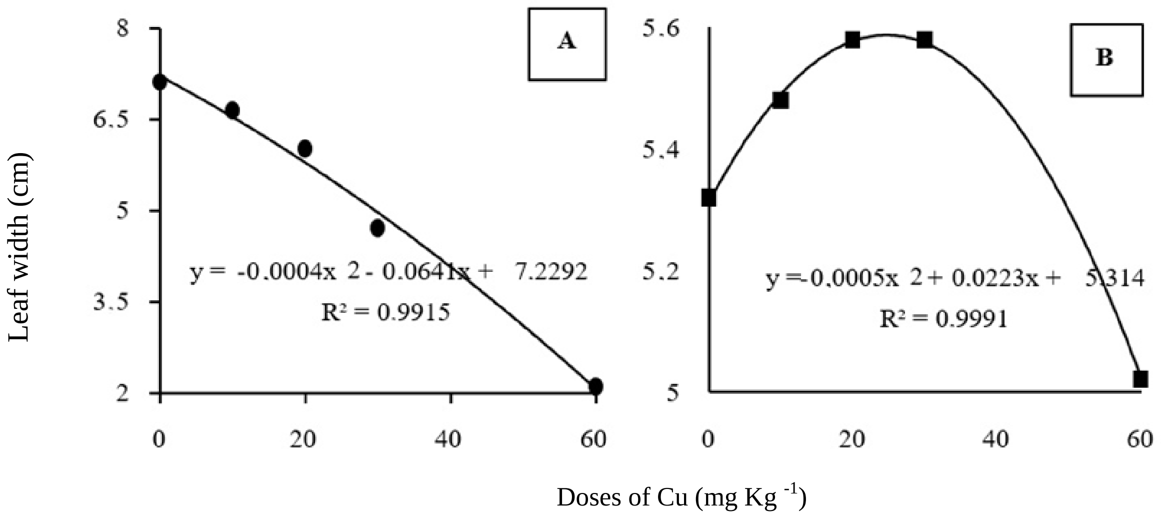

Figure 1 – Leaf width (LW) in cowpea cultivars Canapu (A) and BR3 Tracuateua (B), as a function of copper doses

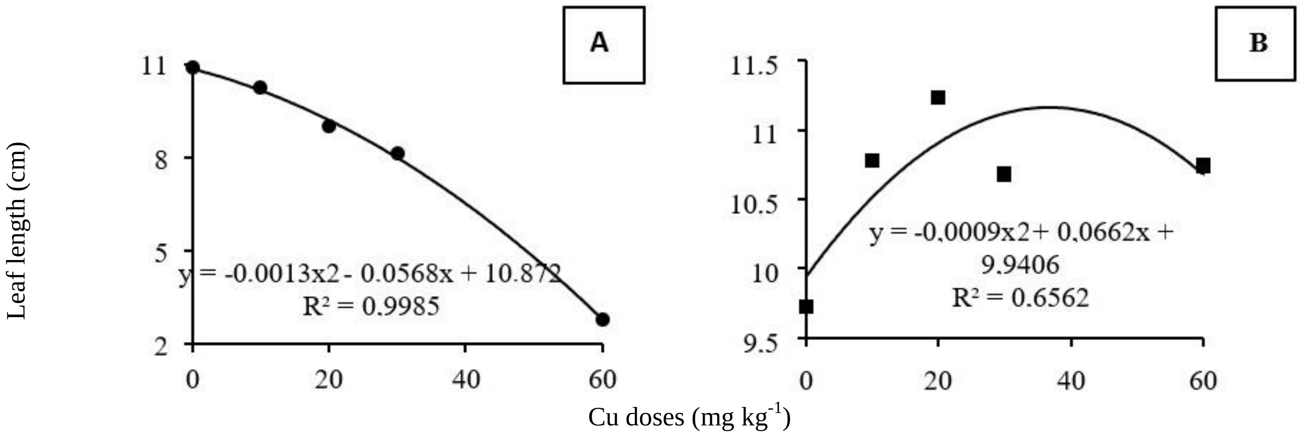

Figure 2 – Leaf length (LL) in cowpea cultivars Canapu (A) and BR3 Tracuateua (B), as a function of copper doses.

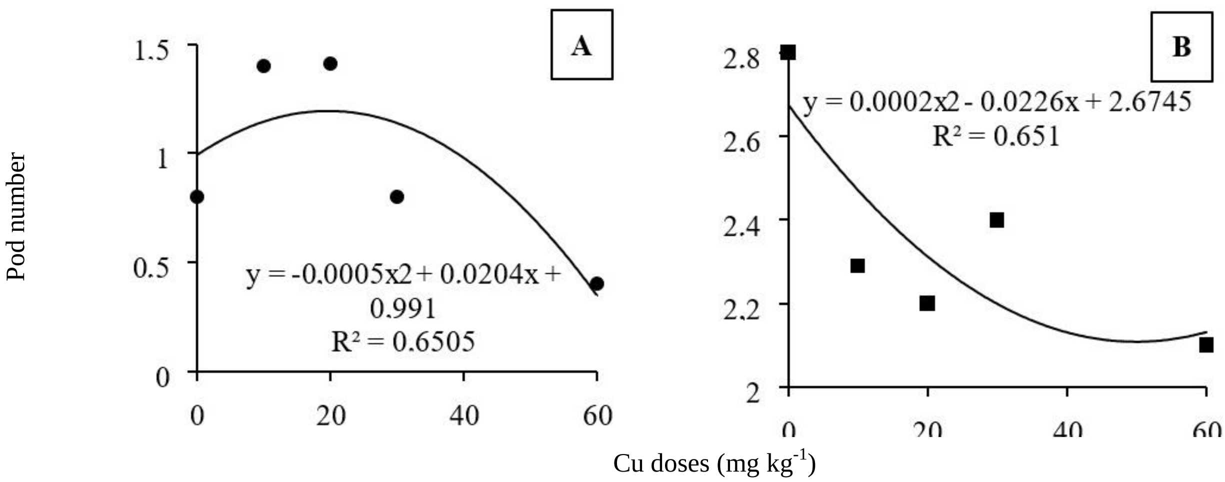

Figure 3. Pod number (PN) in cowpea cultivars Canapu (A) and BR3 Tracuateua (B), as a function of copper doses.

Pod length (PL) was responsive to Cu doses in Cultivar BR3 Tracuateua, with the estimated optimal dose of 4.78 mg kg^{-1} of Cu that provided the maximum PL of 16 cm, according to the model quadratic (Figure 5B). PL was also responsive to Cu in cultivar Canapu, with an estimated optimal dose of 19.9 mg kg^{-1} which provided the highest PL of 7.0 cm estimated by quadratic equation. After this dose, PL showed a depressive effect (Figure 5A), in addition to the fact that the soil acidity may have contributed to increase Cu availability. Conversely, Santos and Brasil (2007) found no significant differences in PL between Cu doses applied to cowpea.

PL for BR3 Tracuateua was 16 cm, which is considered a good length, according to Freire Filho et al. (2009) where BR3 Tracuateua had an average PL of 16.8 cm, while Canapu showed an average of only 7 cm in our study. Regarding the leaf dry matter content (LDMC), the quadratic model was the equation that best fitted to explain the effect of Cu doses for both cultivars (Figures 6A and 6B). For cultivar Canapu, the estimated optimal dose was 27.2 mg kg^{-1} of Cu for a maximum LDMC of 6.8 g/plant (Figure 6A).

For cultivar BR3 Tracuateua, the estimated optimal dose was 19.2 mg kg^{-1} of Cu for a maximum LDMC of 4.7 g/plant (Figure 6 B). In this context, the absence of Cu supply can be considered a limiting factor to LDMC of Canapu and BR3 Tracuateua cultivars, since these cultivars need a certain amount of Cu to express their maximum potential for LDMC. In legumes, the adequate level is between 2-20 mg kg^{-1} of Cu, rarely exceeding 10 mg kg^{-1} of Cu (Mengel and Kirkby, 1987).

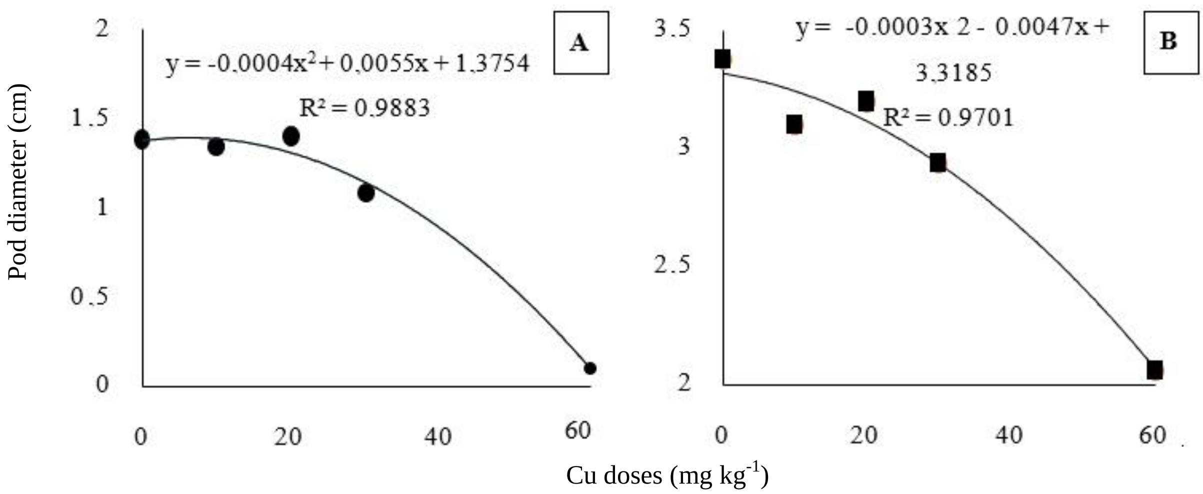

Figure 4. Pod diameter (PD) in cowpea cultivars Canapu (A) and BR3 Tracuateua (B) as a function of copper doses.

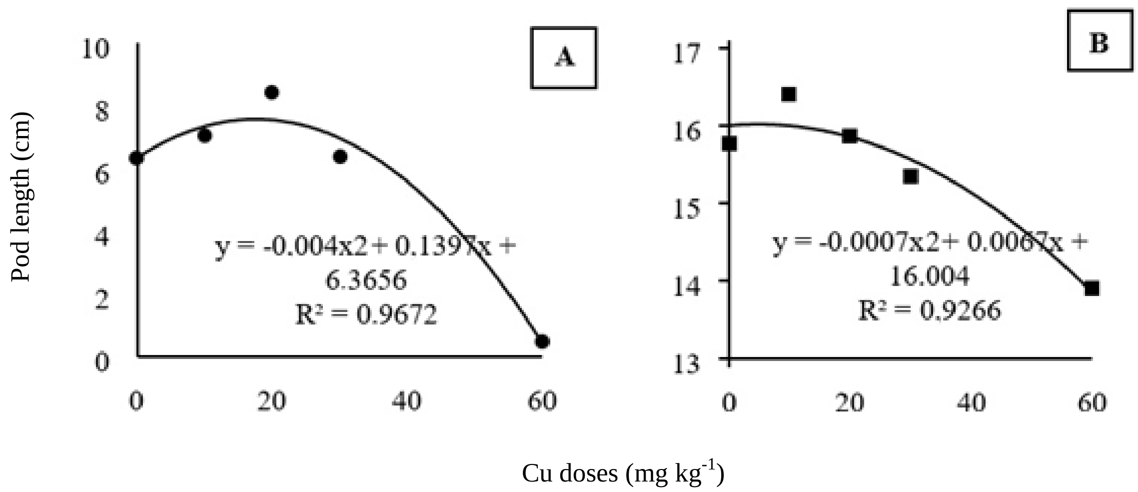

Figure 5. Pod length (PL) in cowpea cultivars Canapu (A) and BR3 Tracuateua (B), as a function of copper doses.

Regarding the production of pod husk dry matter (PHDM), cultivar Canapu showed similar behavior of LL and LW, that is, a decrease of these variables with the increase of Cu doses. The concentration of 0.2 mg dm^{-3} of Cu in the soil was sufficient to meet the demand of Canapu (Figure 7A), while cultivar BR3 Tracuateua showed a quadratic behavior and the estimated optimal dose of 27.2 mg kg^{-1} provided a reduction of PHDM (6.81 g) (Figure 9B).

Grain dry matter (GDM) presented a different behavior for the cultivars indicating that the Cu content in the soil (Table 2) was sufficient to reach themaximum yield, as increasing Cu doses reduced GDM (Figures 8A and 8B). In the absence of Cu application, cultivar BR3 Tracuateua was more productive than Canapu, possibly because Canapu has a greater sensitivity to Cu, indicating that this cultivar is less tolerant to the possible toxicity caused by Cu or by the genetic potential of the grow crops. Mendes (1997) studied cowpea added with Cu, Zn, and Mo and found that the addition of these micronutrients did not significantly alter the grain yield and plant dry matter.

Total dry matter (TDM) decreased linearly with increasing Cu doses in Canapu (Figure 9A), while cultivar BR3 Tracuateua showed a response to Cu supply, allowing to determine the estimated optimal dose of 32.5 mg kg^{-1} of Cu that provided the maximum estimated TDM of 17 g/plant (Figure 9B) with manual sowing at spacing of 0.40 x 0.20 m, with two plants per hole (family farming) and an estimated population of 250,000 plants/ha of cowpea, 1750 kg ha^{-1} of TDM. Silva et al. (2014) observed a decrease of TDM with the increase of Cu doses. The authors reported a beginning of toxicity in the plants because of greater nutrient absorption.

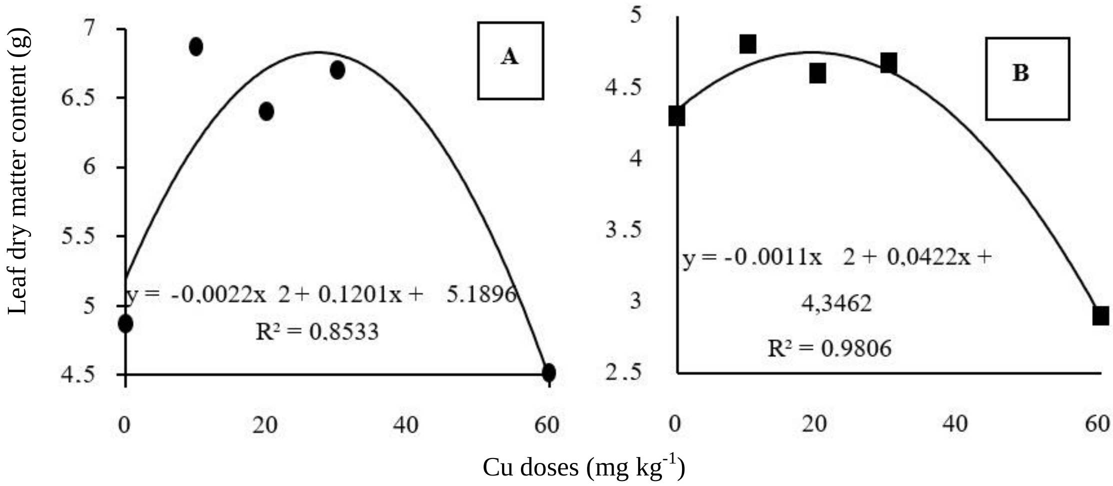

Figure 6. Leaf dry matter content (LDMC) in cowpea cultivars Canapu (A) and BR3 Tracuateua (B), as a function of copper doses.

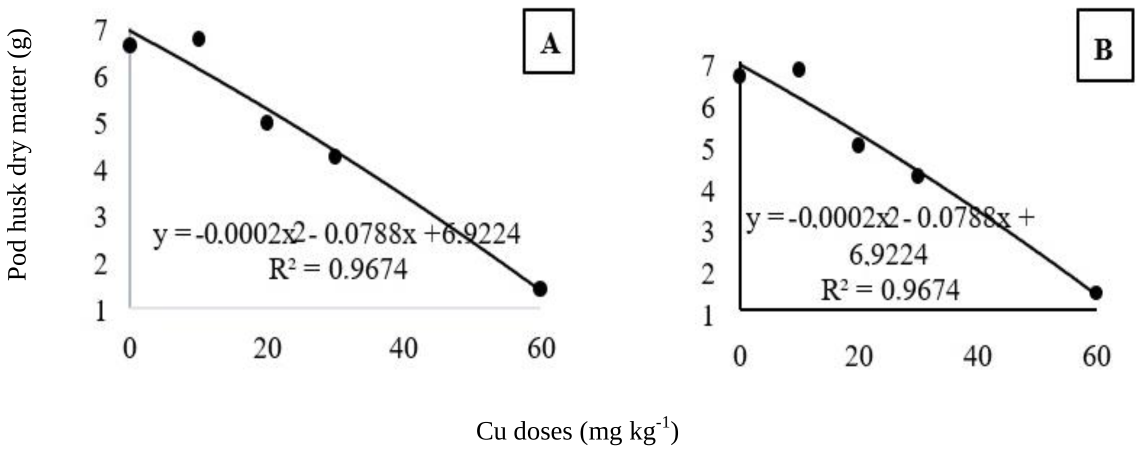

Figure 7. Pod husk dry matter (PHDM) in cowpea cultivars Canapu (A) and BR3 Tracuateua (B), as a function of copper doses.

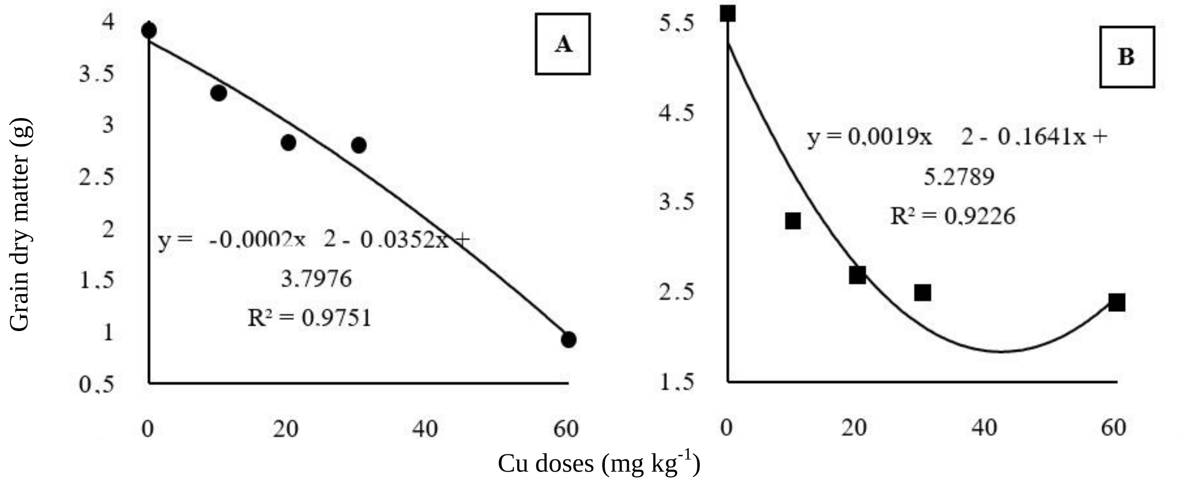

Figure 8. Grain dry matter (GDM) in cowpea cultivars Canapu (A) and BR3 Tracuateua (B), as a function of copper doses.

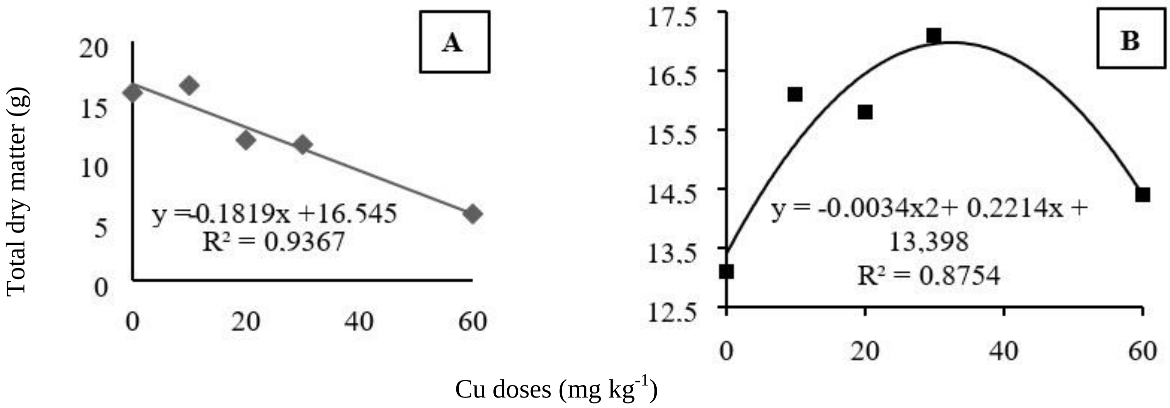

Figure 9. Total dry matter (TDM) of cowpea cultivars Canapu (A) and BR3 Tracuateua (B), as a function of copper doses.

4. Conclusions

Cowpea bean cultivars have different behaviors in terms of Cu requirement and cultivar BR3 Tracuateua, in general, is more responsive to Cu supply than Canapu. The estimated dose of 32.5 g kg^{-1} of Cu provided the maximum production of TDM of cultivar BR3 Tracuateua at in 60 days after planting

Authors' Contribution

Silvia Lima, Alasse Silva, Elane Conceição, Aline Silva and Jhonatah Gomes contributed to the design of the experiment, evaluations, data collection, tabulation and writing of the manuscript. Dr. Ismael Viégas assisted in setting up the experiment, reviewing the data, writing the manuscript, analyzing the data, preparing the graphs and oriented all the other authors.

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