Original Article

MICRONUTRIENTS CONTENT IN *Pueraria phaseoloides* L. ON SOILS UNDER OIL PALM PLANTATIONS IN TAILÂNDIA, STATE OF PARÁ

*ACÚMULO DE MICRONUTRIENTES EM KUDZU TROPICAL (*Pueraria phaseoloides *L.) EM SOLOS SOB PLANTAÇÕES DE DENDÊ EM TAILÂNDIA – PARÁ*

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ABSTRACT: The adoption of cover crops in commercial plantations has been shown to be an alternative to promote greater soil protection, enhancement in its structure and aggregation, optimization of accumulation and nutrient cycling to obtain greater production of biomass and higher nitrogen fixation. To determine the accumulation of micronutrients of *Pueraria phaseoloides* L., according to age, established as a soil cover in industrial oil palm crops, an experiment was carried out at Companhia Agroindustrial (CRAI) in the municipality of Tailândia, State of Pará, in an Oxisol. The experimental design was a randomized block with four replicates. The results allow to conclude that the accumulation of nutrients, except for Mn and Cu in the live *Pueraria phaseoloides* L. plant cover reduced over the years and those of B, Mn, Zn, and Cu were greater in the dead *Pueraria phaseoloides* L. plant cover and for Cl it was in the live *Pueraria phaseoloides* L. plant cover. The decreasing order of total micronutrient extraction was the following: Cl> Mn> B> Zn> Cu.

KEYWORDS: Legume. Live and dead plant cover. Micronutrient extraction. Oil palm crop

INTRODUCTION

The oil palm (*Elaeis guineensis* Jacq.) is crop grown for industrial purposes and is widely cultivated. Its primary product is the oil, industrially extracted from the fruit pulp. Currently, oil palm cultivation has a strong expression in the Amazon region, especially in the state of Pará, which is the country's largest producer, accounting for more than 85% of total production and with a planted area of more than 164,443 hectares divided among 37 municipalities (BICALHO et al., 2016; BENTES; HOMMA, 2016).

According to Rodrigues et al. (2002), the adoption of cover crops in soils under oil palm plantation is very common, and *Pueraria phaseoloides* L. is the most commonly used species in such intercropping. Clermont-Dauphin et al. (2016) point out that kudzu is completely accepted by farmers to be used as a cover crop due to its capacity of providing several improvements to the soil. These authors evaluated the effect of using kudzu plants in rubber tree (*Hevea brasiliensis* L.) plantations and found that rubber trees had shown a satisfactory development when intercropped with kudzu, with exception to sites where problems with hydric stress were observed.

As a result, the usage of plants as green manures in commercial plantations stood out as a considerably profitable alternative (MARCANTE et al., 2011; CARVALHO et al., 2013) since they provide a larger soil protection against erosion, improvements in soil structure and aggregation and optimization of nutrients storage and cycling due to the large production of biomass from these species and fixation of N_2 in the case of legume species (BARROS et al., 2013; YUAN et al., 2016).

Regarding cycling of nutrients, a fundamental factor that must be considered is the dynamics of extraction and reposition of nutrients by remains of plants from the cover crops (FAVERO et al., 2000). The knowledge of the amount of nutrients in tissues of dead and live plants on soil allows the understanding of the magnitude of reposition of these nutrients to the soil. Moreover, it can assist in the taking of decisions regarding management of crop nutritional quality.

In this context, Almeida et al. (2014) states that the concern with management and reposition of micronutrients has been increasing, aiming at reaching high levels of nutritional efficiency. Wei et al. (2006), concluded that, despite being required in a smaller amount, micronutrients deficiency is very normal in many planting species, requiring an intervention by means of practices of fertilization.

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Those authors also claim that the micronutrients are quite sensible to the variation regarding management and tillage time. The objective of this study was to evaluate the quantity of micronutrients in tissues of live and dead Kudzu plants in soil under oil palm plantation according to the Pueraria's plantings ages.

MATERIAL AND METHODS

The study was carried out in plantations of oil palm hybrid Tenera (Dura x Psifera), owned by Companhia Real Agroindustrial (CRAI), located at the municipality of Tailândia, State of Pará. In the plantation of oil palm, the legume Kudzu (*Pueraria phaseoloides* L.) was used as a soil cover crop whose planting is made by sowing to haul with inoculated seeds after soil preparation (1 kg ha^{-1}). The climate type in the region is Ami type according to the classification of Köppen (SEPOF, 2011; RODRIGUES et al., 2005). The predominant soils in the region are Typic Hapludox, according to the classification proposed by USDA (1999). The soil under the study area is classified as an Oxisol with average texture according to the classification proposed by Santos et al. (2013). The results of physical and chemical analysis of the soil at a depth from 0 to 30 cm in the areas of kudzu sampling are found in Table 1.

Table 1. Chemical and Physical analysis of soil samples from the studied areas at the 0-30 cm depth.

Soil Characteritics	Plantation age (years)						
	2	3	4	5	6	7	8
pH ($CaCl_2$)	4.3	4.4	4.1	4.0	4.0	4.3	4.0
K^+ ($mmol_c$ dm^{-3})	0.7	0.6	0.5	0.7	0.5	0.5	0.6
Ca^{+2} ($mmol_c$ dm^{-3})	7.0	7.0	9.0	8.0	7.0	7.0	6.0
Mg+2 ($mmol_c$ dm^{-3})	4.0	2.0	2.0	3.0	3.0	3.0	3.0
Al^{+3} ($mmol_c$ dm^{-3})	4.0	3.0	3.0	5.0	8.0	4.0	6.0
H+Al ($mmol_c$ dm^{-3})	34	28	31	38	34	26	34
SB ($mmol_c$ dm^{-3})	11.7	9.6	11.5	11.7	10.5	10.5	9.6
P* (µg cm^{-3})	4	6	5	6	6	6	8
V (%)	24	24	26	22	22	27	20
O.M. (g dm^{-3})	16	23	15	19	20	21	18
Sand (g kg^{-1})	730	620	690	680	590	650	740
Silt (g kg^{-1})	40	160	80	100	80	100	60
Clay (g kg^{-1})	230	220	230	220	330	240	200

K^+, Ca^{+2}, Mg^{+2}, Al^{+3}: Exchangeable calcium, magnesium, potasium and aluminum; H+Al: Potential acidity; SB: Sum of the bases; P: Available phosphorus; V: Bases Saturation; O.M.: Organic Matter.

The experimental design was completely randomized, with seven treatments and four replications for each treatment, where treatments corresponded to seven plantations of oil palm. Each one of the plantations were at a particular age: 2, 3, 4, 5, 6 and 7 years of plantation.

In each treatment, samples of live and dead tissues of kudzu plants (live plants and dead plants cover, respectively) were randomly sampled using a 0.50 x 0.50-m frame collector, which corresponds to an area of de $0.25m^2$. The samples were placed in paper bags, weighed, and washed with deionized water and placed in a stove with forced air circulation at a temperature of 70 ºC. These samples were daily weighed until reaching a constant weight, denoting that the tissues were completely dried. The dry matter at different ages was determined.

After obtaining dry tissues in samples, they were ground in Wiley-type mill. The ground samples were sent to Plant Laboratory at the Soil and Plant Nutrition Department at Embrapa Amazônia Oriental for determination of the following micronutrients: boron (B), chlorine (Cl), copper (Cu), manganese (Mn) and zinc (Zn). These analyses were performed according to the method described by Sarruge and Haag (1974). Boron was determined by the method of azomethine-H. Analysis of Cl was made with the titration with silver nitrate, according to the method described by I.R.H.O. (1980). The determination of Cu, Mn, and Zn was performed through the atomic absorption spectrophotometry (AAS). Content of micronutrients was estimated by multiplying the micronutrients content by the values of the dry matter for live and dead kudzu plants cover.

For each variable, the Kolmogorov-Smirnov (5%) normality test was performed and in relation to the non-normal variables, the Box-Cox transformation was used. Then, the variables were submitted to analysis of variance (ANOVA) by the F-test with 5% of significance. Moreover, regression equations were fitted for each micronutrient content (y) in function of the plantation age (x). For each micronutrient, the selection of the best regression fitting was performed based on the following criteria: p-value<0.05, the largest coefficient of determination (R^2) and the smallest standard error of the estimation (Syx%).

RESULTS AND DISCUSSION

Dry matter data (Figure 1) show the superiority of biomass production for cover with dead plant material, which has a square fitting — in comparison to cover with live plant material — which has obtained the exponential model as the best one. This fact can be explained by the successive content of plant material at the decomposition stage, which is present while the death of vegetal tissues from live plant material cover occurred (LIMA FILHO et al., 2014). So, the accumulation of aboveground biomass may provide higher rates of C/N ratio, which makes the decomposition of vegetal tissues more difficult in such conditions (BRADY; WEIL, 2013). Such biomass accumulation of dead plant cover, typical for kudzu plants established as cover crop.

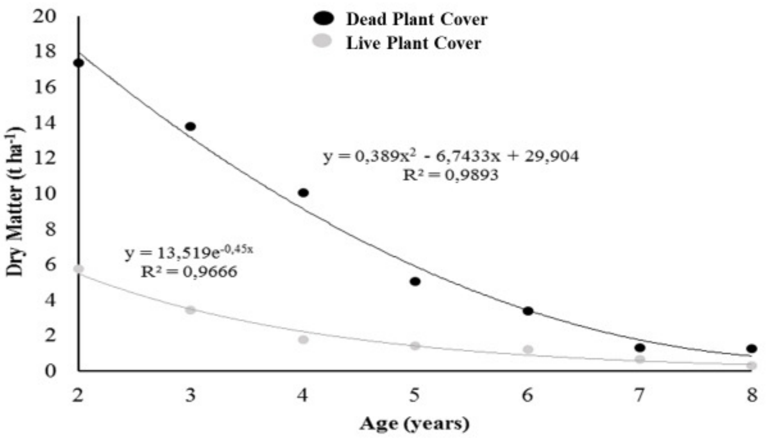

Figure 1. Dry matter (t ha^{-1}) in the live and dead *Pueraria phaseoloides* L. plant cover according to the age of the plantation (years). p-value<0.05

For both types of plant cover, a reduction in the accumulation of biomass has occurred in function of the age of palm tillage. The decrease in the dry matter in live plants is probably due to the reduction in their metabolic status. This reduction normally causes the reduction in the absorption of nutrients and in the photosynthesis, contributing to the reduction in the biomass growth (MALAVOLTA, 2006). In addition, the oil palm growth could also influence the drop in the metabolic status of kudzu because of the reduction in the light energy availability for kudzu plants due to the oil palm shading. This fact may also contribute to a decrease in the biomass production due to the less availability of sun light. The reduction in the biomass of dead plant material cover, in turn, may be associated with the substantial increase in the biological activity, which is responsible for decomposing the biomass deposited on the soil. Carvalho et al. (2014) evaluated the performance of biomass production for cover plants according to the time and also observed a reduction in the dry matter of such species, and they attributed this result to the rise of the decomposition process.

In general, this pattern of dry matter decline is reflected in the behavior of the micronutrients especially in dead plant cover, which was also diminished over the years. So, the reduction in the content of micronutrients in kudzu live plant cover may be explained by the reduction in the physiological activity and in the production of biomass in addition to the diminution of light intensity as a result of the growth of the palms (Figure 2). For the dead plant cover, in turn, this decrease in the content of micronutrients may be associated with the increase in the decay process of plant tissues, causing the carbon volatilization and the release of nutrients through microbial activity (BRADY; WEIL, 2013; SEQUEIRA, 2007).

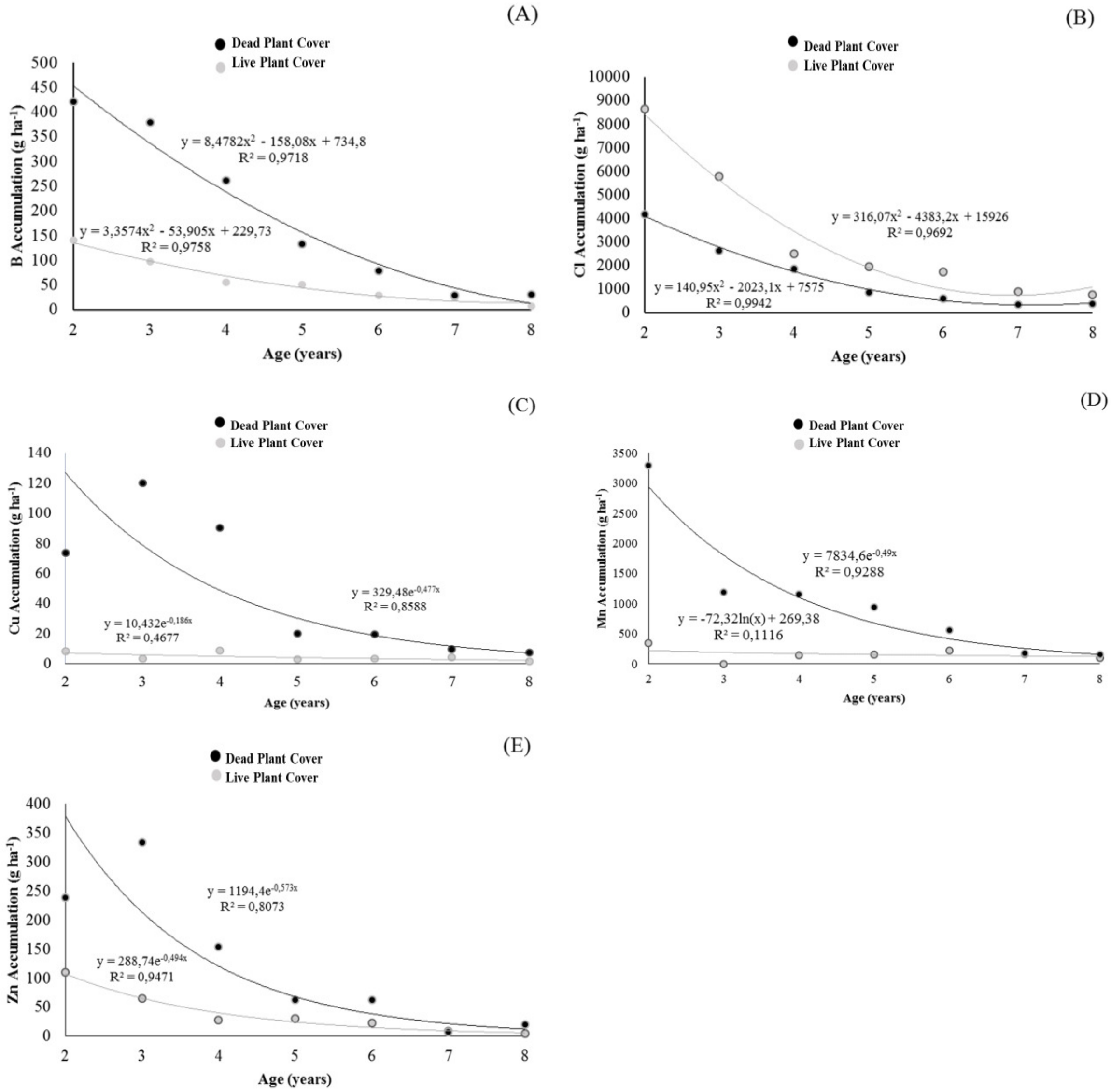

Figure 2. Contents of B (A), Cl (B), Cu (C), Mn (D) and Zn (E) (g ha^{-1}) in *Pueraria phaseoloides* L. according to the ages of plantation (years).

Such decrease in the contents of micronutrients caused by the organic matter mineralization and the subsequent release of these nutrients highlight the benefit provided to oil palm crop since the availability of these nutrients allows that such crop use them in its development, establishment, and reproduction. Clermont-Dauphin et al. (2016) presented similar conclusions when evaluating the association among kudzu established as a cover crop in rubber tree plantation by means of biomass analysis and nutrient transference between both species.

It was observed that the equation of adjustment for the content of B (g ha^{-1}) according to the time presented a polynomial fit as the best adjustment for live and dead plant cover data and both kudzu cover showed an accentuated reduction in the pattern for this micronutrient (Figure 2-A).

The dead plant cover presented greater accumulated values of B than the live plant cover. The greater B content in the dead tissue was 421.16 g ha^{-1}, while the live plant cover obtained 139 g ha^{-1} of B, both in the second year. This result might be explained by the large relationship between this nutrient and organic matter in tropical soils (ABREU et al. In NOVAIS et al., 2007). It is possible that the organic matter from the dead plant cover practices provides a considerable availability of B in the soil. Elevated values of B, as an essential element for cell enlargement and differentiation and root growth, are commonly found in legume species used as cover plants, according to Teixeira et al. (2008).

A significant decrease was also found for Cl in live and dead plant cover data according to the ages of plantation (Figure 2-B). The greatest Cl content was observed in the second year, which corresponded to 8,640.0 g ha^{-1} in the live biomass of kudzu and to 4170.0 g ha^{-1} for the biomass at the decomposition stage. Therefore, it is highlighted the superiority of live plant cover with regard to this micronutrient, which can be explained by the greater demand of this nutrient by the plants in comparison to other micronutrients, as Mn, Fe, and Zn, even in the later lifecycle stages of the vegetal due to its enzymatic, estomatic and osmoregulation roles (MALAVOLTA, 2006).

This also explains the fact that chlorine shows itself as the most extracted micronutrient by the plant. The greatest total content occurred in the second year with 1281.0 g ha^{-1}, and the smallest values occurred in seventh and eighth years with 1,240.0 and 1,130.0 g ha^{-1} of Cl, respectively. The reduction in the chlorine total content reached a value of 11.33 times higher. This higher Cl extraction by kudzu is beneficial because it helps in the supply of this nutrient for oil palm plants (VIÉGAS 1993).

It was verified that only in the cover with dead plants of kudzu, the decrease in the content of Cu was observed with planting age (Figure 2-C). In cover with live plants, although a reduction of copper content has occurred, such decrease was not enough to indicate considerable variations, differently from what was found by Silveira et al. (2005), who observed an increase in the concentration of this micronutrient and a subsequent diminution in tissues of *Cajanus cajan* (L.) Millsp. and *Stylosanthes guianensis* var. vulgaris cv. Mineirão used as cover crops. For the dead plant cover, even with the reduction in the content of Cu just at three years of implantation, the regression curve followed an exponential adjustment with a decreasing tendency.

For values of Mn, the accumulated amounts of manganese in live and dead plant cover showed a logarithmic and exponential adjustment, respectively (Figure 2-D). The content of dead plant cover denoted a decrease as plants got older, which did not occur in the live plant cover. This fact is probably due to the decomposition of the dead plant cover and to the increase of availability of nutrients in the soil in contrast with the content of nutrients in tissues of live plants. The highest content of Mn in dead kudzu plants cover was 3,289.55 g ha^{-1}, which occurred in the second year and for the years seven and eight, such content corresponded to 177.43 g ha^{-1} and 153.19 g ha^{-1}, respectively. Thus, Mn was the micronutrient that presented the highest amount of total extraction by kudzu plants, especially for the second age (2 years).

Manganese extraction obtained by Guerrini (1983) in *Pueraria phaseoloides* L. plants in the third year was 2450 g ha^{-1} and in the fourth year, it was 6285,3 g ha^{-1} which is greater than that determinate in present study (1,345.1 g ha^{-1} and 1,301.8 g ha^{-1} of Mn, respectively). Pittelkow et al. (2012) evaluated the accumulation of Mn in some cover crops, such as crotalaria (*Crotalaria juncea* L.) and millet (*Pennisetum glaucum* (L.) R. Br.) and they found values of Mn content of 158.8 kg ha^{-1} for crotalaria and 200.1 g ha^{-1} for millet, drawing back to the superiority of *Pueraria phaseoloides* L. in relation to the content of this micronutrient when compared to other cover crops.

For Zn, the best model fit was the exponential for both covers of *Pueraria phaseoloides* L.. The content of Zn was also reduced as the plantation aged, following a chronological sequence except for the second and the seventh years in dead cover (Figure 2-E). The amount of zinc in the second year in the dead cover was higher than green cover and corresponded to 109.82 g ha^{-1} of Zn in the second year. The content of Zn found in *Pueraria phaseoloides* L. plants was greater than in the other cover crops such as crotalaria (*Crotalaria juncea* L.), Sesban (*Sesbania sesban* (L.) Merr.), lab lab (*Dolichos lablab* cv. Rongai) and pigeon pea (*Cajanus cajan* (L.) Millsp.), which were studied by Cavalcante et al. (2012).

CONCLUSIONS

The decreasing order of extraction of micronutrients from *Pueraria phaseoloides* L. was, as follows: Cl > Mn > B > Zn > Cu.

The reduction in the contents of nutrients in dead plant cover denotes the possibility of nutrients availability in the soil for oil palm crop. Therefore, the adoption of *Pueraria phaseoloides* L. as soil cover plant might be a suitable practice in order to provide micronutrients for oil palm crop.

RESUMO: A adoção de plantas de cobertura em plantios comerciais tem se mostrado uma alternativa para promover ao solo maior proteção, melhorias em sua estrutura e agregação e otimização de acúmulo e ciclagem de nutrientes visando maior produção de biomassa e maior fixação de N_2. Com o objetivo de determinar o acúmulo de micronutrientes puerária (*Pueraria phaseoloides* L.), em função da idade, estabelecida como cobertura de solo em plantações industriais de dendezeiros, instalou-se experimento na Companhia Real Agroindustrial (CRAI) no município de Tailândia, Estado do Pará, em Latossolo Amarelo. O delineamento experimental foi o de blocos ao acaso com quatro repetições. Os resultados permitem concluir que: o acúmulo de nutrientes com exceção do Mn e Cu na cobertura verde de *Pueraria phaseoloides* L., reduziu com o decorrer dos anos; os de B, Mn, Zn e Cu foram maiores na cobertura morta, enquanto que o de Cl na cobertura verde. A ordem decrescente da extração total de micronutrientes foi: Cl > Mn > B > Zn > Cu.

PALAVRAS-CHAVE: Extração de Micronutrientes. Leguminosa. Cobertura Verde e Morta. Cultivo de dendê.

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