

RUBBER TREE RESPONSE TO N, P AND K DOSES IN FERTILIZATION AT PLANTING

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Resumo

Resposta da seringueira a dosagens de N, P e K em adubação de plantio. O objetivo desse estudo foi avaliar, sob condições de casa de vegetação, o crescimento, acúmulo de massa seca de raiz e parte aérea e o estado nutricional da fase inicial de cultivo da seringueira, em diferentes combinações de doses de nitrogênio (N), fósforo (P) e potássio (K). Foram testadas as combinações das seguintes doses: (0, 20, 40 e 80 kg ha⁻¹ de N), (0, 50, 100 e 200 kg ha⁻¹ de P₂O₅) e (0, 25, 50 e 100 kg ha⁻¹ de K₂O). As combinações de adubação N, P e K aplicadas no plantio de mudas da seringueira em casa de vegetação somente apresentaram respostas significativas em crescimento em função da ausência de N e presença desse nutriente na dose de 80 kg ha⁻¹. Os resultados da análise foliar demonstram que as adubações nitrogenadas e fosfatadas de plantio estão suprindo adequadamente as necessidades da cultura, enquanto as doses de potássio testadas não atingiram os níveis adequados de suficiência para a seringueira.

Palavras-chave: *Hevea brasiliensis*; nutrição de plantas; biomassa aérea e radicular

Abstract

The objective of this study was to evaluate the growth, root and shoot dry mass accumulation and nutritional status of rubber tree in the initial stage of cultivation, under different combinations of nitrogen (N), phosphorus (P) and potassium (K). Combinations of the following doses were tested: 0, 20, 40 and 80 kg ha⁻¹ of N; 0, 75, 150 and 300 kg ha⁻¹ of P₂O₅; and 0, 25, 50 and 100 kg of K₂O. Under the soil and climate conditions analyzed, the combinations of NPK fertilization applied at planting only caused significant growth responses of rubber tree plants as a function of the absence of N and its presence at the dose of 80 kg ha⁻¹. Through leaf analysis it was possible to verify that N fertilization and P fertilization are adequately meeting the needs of rubber tree plants, while the K doses tested did not reach the adequate levels of sufficiency.

Keywords: *Hevea brasiliensis*; plant nutrition; shoot and root biomass

INTRODUCTION

Currently, Brazil accounts for approximately 1% of the global production of natural rubber, but despite this small contribution, the sector has great importance in the country, which is confirmed by the presence of numerous rubber processing industries, especially pneumatic, and by a demand that is still far from being met by national production (RODRIGUES; COSTA, 2009; GONÇALVES *et al.*, 2010; BARRETO *et al.*, 2016). According to Sampaio Filho *et al.* (2006), the projection of consumption of natural rubber in Brazil, by the year 2030, can reach 1 million tons. Due to this increase in the demand for natural rubber, in Brazil there is an expansion of the areas destined for the planting of rubber trees for latex production (ABRAF, 2012).

The continued requirement in the absorption of macronutrients by rubber tree (*Hevea brasiliensis*), added to the fact that majority of its planting is carried out in lands with low natural fertility, highlights the importance of correction and maintenance fertilization via fertilizers in the various stages of crop development (GONÇALVES *et al.*, 2010; DAMRONGRAK *et al.*, 2015). According to Cavalcante and Conforto (2013), the routine use of soil analysis and assessment of the nutritional status of rubber tree leaves are an important basis for the identification of yield-limiting nutritional factors.

Thus, good development of rubber tree in the field, after transplantation, depends greatly on its nutritional status (CAVALCANTE and CONFORTO, 2013), because young plants grow with continuous flushes of new leaves until the fourth or fifth year of age, and it is in this period that the absorption of nutrients essential for plant growth and

development occurs. In the same period, the production of seeds begins and, around six or seven years, the production of latex begins.

Therefore, an adequate, balanced fertilizer recommendation in the early stages of rubber tree cultivation will assist in the production of plants with high vigor and yield (SALISU and DAUD, 2016). In the literature, there are few recent studies detailing the issue of rubber tree fertilization and nutrition in Brazil (CORREIA *et al.*, 2017), especially in its initial stage of transplanting.

Thus, the objective of this study was to evaluate under greenhouse conditions the growth, root and shoot dry mass accumulation and nutritional status of rubber tree in the initial stage of cultivation, under different combinations of nitrogen (N), phosphorus (P) and potassium (K) doses.

MATERIAL AND METHODS

The fertilization experiment was conducted in a greenhouse, during the period between June 25, 2015 and January 10, 2016.

Seedlings of the rubber tree clone FX 3864 were produced by grafting on a GT 1 clone rootstock at the State Center for Agroforestry Research (CEPA) of the Rio de Janeiro State Agricultural Research Company (PESAGRO), located in the municipality of Silva Jardim, RJ, Brazil.

In the experiment, the following doses were tested: 0, 20, 40 and 80 kg ha⁻¹ of N; 0, 50, 100 and 200 kg ha⁻¹ of P₂O₅; and 0, 25, 50 and 100 kg ha⁻¹ of K₂O, which were combined and resulted in different doses between the N-P-K doses (0-0-0; 20-50-25; 40-100-50 and 80-200-100, for instance). N-P-K fertilization doses were applied in each pot and later homogenized for seedling planting.

The experiment was carried out in a completely randomized design in a factorial scheme, where the different N-P-K doses were combined, with 3 replicates. Each replicate was composed of one rubber tree plant at 36 months of age, and 192 experimental units were used. The average height of the plants was 51 cm and they were cultivated in plastic pots with capacity for 12 liters, where 10 kg of soil were added. Roots were not pruned for the implementation of the experiment.

The pots were filled with material from the 0-20 cm layer of a medium-textured *Argissolo Amarelo* (Ultisol). The principal chemical and physical soil attributes were as follows: pH H₂O (5.0); P (5.3 mg dm); Ca+Mg (2.8 cmol_c dm⁻³); Al (0.2 cmol_c dm⁻³); K (0.2 cmol_c dm⁻³); H+Al (4.0 cmol_c dm⁻³); sum of bases (2.9 cmol_c dm⁻³); cation exchange at pH 7.0 (6.9 cmol_c dm⁻³); base saturation (40%); organic carbon (15.3 g kg⁻¹) and clay content (280 g kg⁻¹). Material of this soil order was collected for the experiment because most areas suitable for rubber tree cultivation in the state have this type of soil.

Liming was not performed, since base saturation was close to the recommended level (50%) for rubber tree cultivation (BATAGLIA *et al.*, 1998). The plants were irrigated maintaining 60% of soil field capacity, and the average temperature within the greenhouse during the experiment was 31.8 °C.

After the installation of the experiment, monthly up to 176 days, plant height was evaluated with a measuring tape and shoot diameter was measured just above the grafting point with a digital caliper.

At the end of 176 days, the plants were carefully collected and taken to the laboratory, where they were separated into roots, stem and leaves. The samples were placed in a forced air circulation oven at 65 °C and kept until they reached constant weight. After drying, the samples were weighed to obtain root dry mass (RDM), stem dry mass (SDM) and leaf dry mass (LDM). For the evaluation of the nutritional status of the seedlings, the leaves were ground in a Wiley-type mill. N contents were determined using the Dumas method in an N analyzer device (*Rapid N - Elementary* brand). The nitric-perchloric digestion method was used to determine the P and K contents, according to Malavolta *et al.* (1997).

The results were subjected to analysis of normality of error distribution (Lilliefors test) and homogeneity of error variance (Cochran test). As the assumptions of normality and homogeneity were met, the mean values were compared using the Tukey test at 5% probability level.

RESULTS

There was no significant interaction between the N, P and K doses applied for the variables root dry mass, stem dry mass, leaf dry mass and total dry mass. Root dry mass differ only as a function of N doses (Table 1). The highest value of root dry mass was observed in the absence of N (N dose of 0 kg ha⁻¹).

Table 1. Dry mass of roots, stem, leaves and total of rubber tree at 176 days of planting.
 Tabela 1. Massa seca da raiz, caule, folha e total da seringueira aos 176 dias de plantio.

N doses (kg ha ⁻¹)	Root	Stem	Leaf	Total
		(grams)		
0	31.3a	21.3a	21.9ab	74.6a
20	26.6b	18.4a	19.0b	64.0b
40	26.3b	19.1a	21.7ab	67.2ab
80	26.0b	20.3a	22.7a	69.1ab

Means followed by the same letter do not differ statistically from each other, by Tukey test at 5% probability level.
 Médias seguidas de mesma letra não diferem estatisticamente entre si, pelo teste de Tukey a 5% de probabilidade.

For stem dry mass, there was no difference in relation to the N, P and K doses applied. On the other hand, for leaf dry mass and root dry mass, difference was also only observed for the N doses applied, where the highest dose of N fertilizer (80 kg N ha⁻¹) promoted higher leaf mass compared to the lowest dose (20 kg N ha⁻¹) (Table 1). Considering only this result, it is not possible to affirm about the positive effect of this treatment, because the control treatment (0 kg N ha⁻¹) led to the same amount of leaf mass as the two N doses mentioned above.

When considering the values of total dry mass (root+stem+leaves), there were also no differences in the application of P and K, only for the doses of N (Table 1). There was only a higher value of total dry mass in the treatment with N dose of 0 kg ha⁻¹, compared to the N dose of 20 kg ha⁻¹ (Table 1). The absence of N application may have stimulated root development and thus contributed to a higher value of total dry mass.

There were no significant interactions between the applied doses of N, P and K for the variables stem diameter and plant height. The increase in stem diameter showed no difference as a function of the N, P and K doses applied (Figure 1). The comparison in the graph is made separately by nutrients (N with N, P with P, and K with K) between doses.

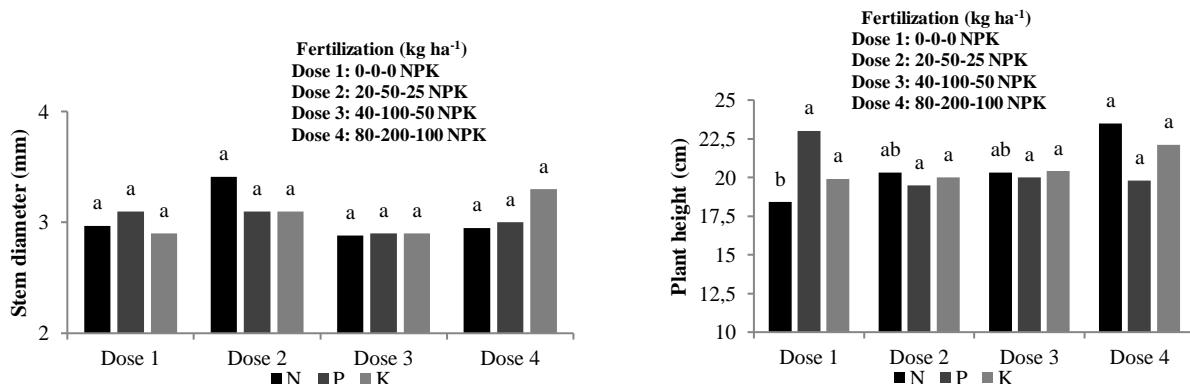


Figure 1. Stem diameter (a) and plant height (b) of rubber tree at 176 days after planting.
 Figura 1. Diâmetro de caule (a) e altura de plantas (b) da seringueira aos 176 dias após o plantio.

For plant height after 176 days of planting, differences were observed as a function of N doses (Figure 1b), and the application of the highest dose (80 kg N ha⁻¹) resulted in a greater growth in height compared to the control (without N application).

Regarding the absence of difference regarding the applications of P doses, there are few studies in the literature that have evaluated the total dry mass production of rubber trees after planting to allow some comparison. The comparison in the graph is made separately by nutrients (N with N, P with P and K with K) between doses.

Figure 2 shows that the highest N dose applied promoted the highest N contents in the leaves, while in the presence of P and K, the doses of 50 kg ha⁻¹ of P and K contributed to the highest N contents in the leaves. For a better understanding of this interaction between nutrient doses, it can be observed in Figure 3 that the interaction between these three doses of N, P and K (80-50-50) was responsible for the highest N content in the leaves.

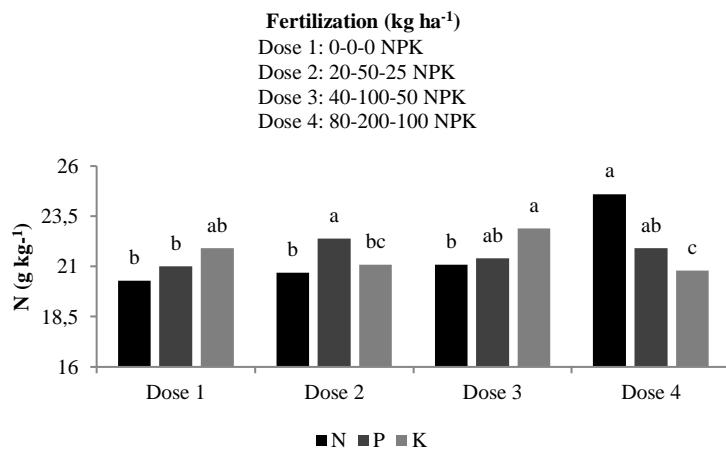


Figure 2. N contents in the leaf as a function of the individual doses of N, P and K.
 Means followed by the same letter do not differ statistically from each other, by Tukey test at 5% probability level.
 Figura 2. Teores de N na folha em função das doses isoladas de N, P e K.
 Médias seguidas de mesma letra não diferem estatisticamente entre si, pelo teste de Tukey a 5% de probabilidade.

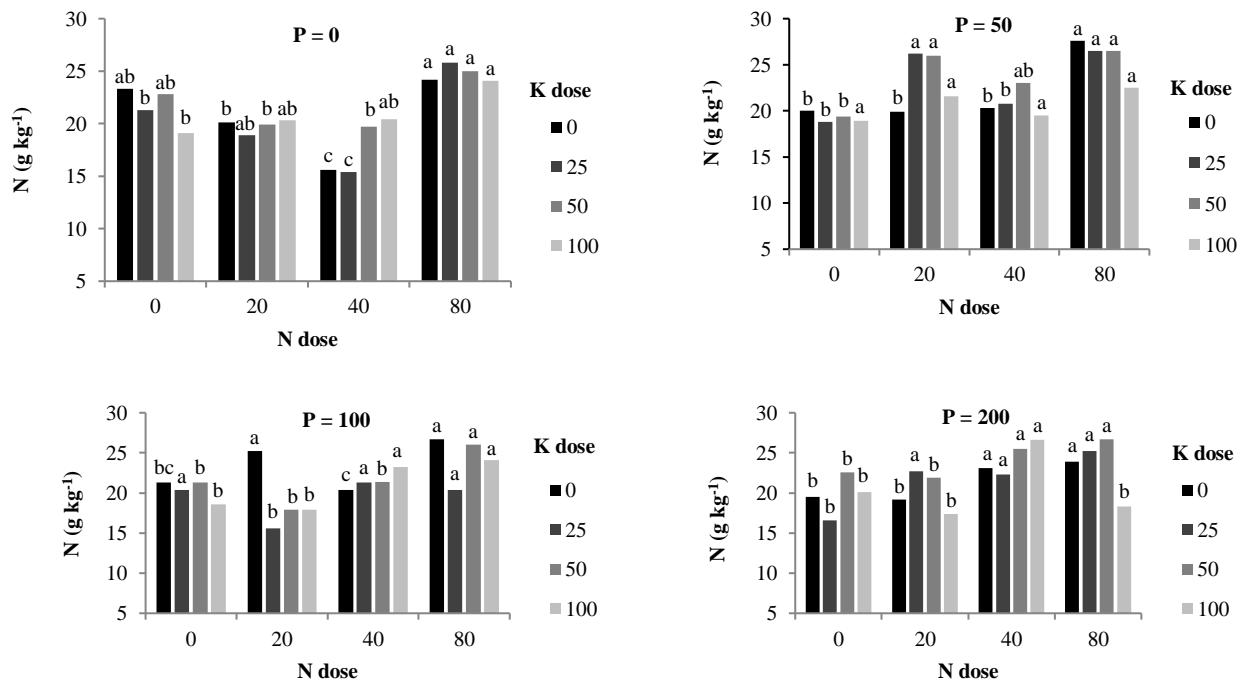


Figure 3. N contents in the leaf as a function of N, P and K dose interactions. Means followed by the same letter do not differ statistically from each other, by Tukey test at 5% probability level.
 Figura 3. Teores de N na folha em função das interações das doses N, P e K.
 Médias seguidas de mesma letra não diferem estatisticamente entre si, pelo teste de Tukey a 5% de probabilidade.

The highest P contents in the leaves were quantified under individual doses of N (20 kg ha⁻¹) and P (100 and 200 kg ha⁻¹), and no differences were observed between the K doses tested (Figure 4). By evaluating the interaction between the N, P and K doses on the P contents in the leaves, it is possible to state that the N-P-K dose of 20-100-0

promoted the highest P contents in rubber tree leaves (Figure 5). The comparison in the graph is made separately by nutrients (N with N, P with P and K with K) between doses.

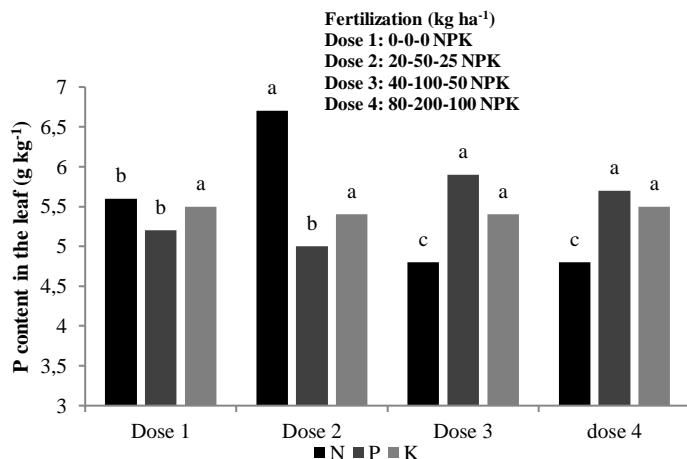


Figure 4. P content in the leaf as a function of the individual doses of N, P and K.

Figura 4. Teores de P na folha em função das doses isoladas de N, P e K.

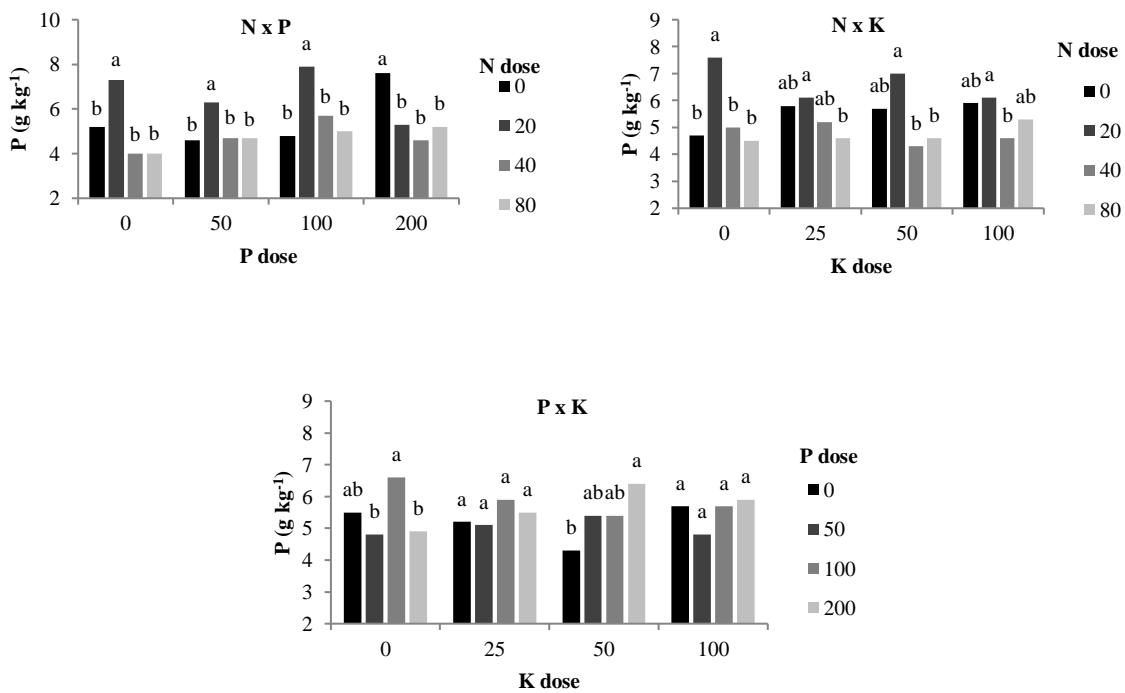


Figure 5. P content in the leaf as a function of N, P and K dose interactions.

Means followed by the same letter do not differ statistically from each other, by Tukey test at 5% probability level.

Figura 5. Teores de P na folha em função das interações das doses N, P e K.

Médias seguidas de mesma letra não diferem estatisticamente entre si, pelo teste de Tukey a 5% de probabilidade.

The highest K contents in the leaves were quantified when the highest doses of this nutrient were applied (Figure 6).

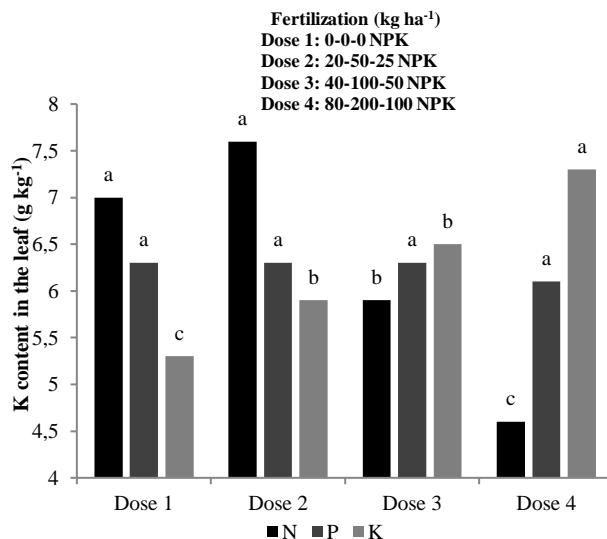


Figure 6. K contents in the leaf as a function of individual doses of N, P and K.
Figura 6. Teores de K na folha em função das doses isoladas de N, P e K.

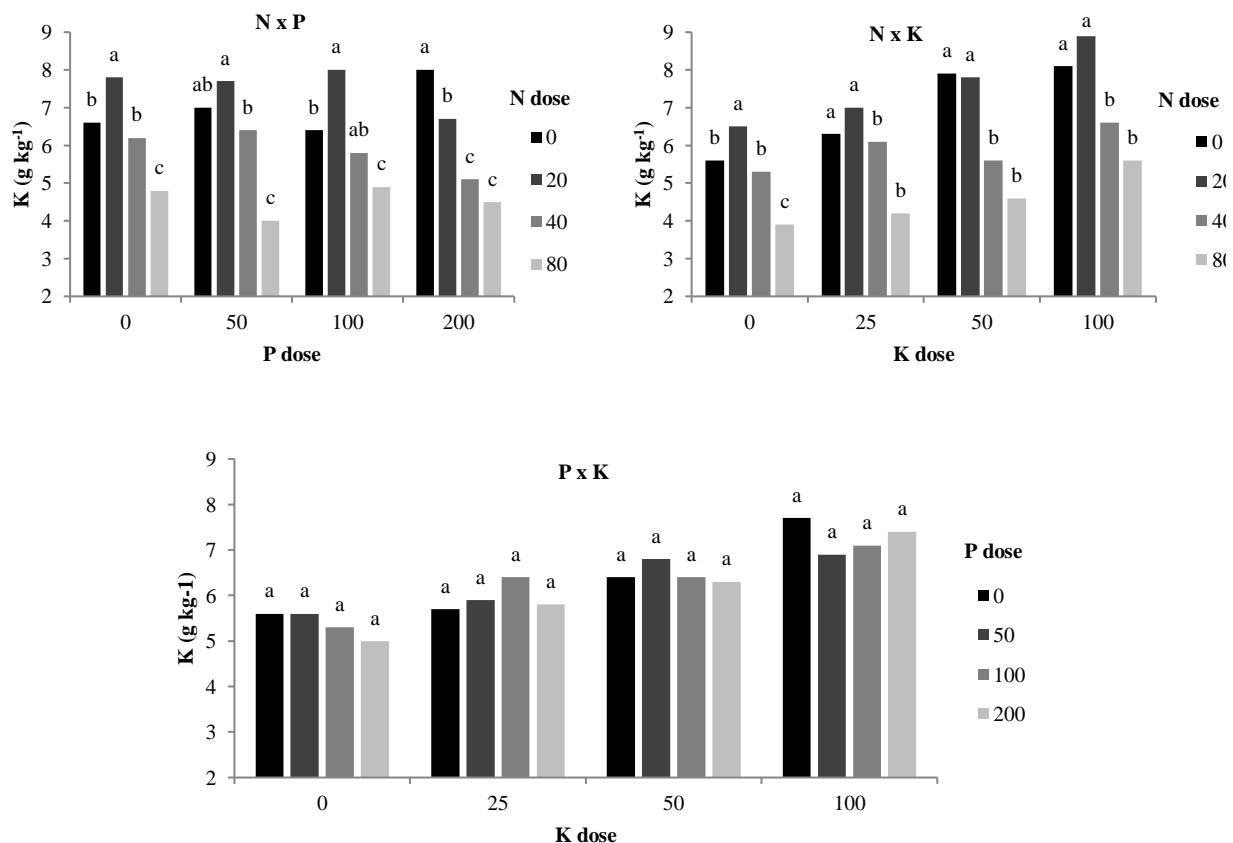


Figure 7. K contents in the leaf as a function of N, P and K dose interactions.

Means followed by the same letter do not differ statistically from each other, by Tukey test at 5% probability level.

Figura 7. Teores de K na folha em função das interações das doses N, P e K.

Médias seguidas de mesma letra não diferem estatisticamente entre si, pelo teste de Tukey a 5% de probabilidade.

DISCUSSION

The results observed for root dry mass can be attributed to the greater investment of the plant in roots to explore the soil N and thus supply its deficiency. It can also be affirmed that, in the presence of N fertilizer, the plant invests less in root growth, considering that it already has the supply of this nutrient more easily and available. This pattern is characteristic of rubber tree plants. According to Pereira *et al.* (1998), the rubber tree root system under conditions of water and/or nutritional stress invests in the production of large volume of roots to explore water and nutrients in more subsurface layers. This allows rubber trees to explore a larger volume of soil, utilizing nutrients located in deeper layers, which promotes a greater benefit for the crop (Pereira *et al.*, 1998). For the patterns observed for leaf dry mass and root dry mass, it can be inferred that the higher root development of rubber tree in the absence of N fertilizer (Figure 1) was efficient in supplying the plant with soil N for the formation of stem and leaves. An example of this is described in the work of Cabezas (2011) with corn crop, in which the author reports that the absence of N fertilizer application can be supplied by the gradual release of nutrients during the decomposition of soil organic matter and that in these circumstances the plant invests in root system to search for limiting nutrients.

Regarding the variables stem, leaf and total dry masses, the absence of difference for the stem occurred due to the short evaluation time of the experiment, because certain trends of the results that have not yet become significant were observed. Bataglia *et al.* (1999) when evaluating the effect of N, P and K fertilization on rubber trees, verified the first significant responses in plant growth at 24 months after planting.

In relation to stem diameter, absence of significant interactions between N, P and K doses was also verified by Bataglia *et al.* (1999), who evaluated rubber tree plants after 12 months of planting and found no differences for this variable under increasing doses of P and K. It can be inferred that this situation occurred in both studies because this variable only begins to show a significant response after 24 months of age, or just over a year after the beginning of fertilizer applications.

For plant height, the occurrence of differences for N doses, after 176 days, at the highest dose of N (80 kg ha⁻¹) helps in understanding the dynamics of absorption and investment of N in rubber tree, that is, when this result (Figure 3b) is compared with the values of root dry mass (Figure 1), it is possible to verify that, with the lack of N, the plant invests in its root system to explore more soil and absorb N, slightly delaying the development in height, whereas, with available N from the fertilizer, the plant starts to invest more in shoots (height) and less in the root system. This inverse situation clearly shows the response to or need for N supply in this development stage of rubber tree.

In a general analysis of these evaluations of total dry mass and height of rubber tree, it can be noted that this plant in its initial stage (176 days after planting) did not respond to fertilizations with P and K. This result can be attributed to the short evaluation time (BATAGLIA *et al.*, 1999), as discussed previously, and to the sufficiency of the tested soil to provide these nutrients for this plant. However, it is worth pointing out that the absence of these nutrients in the fertilization of this crop should not be recommended as a common practice, as such nutrients exported by the crop should be replaced to the soil, avoiding its degradation. Divergent results were found by Correia *et al.* (2017), who evaluated rubber tree plants at 35 days after planting and obtained a maximum total dry mass production of 141.72 g of plant⁻¹ at a rate of 0.2 kg m⁻³ of K₂O. It is believed that this contradiction of results originated from the different edaphic-environmental conditions between the experiments (BATAGLIA *et al.*, 1999), as a clayey *Latossolo* (Oxisol) was used for the experiment in Araguatins-TO in the work of Correia *et al.* (2017).

One of the ways to evaluate whether fertilization is adequately meeting the needs of the plant is through leaf analysis (BATAGLIA *et al.*, 1999). For a better understanding of this interaction between nutrient doses, it can be seen in Figure 5 that the interaction between these three doses of N, P and K (80-50-50) was responsible for the highest N content in the leaves. It is also emphasized that these N contents in the leaf with this combination of N, P and K doses are within the range considered suitable for rubber tree (26-35 g kg⁻¹) (MENDES *et al.*, 2012). These results show that, although the growth variables discussed above did not show significance under the increasing doses of P and K applied, when the possible interactions between nutrients in leaf tissue are analyzed with greater discrimination, it is possible to note total interdependence between the macronutrients N, P and K, supplied via fertilization (Bataglia *et al.*, 1999).

For P, low values of the interaction between N and P were also verified by Bataglia *et al.* (1999), who also found this pattern in the interaction between N and P in rubber tree cultivation. The authors mention that, in the absence

or at low doses of K fertilization, the relationships between N and P must be seriously considered in fertilization. The P contents in rubber tree leaves in this treatment (20-100-0) were higher than the reference values considered adequate (2.0 to 2.5 g kg⁻¹) (GARCIA *et al.*, 1999). In addition, in any of the treatments, including the control, the P contents quantified in the leaf were below the range considered adequate, that is, it can be said that the soil was sufficient to provide P for the plants and that the supply of nutrients via fertilizers acted as maintenance fertilization.

Regarding K, low contents were observed in the leaves but, regardless of treatment, the values found in the leaf are below those considered adequate (2.0 to 2.5 g kg⁻¹) for this crop (GARCIA *et al.*, 1999). These results may be due to the redistribution of this cation to the stem (Correia *et al.*, 2017).

When the highest doses of N were applied, there was a reduction in the K contents in the leaf (Figure 6). The opposite was also verified for N contents in the leaf under the highest doses of K (Figure 3). The combination of the lowest doses of N with the highest doses of K and intermediate doses of P in the combination N, P and K (20-50-100) was the one that contributed to the highest contents of K in the leaves (Figure 7). This antagonism between N and K in the leaf can be explained by the fact that the distribution of N as soluble compounds and proteins in the leaves is compromised by the increase in K contents (RODRIGUES *et al.*, 2013).

The relative order of macronutrient contents in rubber leaves found in this study was: N>K>P, and these results were in agreement with those found by Mendes *et al.* (2012), who evaluated the dynamics of mineral nutrients during the different leaf stages of RRIM-600 clone plants from a rubber tree plantation located in Nepomuceno, MG.

CONCLUSIONS

- Under the edaphoclimatic conditions analyzed, the absence of N application stimulated root growth, but the dose that generated the best ranges of adequate concentration of this nutrient in the leaf and greater plant height compared to the control was 80 kg ha⁻¹ of N.
- Through leaf analysis, it was possible to verify that nitrogen fertilization and phosphate fertilization at planting are adequately supplying the needs of rubber tree plants, whereas the potassium doses tested did not reach the adequate levels of sufficiency.
- Among all the interactions analyzed, the 80-50-100 (N, P and K) dose can be considered the most appropriate and the one with best cost/benefit ratio, because it promoted in leaf analysis adequate levels of N, twice the adequate level of P and about half of the adequate level of K. However, new experiments should be carried out mainly focusing on K fertilization, because the doses analyzed in this experiment could not reach the appropriate concentration range of this nutrient in the leaf. In addition, an antagonism was observed in the N and K contents in the leaf, where low potassium supply favors nitrogen accumulation, and vice versa.

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