Nitrogen and phosphorus fertilization in upland rice in the municipality of Humaitá at Amazonas State

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ABSTRACT

The fertilization management can contribute to a better agronomic performance of rice (*Oryza sativa* L.) plants in upland conditions. Thus, the objective in this study was to evaluate the development of rice plants fertilized with different doses of nitrogen and phosphorus in upland soil. The experiment was conducted in a greenhouse using pots containing soil collected in the soil top layer of a plinthic alitic Haplic Cambisol. The design was completely randomized with a 4 x 4 factorial scheme, corresponding to 0 (zero), 150, 300 and 450 kg ha^{-1} of phosphorus and 0 (zero), 100, 200 and 300 kg ha^{-1} of nitrogen. Plant height, shoot dry matter, grain weight and number of tillers were evaluated. Fertilization with nitrogen and phosphorus positively affects the growth and development of rice plants in Humaitá, Amazonas state, grown in upland soil up to doses between 200 and 300 kg ha^{-1} of N and around 300 kg ha^{-1} of P_2O_5, in a plinthic alitic Haplic Cambisol.

Keywords: *Oryza sativa* (L); fertilizer; cambisol.

INTRODUCTION

Rice is one of the most important annual crops in Brazil, economically and socially (Zanin *et al.*, 2019). The irrigated rice is the main production systems in national production, with 80% of the cultivated area (Conab, 2022), however the upland rice cultivation can be an alternative in regions where edaphoclimatic conditions make it difficult to grow rice flooded.

Under upland rice growing conditions, nitrogen and phosphorus are important nutrients to achieve high productivity. Nitrogen (N) stimulates rice root system growth and increases the number of stalks and panicles per area, the number of spikelets per panicle, fertility, grain weight and the percentage of protein in the grains (Farinelli *et al.*, 2004).

However, high N levels in the plants can increase the crop's susceptibility to blast and promote plant laying, which interferes with the harvesting process and accentuates the hydric stress effects, especially in the plant's reproductive phase (Hernandes *et al.*, 2010; Ishfaq *et al.*, 2021).

Currently, it has been observed the use of higher doses of N in the upland rice cultivation system, mainly when the most responsive cultivars are adopted or in systems where the water availability is not limiting (Cancellier *et al.*, 2011). Researches indicate a positive response of upland rice crop to nitrogen fertilization (Barreto *et al.*, 2012; Fidelis *et al.*, 2012; Prado *et al.*, 2019).

The phosphorus (P) contents in the soil solution are generally very low in Brazilian soils and this characteristic, associated with the high capacity of soils to adsorb phosphorus in the solid phase (Brady & Weil, 2014; Rittmann *et*

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al., 2011) is the main limitation for the development of any profitable agricultural activity. Therefore, it is necessary to apply high amounts of phosphate fertilizers to meet the plant's needs (Souza & Lobato, 2003).

The phosphorus is a non-mobile nutrient and the root ion contact occurs by diffusion, forcing a constant growth of the root system. The soil P diffusion is more limiting for P uptake than the root uptake rate (Araújo, 2000). Density, diameter and length of root hairs are factor that affecting P uptake by plants (Jorhi *et al.*, 2015; Kaiser *et al.*, 2015; Van de Wiel *et al.*, 2016).

Tillering, plant height, root system development, grain quality and seed formation are influenced by the P content available to the rice plant (Fageria, 1992; Tabar, 2012). Thus, phosphate fertilization is essential to raising levels in the soil solution and increase crop productivity (Crusciol *et al.*, 2013; Fageria & Oliveira, 2014).

An interaction was observed between the NPK treatments in the upland rice cultivation on Oxisols (Fageria & Oliveira, 2014). Also, Du *et al.* (2022) verify NPK interaction effect in increase grain yield. Study of interaction effect of N and P-fertilizer was significant in fertile tiller and 1000-grain weight (Tabar, 2012). In the same way, Hasanuzzaman *et al.* (2012) observed a significant interaction between the fertilization of rice plants with N and P.

In this context, this study aimed to evaluate increasing doses of nitrogen and phosphorus in the growth and development of rice plants (*Oryza sativa* L.) in a greenhouse in the municipality of Humaitá in Amazonas state.

MATERIAL AND METHODS

The experiment was carried out in a greenhouse at the Institute of Education, Agriculture and Environment of the Federal University of Amazonas in the municipality of Humaitá.

The climate of the southern region of Amazonas, according to Koppen classification, is tropical rainy type (monsoon type rainfall), with an average rainfall of 2500 mm, annual average temperatures vary between 25 ºC and 27 ºC and relative humidity between 85 and 90% (Brasil, 1978; Alvares *et al.*, 2014).

The test was carried out using soil collected in the 0.0 – 0.20 m layer of a plintic alitic Haplic Cambisol, with 42% clay, which the chemical characteristics: pH ($CaCl_2$) = 4.37; 22.51 g dm^{-3} of MO; P = 1 mg dm^{-3}; K = 30 mg dm^{-3}; Ca = 2.37 cmol$_c$ dm^{-3}; Mg = 0.87 cmol$_c$ dm^{-3}; H + Al = 5.94 cmol$_c$ dm^{-3}; V = 41.2%.

Five liters pots were used, which were filled with soil. Dolomite limestone was used as a filler with 100% PRNT, applying the equivalent of 1.12 Mg ha^{-1}. The pots were individually covered with plastic bags and kept moist for 30 days.

The treatments were doses of 0 (zero), 150, 300 and 450 kg ha^{-1} of phosphorus, equivalent to P_2O_5, and 0 (zero), 100, 200 and 300 kg ha^{-1} of nitrogen, equivalent to N. The fertilizers used were triple superphosphate as a source of phosphorus and urea as a source of nitrogen. It was used a completely randomized design with a 4 x 4 factorial scheme corresponding to the levels of nitrogen and phosphorus (P_0N_0, $P_{150}N_0$, $P_{300}N_0$, $P_{450}N_0$, P_0N_{100}, $P_{150}N_{100}$, $P_{300}N_{100}$, $P_{450}N_{100}$, P_0N_{200}, $P_{150}N_{200}$, $P_{300}N_{200}$, $P_{450}N_{200}$, P_0N_{300}, $P_{150}N_{300}$, $P_{300}N_{300}$ and $P_{450}N_{300}$), with four replications.

Nitrogen fertilization was applied in three portions with the equivalent of 100 kg ha^{-1} per application. The first application was carried out with sowing and the other two every 20 days. Phosphorus was applied in a single dose, incorporating it into the soil immediately before sowing. All pots received potassium chloride fertilizer, using the equivalent of 75 kg ha^{-1} of K_2O.

Sowing was carried out using 6 seeds per pot and after germination and emergence the seedlings were thinned, leaving two plants per pot. Rice seeds of cultivar BRS Primavera were used.

Plots were evaluated for the plant height: obtained by measuring the plants in each plot, at 40 and 80 days after sowing, considering the height from the soil surface to the insertion of the last fully expanded leaf; number of tillers: counting the number of tillers per plot at 40 days after sowing; grain weight: weighing of grains per plot at harvest time; shoot dry matter: 80 days after sowing, the plants of each plot were cut close to the ground and dried in a forced air circulation oven at 60 ºC until constant weight.

The data obtained were subjected to analysis of variance and polynomial regression analysis, through the SISVAR software (Ferreira, 2019).

RESULTS AND DISCUSSION

It is observed a significant difference between doses of phosphorus in the height of plants at 40 of 80 days after sowing. The weight of grains and number of tillers showed significant difference for the isolated effects of nitrogen and phosphorus doses. Finally, it was observed a significant effect for the nitrogen and phosphorus interaction on shoot dry matter (Table 1).

Table 1: Analysis of variance of plant height at 40 (PH40) and 80 days (PH80), weight of grains (WG), shoot dry matter (SDM) and number of tillers (NT) of rice plants fertilized with nitrogen and phosphorus

SV	DF	Mean Squares				
		PH40	PH80	WG	SDM	NT
Nitrogen (N)	3	35.62^{ns}	55.50^{ns}	66.61**	366.00**	8.87**
Phosphorus (F)	3	9959.04**	4700.79**	676.56**	1694.31**	86.21**
N*F	9	48.96^{ns}	116.31^{ns}	7.45^{ns}	47.60**	1.31^{ns}
Residual	48	97.70	78.56	4.13	9.40	0.70
C.V. (%)	-	12.62	8.84	17.12	16.47	19.15

**Significant at 1% probability; ^{ns}Not significant; SV: source of variation; DF: degrees of freedom; C.V.: coefficient of variation.

With the increase in the phosphorus dose, a significant increase in plant height was observed at 40 and 80 days after sowing, reaching the maximum height at the doses of 309.14 kg ha^{-1} and 303.54 kg ha^{-1} of phosphorus, respectively (Figure 1). Also, Fageria & Oliveira (2014) verified a positive effect of the phosphorus level on the growth of upland rice. Growing rice in upland soil in an environment with low phosphorus content can result in plants with shorter heights (Fidelis *et al.*, 2015).

According to Fageria (1992), the soil phosphorus content interferes on rice plant height growth, tillering, the development of the root system and the formation of seeds. In plants, phosphorus is an essential element for plant growth, being part of the composition of nucleic acids, DNA and RNA, ATP and phospholipids, and acting in photosynthetic and enzymatic regulation (Marschner, 2012). Thus, in soils with low levels of this nutrient, it must be replaced by phosphate fertilizers.

There was a significant increase in plant shoot dry matter when nitrogen fertilization was carried out, associated with the application of phosphorus, except for the zero dose of phosphorus, for which no significant response to the nitrogen application was observed (Figure 2A). The higher soil phosphorus availability through fertilization significantly increases the macronutrient content in the upland rice plant cultivars (Crusciol *et al.*, 2013), enabling greater plant growth and response to nitrogen fertilization.

The increase in the nitrogen dose showed a linear increase in dry matter for the doses of 300 and 450 kg ha^{-1} of phosphorus. For the dose of 150 kg ha^{-1} of P_2O_5 there was a quadratic dry matter response to the increase in N application (Figure 2A). In this condition, it is probably that the limitation in phosphorus availability has reduced the plant's response to higher doses of nitrogen.

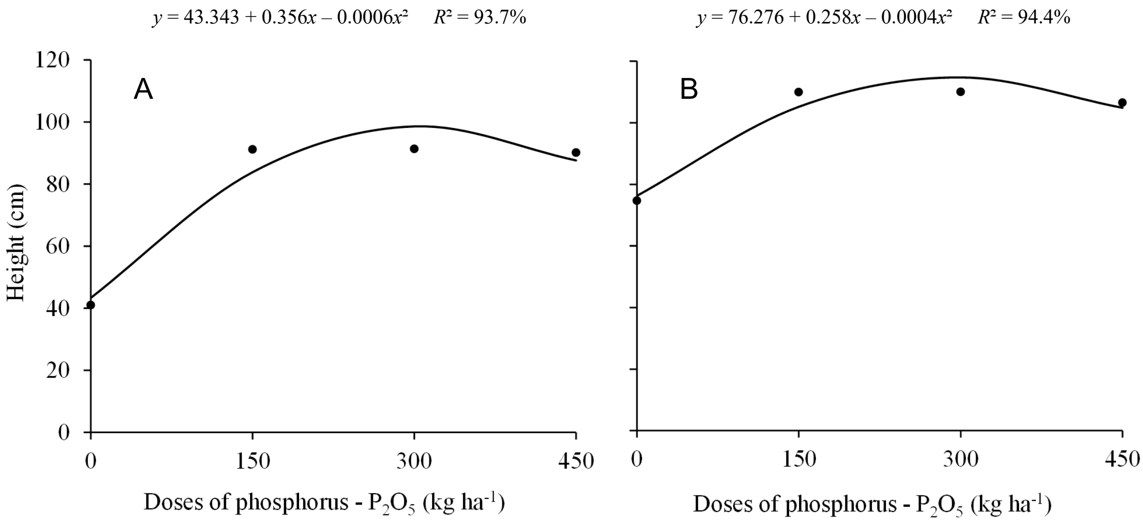

Figure 1: Height (cm) of rice plants, at 40 (A) and 80 (B) days after sowing, subjected to application of different doses of phosphorus (P_2O_5) in Humaitá/AM.

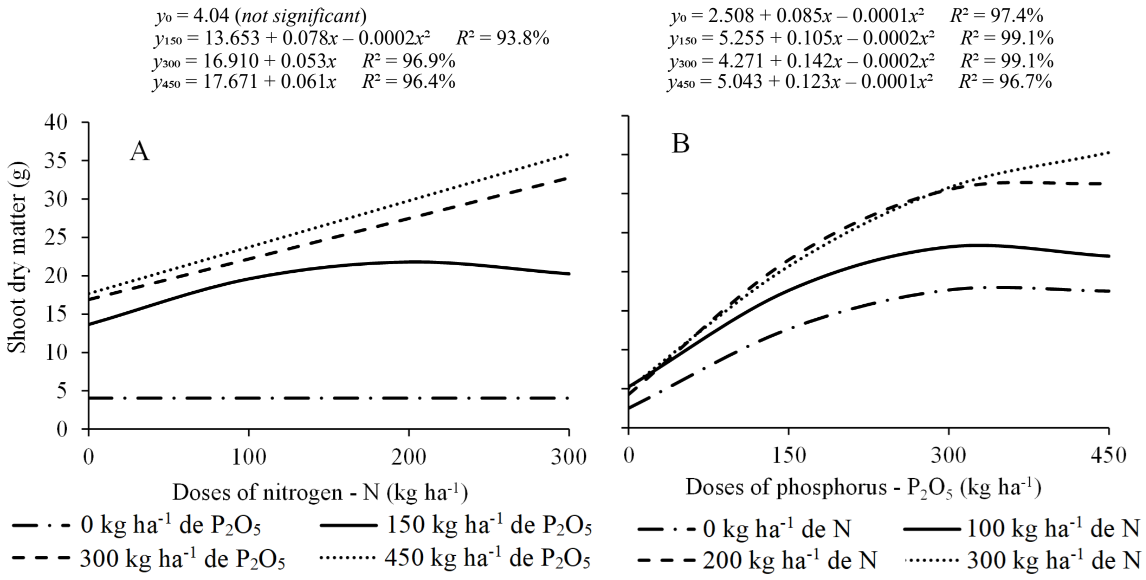

Figure 2: Interaction between nitrogen (N) and phosphorus (P_2O_5) doses on the shoot dry matter of rice plants in Humaitá/AM.

There was a quadratic adjustment of plant dry matter when phosphate fertilization was applied (Figure 2B). The maximum dry matter production was obtained with the application of 339.2; 349.8; 406.4 and 492.6 kg ha^{-1} of phosphorus, when levels of 0 (zero); 100; 200 and 300 kg ha^{-1} of nitrogen were used, respectively. The higher the dose of N applied, the higher is the dry matter maximum production that can be achieved with phosphate fertilization. Also, Fageria & Oliveira (2014) working with NPK fertilization, in different doses of these elements, verified a significant interaction and greater plant growth and productivity in doses of 300 mg kg^{-1} of N and 200 mg kg^{-1} of P.

The better plant growth verified by the application of nitrogen fertilizer can improve phosphorus absorption (Fageria *et al.*, 2011) because the greater growth of roots reduces the distance between the ion and the root system (Rosolem *et al.*, 2003) which is important for P uptake because low phosphorus mobility in soil (Brady & Weil, 2014).

Even at high doses of phosphorus, the rice plant dry matter accumulation is limited by the low levels of N applied to the soil. The plant's response to the nutrient increase depends on the availability of other nutrients in the soil (Wilson, 1993), reinforcing the importance of the balance between nutrients in planning of soil chemical correction, as proposed by Justus von Liebig in the Minimum Law in 1850.

It is also observed that, for the zero-phosphorus dose, regardless of the N dose applied, there was a lower shoot dry matter. This occurs because the plant prioritizes resources to the growth of the root system at the expense of the shoot (Crusciol *et al.*, 2013), in addition to other disturbances.

These results corroborate those of Fageria & Oliveira (2014) who report the interaction between nitrogen and phosphorus. Studies show that nitrogen and phosphorus directly affect rice production, the point of maximum production being with a ratio of 5:1 between absorbed nitrogen and phosphorus (Basak, 1962; Oliveira *et al.*, 1994).

Greater shoot dry matter accumulation in upland rice cultivars as a function of phosphate fertilization was also verified in other research studies, such Garcia *et al.* (2009) and Fageria & Oliveira (2014) with dose of 286 kg ha^{-1} and 200 mg kg^{-1} of phosphorus, respectively.

There was a quadratic effect on grain weight for the application of N and P, but independently (Figure 3). Plants responded to nitrogen fertilization with an increase in grain weight up to 239.66 kg ha^{-1} of N. Lopes *et al.* (2013), Nascimento *et al.* (2013) and Banheza *et al.* (2012) also verified the response of upland rice crops to nitrogen fertilization, obtaining better plant growth and development responses to the dose of 200, 85 and 120 kg ha^{-1} of N, respectively. These differences observed between the doses of N with better agronomic performance for rice cultivation may be related to the type of soil, cultivars, application method and other variables, which may affect the response of the plant.

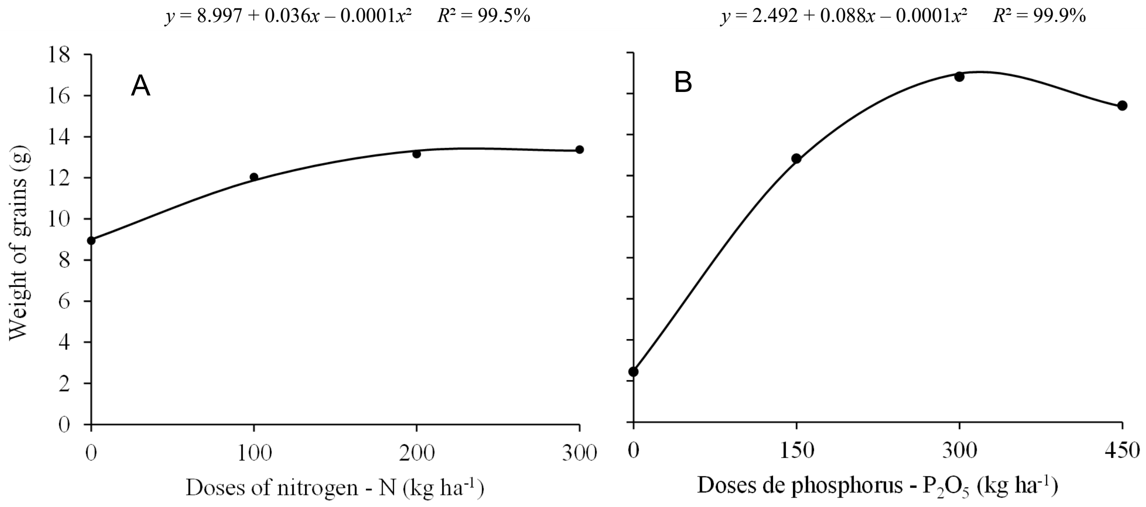

Figure 3: Weight (g) of grains from rice plants subjected to nitrogen (N) (A) and phosphorus(P_2O_5) (B) fertilization in Humaitá/AM.

There was a quadratic response in the grain weight to P application (Figure 3B). It is important to emphasize the low grain production when phosphate fertilization was not carried out, reinforcing that in upland soils the low phosphorus content is among the main factors that limit rice production. Similar results were obtained by Fageria & Oliveira (2014), who did not obtain grain production when P was not applied. Increasing doses of P applied the rice plants response up to the estimated limit of 351 kg ha^{-1} of phosphorus.

These results corroborate the study of Lange *et al.* (2016) with a significant positive response in upland rice yield with phosphate fertilization up to 168 kg ha^{-1} of P_2O_5. However, Dias *et al.* (2010) found no significant response to phosphate fertilization in upland rice cultivation using 80 kg ha^{-1} of P_2O_5, however in a soil with higher initial P contents.

It was verified for the number of tillers a linear response to nitrogen fertilization and quadratic for phosphate fertilization (Figure 4A and 4B). The higher the dose of N applied, the greater number of tillers on rice plants within the limits studied. Nitrogen fertilization induces tillering and, consequently, greater number of panicles in upland rice plants (Fageria *et al.*, 2011). The number of panicles is an important characteristic because show a high correlation with grain yield (SOSBAI, 2014; Ramão *et al.*, 2019).

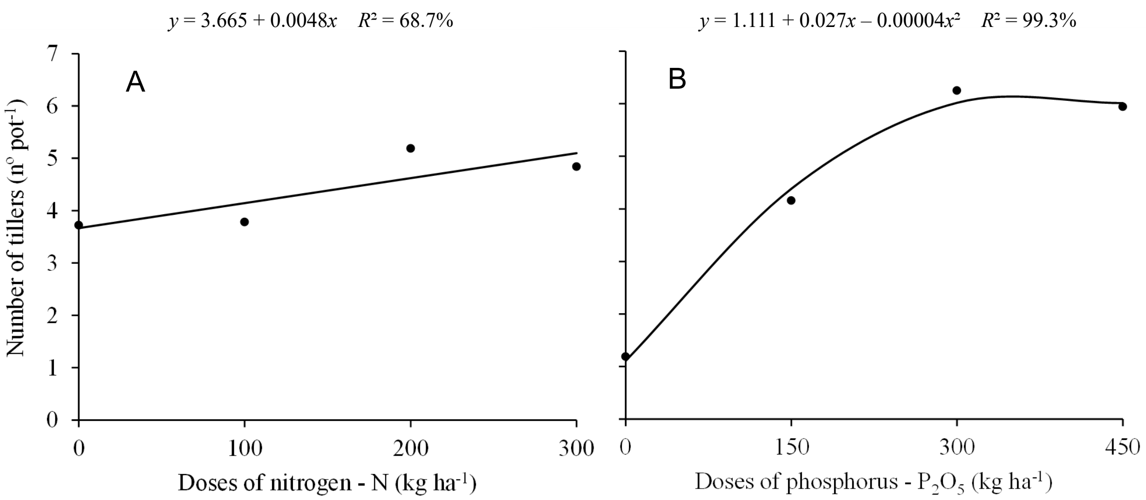

Figure 4: Number of fertile tillers of rice plants subjected to nitrogen (N) (A) and phosphorus (P_2O_5) (B) fertilization in Humaitá/AM.

Also, Ferrari *et al.* (2017) verified higher tillering of upland rice plants, as well as higher productivity, with increasing N doses up to 123 kg ha^{-1}. In the same way, Tabar (2012) obtained better results from fertile tiller and 1000-grain weight in rice with application of 150 kg ha^{-1} N-fertilizer and 90 kg ha^{-1} P-fertilizer.

It was observed an increasing response to phosphorus fertilization in the number of tillers up to dose of 274 kg ha^{-1} of P_2O_5. The increase in the number of tillers and, consequently, the number of panicles is important in the production of rice grains. Lange *et al.* (2016) also found a greater number of tillers in upland rice plants fertilized with different sources of phosphorus at dose 120 kg ha^{-1} of P_2O_5.

CONCLUSION

Fertilization with nitrogen and phosphorus positively affects the growth and development of rice plants in Humaitá, Amazonas state, grown in upland soil up to doses between 200 and 300 kg ha^{-1} of N and around 300 kg ha^{-1} of P_2O_5, in a plinthic alitic Haplic Cambisol.

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