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Nitrogen and phosphorus fertilization of sunflower crop in alkaline Cambisol

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Key words:
Helianthus annuus
oilseed crop
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A B S T R A C T

Sunflower is a crop that has aroused the interest of farmers because of its adaptability to wide climatic conditions and for its use in biodiesel production. However, there are only a few studies on sunflower fertilization in alkaline soils. This study aimed to evaluate nitrogen (N) and phosphorus (P) fertilization in sunflower (*Helianthus annuus* L.) cultivated in alkaline soil. A field experiment was carried out in Baraúnas-RN, Brazil, in a Haplic Cambisol derived from calcareous rock, where the sunflower H-251 hybrid was cultivated. The treatments were a combination of four doses of N (30, 60, 90 and 120 kg ha^{-1}) and four doses of P_2O_5 (30, 60, 90 and 120 kg ha^{-1}). Sunflower growth and yield increased with the doses of N and P_2O_5. Doses of 30 kg ha^{-1} of N and 30 kg ha^{-1} of P_2O_5 were more economical, corresponding to grain yield of 2378 kg ha^{-1}. Critical levels associated with these doses of N and P_2O_5 were 28.2 g kg^{-1} for N leaf content, 2.84 for P leaf content, and 6.75 mg dm^{-3} for soil available P extracted by Mehlich-1.

Palavras-chave:
Helianthus annuus
oleaginosa
nitrogênio
fósforo

Adubação nitrogenada e fosfatada na cultura do girassol em Cambissolo alcalino

R E S U M O

O girassol é uma cultura que tem despertado o interesse dos produtores por sua adaptabilidade a diferentes condições climáticas e pela possibilidade de produção de biodiesel. Porém, pesquisas sobre adubação de girassol em solos alcalinos são escassas. Neste trabalho, objetivou-se avaliar a resposta da cultura do girassol (*Helianthus annuus* L.) à adubação nitrogenada e fosfatada em solo alcalino. O experimento de campo foi conduzido no município de Baraúnas, RN, em um Cambissolo Háplico eutrófico, onde se plantou o híbrido de girassol H-251. Os tratamentos resultaram da combinação de quatro doses de N (30, 60, 90 e 120 kg ha^{-1}) e quatro doses de P_2O_5 (30, 60, 90 e 120 kg ha^{-1}). O crescimento e a produtividade do girassol aumentaram com o incremento das doses de N e de P_2O_5. As doses de 30 kg ha^{-1} de N e 30 kg ha^{-1} de P_2O_5 se mostraram mais econômicas, correspondendo à produtividade de 2.378 kg ha^{-1} de grãos. Os níveis críticos associados a essas doses econômicas de N e de P_2O_5 foram 28,2 g kg^{-1} para o teor de N na folha, 2,84 g kg^{-1} para o teor de P na folha, e 6,75 mg dm^{-3} para o P disponível no solo pelo extrator Mehlich-1.

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Introduction

Sunflower (*Helianthus annuus* L.) has high potential for cultivation in Northeast Brazil because of its easy adaptation, great agro-energetic potential, easy management and good economic performance. In the 2014/2015 season, sunflower production (grains) in Brazil reached 153 thousand tons, with mean yield of 1,374 kg ha^{-1} (CONAB, 2016). In the Northeast region of Brazil, sunflower is still not much cultivated and, when cultivated, low yields are obtained because of the low technological level used by farmers.

At the Apodi Plateau, there is a predominance of soils derived from limestone of the Jandaíra Formation, which in some areas is covered by more recent sandy sediments from the Barreiras Group (Mota et al., 2007). Alkaline Cambisols in Brazil, in general, exhibit very low contents of available phosphorus, micronutrients and organic matter, requiring fertilizations for adequate crop development (Lemos et al., 1997). In the sunflower crop, N is a crucial element for seed and oil production (Alves et al., 2016), and P is directly related to seed production and quality (Silva et al., 2011).

Hence, the practice of N and P fertilization becomes indispensable for crops to obtain high yields in these alkaline soils. Studies on fertilization in the country recommend for the sunflower crop N doses from 25 to 100 kg ha^{-1} and P_2O_5 doses from 0 to 110 kg ha^{-1} (CFSEMG, 1999; SBCS, 2004; Leite et al., 2007; Bezerra et al, 2014; Campos et al., 2015).

Considering the increasing importance of sunflower in the Brazilian semi-arid region and the lack of research on its fertilization in alkaline soils of the northeast region, this study aimed to evaluate the response of sunflower to nitrogen and phosphate fertilizations in alkaline soil at the Apodi Plateau, RN, Brazil.

Material and Methods

The experimental area is located in the municipality of Baraúnas-RN, Brazil (5° 04' 48" S; 37° 37' 00" W; 94 m). The soil of the area is an alkaline eutrophic Haplic Cambisol, with clay texture, derived from limestone of the Jandaíra Formation, little developed and with a small difference between horizons (Mota et al., 2007).

Before conducting the field experiment, a soil sample was collected in the 0-20 cm layer for chemical and physical characterization (EMBRAPA, 1997), and its characteristics are: pH (water) = 7.4; P = 1.8 and K = 210.3 mg dm^{-3}; Ca^{2+} = 4.8; Mg^{2+} = 1.3; Al^{3+} = 0.0; (H + Al) = 1.98; Na^{+} = 11.5 $cmol_c$ dm^{-3}; Sand = 176.6; Silt = 330.9 and Clay = 492.5 g kg^{-1}.

The area was subjected to double cross-subsoiling at 40 cm depth and double cross-harrowing at 20 cm depth. Each plot had four 6-m-long rows spaced by 0.90 m and the two central rows were used for evaluation, disregarding 0.5 m on each end. The H-251 sunflower hybrid, which is small, with short cycle and high yield, was planted at spacing of 0.90 x 0.30 m.

The experimental design was randomized blocks with four replicates and treatments resulted from the combination of four N doses (30, 60, 90 and 120 kg ha^{-1}) and four P_2O_5 doses (30, 60, 90 and 120 kg ha^{-1}). The experiment did not use doses of 0 (zero) kg ha^{-1} of N or P_2O_5, because the soil in the area was very poor in N and P. At planting, P doses were applied according to each treatment, besides 1.5 kg ha^{-1} of B, 1 kg ha^{-1} of Zn and 0.5 kg ha^{-1} of Cu. For N doses, 20% of the dose was applied at planting in the form of urea and the rest was divided into two top-dressing fertilizations at 30 and 50 days after emergence (DAE), using ammonium sulfate. 75 kg ha^{-1} of K_2O were applied, 50% of the dose at planting and the rest at 30 DAE.

Irrigations were performed using a drip system, with pressure-compensating drippers, and the interval between irrigations was based on crop Kc and potential evapotranspiration. Weeds were controlled by two manual weedings until 35 DAE. At 47 DAE, 12 soil samples were collected in the 0-20 cm layer (Oliveira et al., 2007) in the evaluation area of each plot, to determine P contents (EMBRAPA, 1997). At 67 DAE, leaves from the upper middle third of 14 plants were collected in the evaluation area of each plot (Malavolta et al., 1997) for the analysis of N and P contents, according to Tedesco et al. (1997).

At the end of the experiment, at 118 DAE, 10 plants were randomly selected in the evaluation area of each plot and analyzed for: plant height (distance from soil to capitulum insertion), stem diameter (5 cm away from the soil) and capitulum diameter. Plants in the evaluation area of each plot were counted and their capitulum were cut and placed in cloth bags to dry in the sun. Capitulum grains of each plot were manually separated and weighed to obtain grain yield and 1000-grain weight.

A multiple linear regression model was fitted to the means of each treatment and, after selecting the model with best fit, response surfaces were constructed using the program Statistica 6.0 for Windows.

The economic analysis considered the mean price of fertilizers and sunflower bag in the region. Grain yields were estimated for each combination of N and P doses using the fitted multiple regression model, calculating gross revenue, expenditure with fertilizers and net revenue for each combination of N and P doses.

Results and Discussion

The effects of N and P_2O_5 doses on sunflower growth characteristics, despite being significant, were of small magnitude. The interactions between N and P_2O_5 doses were not significant. Plant height was higher with the increment in N and P_2O_5 doses up to the maximum value of 1.86 m, corresponding to the doses of 99 kg ha^{-1} of N + 99 kg ha^{-1} of P_2O_5 ($Y = 1.40 + 0.00325^{**}N - 0.00001646^{*}N^2 + 0.006023^{**}P - 0.00003035^{**}P^2$, $R^2 = 0.89$ - Figure 1).

Sunflower height may exhibit wide variation, reflecting the differences between cultivars regarding plant size. Tomich et al. (2003) found plant height of 2.05 m, whereas Biscaro et al. (2008) estimated that the N dose of 73 kg ha^{-1} was associated with plant height of 1.15 m, which is inferior to the value found in the present study for a similar N dose (Figure 1). On the other hand, Schwerz et al. (2016) did not observe effect of N fertilization on sunflower height.

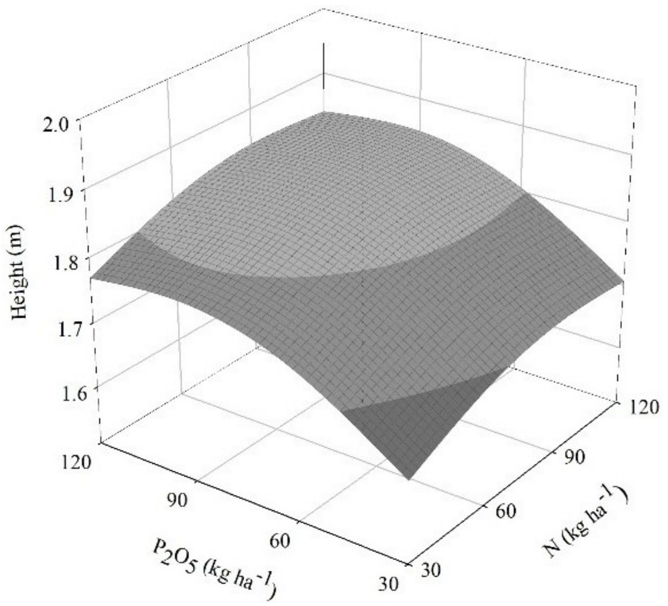

Figure 1. Response surface for sunflower height as a function of N and P_2O_5 doses applied in the soil

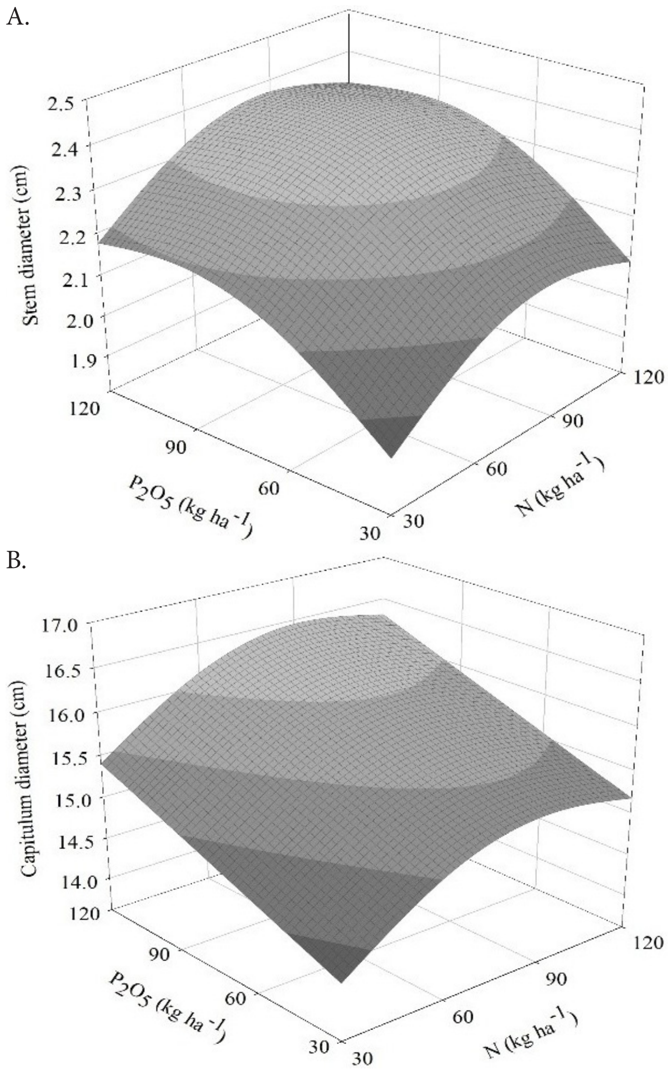

Figure 2. Response surface for stem diameter (A) and capitulum diameter (B) of sunflower plants as a function of N and P_2O_5 doses applied in the soil

The increment in N and P_2O_5 doses increased sunflower stem diameter up to the maximum value of 2.40 cm, corresponding to the doses of 90 kg ha^{-1} of N + 99 kg ha^{-1} of P_2O_5 ($Y = 1.43 + 0.009858^{**}N - 0.00005486^{**}N^2 + 0.01049^{**}P - 0.00005278^{**}P^2$, $R^2 = 0.84$ - Figure 2A). Highest value of capitulum diameter (16.45 cm) was estimated for doses of 95 kg ha^{-1} of N + 120 kg ha^{-1} of P_2O_5 ($Y = 12.68 + 0.04768^{**}N - 0.0002509^{*}N^2 + 0.01261^{**}P$, $R^2 = 0.67$ - Figure 2B).

Biscaro et al. (2008) observed maximum stem diameter of 1.84 cm at the N dose of 48 kg ha^{-1} and maximum capitulum diameter of 11.9 cm at N dose of 45 kg ha^{-1}. Freitas et al. (2012) found capitulum diameter of 15.38 cm with N application of 75 kg ha^{-1}. These differences in the results may be attributed to the genetic differences between the cultivars.

There was no significant effect of N and P_2O_5 doses on leaf N contents, which ranged from 28.2 g kg^{-1} (30 kg ha^{-1} of N + 30 kg ha^{-1} of P_2O_5) to 36.1 g kg^{-1} (120 kg ha^{-1} of N + 60 kg ha^{-1} of P_2O_5). Thus, it can be considered that the critical leaf N content of 28.2 g kg^{-1} is lower than that described by Malavolta et al. (1997) as adequate for sunflower, which ranges from 33 to 35 g kg^{-1}.

The lack of response of leaf N content to the increase in N and P_2O_5 doses can be explained by the effect of dilution of leaf N content due to the greater plant growth in response to the increase in the applied doses of N and P_2O_5 (Figures 1 and 2). Ribeirinho et al. (2012), applying 10 kg ha^{-1} of N, observed leaf N contents in sunflower plants of the order of 36.84 g kg^{-1}, higher than those observed in the present study.

As expected, leaf P contents increased as a function of the P_2O_5 doses, but decreased with the increment in N doses, possibly due to the dilution effect (Figure 3A). Therefore, maximum leaf P content (3.1 g kg^{-1}) was estimated in the combination between the highest P_2O_5 dose (120 kg ha^{-1}) and lowest N dose (30 kg ha^{-1}) ($Y = 2.89 - 0.003993^{**}N + 0.002631^{**}P$, $R^2 = 0.60$).

Leaf P contents in the present study, even the maximum estimated P content (3.1 g kg^{-1}), were below the P range from 4.0 to 7.0 g kg^{-1} considered as ideal by Malavolta et al. (1997) for sunflower. However, Deibert & Utter (1989) indicated P contents between 2.2 and 5.2 g kg^{-1} as adequate for sunflower leaves in early flowering. Available P content in the soil sharply increased with the increment in the P_2O_5 dose applied to the soil, with a slight reduction as N dose increased ($Y = 3.19 - 0.01531^{*}N + 0.1337^{**}P$, $R^2 = 0.81$ - Figure 3B).

Both 1000-grain weight and grain yield increased with the increment in the N and P_2O_5 doses (Figure 4). It is estimated that the highest 1000-grain weight is obtained with the application of maximum doses (120 kg ha^{-1}) of N and P_2O_5, since the plant response to these nutrients was linear ($Y = 53.66 + 0.03711^{**}N + 0.04864^{**}P$; $R^2 = 0.78$ - Figure 4A). Silva et al. (2011) observed increments of approximately 9.5% in 1000-grain weight with the application of 70 kg ha^{-1} of phosphate fertilizer, compared with the control, evidencing the importance of P in the production and quality of sunflower seeds. Maia Filho et al. (2013) found 1000-grain weight varying from 18 to 30.70 g with N and P fertilization at doses of 40 and 70 kg ha^{-1}, respectively, which are much lower than those observed in the present study, 63.94 g.

Grain yield reached 3,026 kg ha^{-1}, with application of 120 kg ha^{-1} of N and 117 kg ha^{-1} of P_2O_5, $Y = 2010.2 + 3.6115^{**}N + 9.9484^{**}P - 0.04245^{*}P^2$ $R^2 = 0.83$ (Figure 4B). This yield is

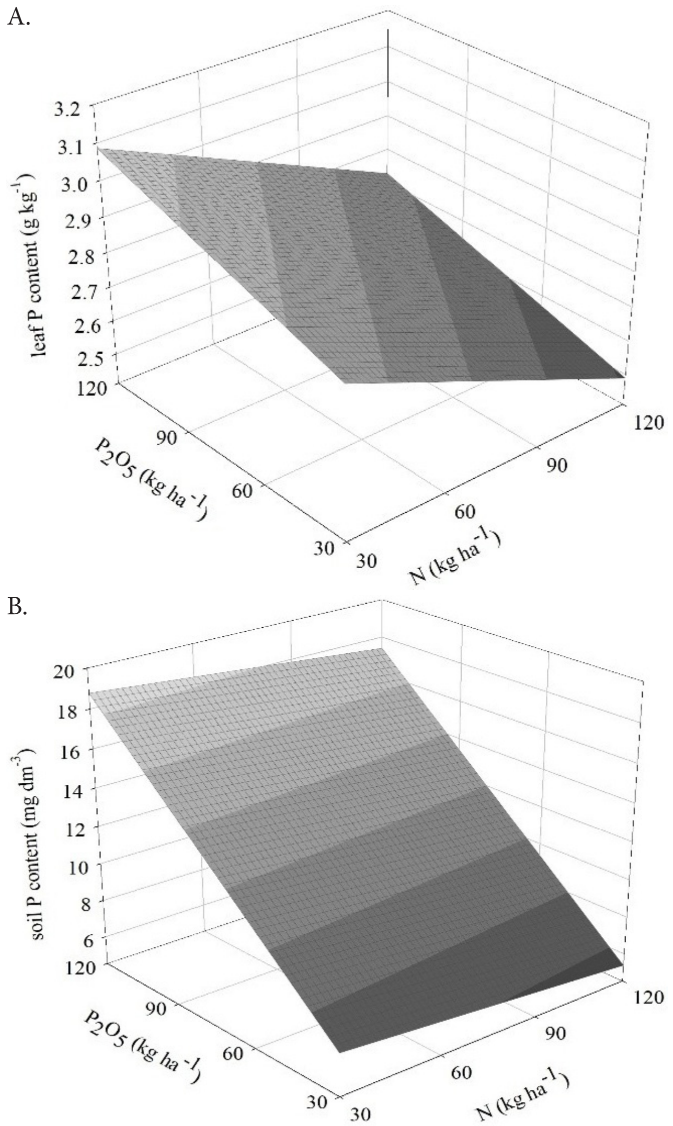

Figure 3. Response surfaces for sunflower leaf P content (A) and soil P content (B), as a function of N and P_2O_5 doses applied to the soil

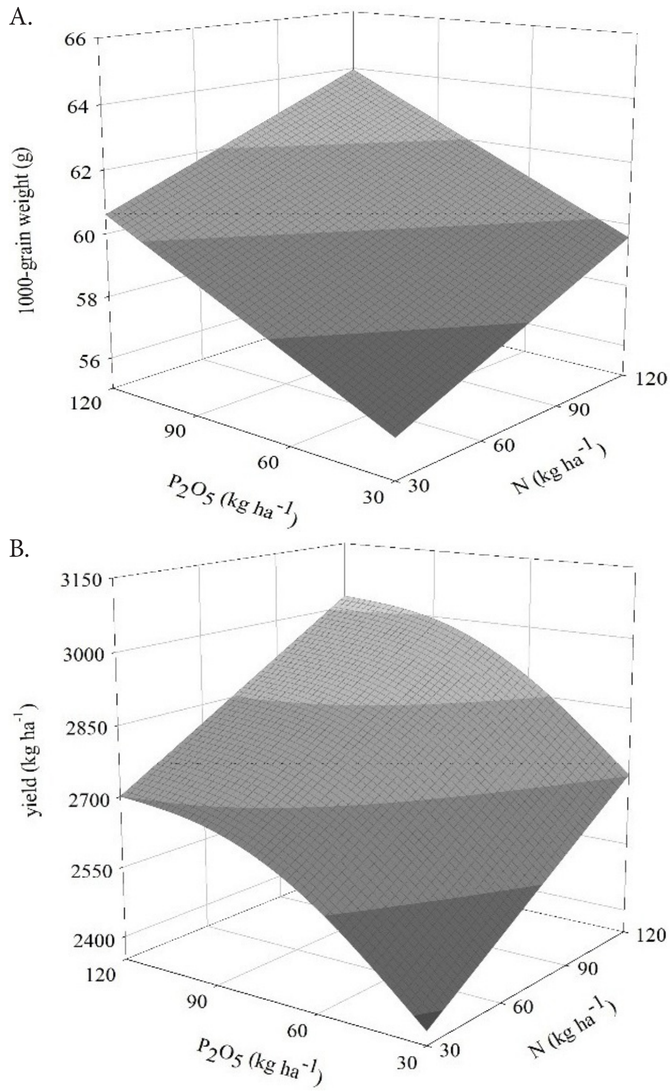

Figure 4. Response surfaces for 1000-grain weight (A) and yield (B) of sunflower as a function of N and P_2O_5 doses applied to the soil

above that observed by Nascimento et al. (2013), 2,210 kg ha^{-1}, who cultivated sunflower fertilized with 20 kg ha^{-1} of N and 70 kg ha^{-1} of P_2O_5. As for the other variables analyzed in the plant (Figures 1 and 2), the magnitude of the positive effects of N and P_2O_5 doses on grain yield was not very high. However, that does not mean the sunflower crop does not respond to N and P fertilizations. Actually, the responses were small because the doses varied from 30 to 120 kg ha^{-1}, without an absolute control with no fertilization. If the doses varied from 0 to 120 kg ha^{-1}, the magnitudes of the responses would probably be higher, especially for the interval from 0 to 30 kg ha^{-1} of N and P_2O_5, due to the very low contents of available P and organic matter in the soil of the experimental area. In the study of Eltz et al. (2010), P_2O_5 doses between 40 and 80 kg ha^{-1} were sufficient to reach sunflower grain yield of 2,000 kg ha^{-1}, whereas Ivanoff et al. (2010) observed yield of 1,639 kg ha^{-1} with N fertilization of 60 kg ha^{-1}, split into 30% at planting and 70% as top-dressing.

In Minas Gerais, the recommendation of phosphate fertilization varies from 30 to 70 kg ha^{-1} of P_2O_5 according to soil P content, and 60 kg ha^{-1} of N should be split into 1/3 at planting and 2/3 as top-dressing (CFSEMG, 1999).

These N and P_2O_5 doses recommended for the sunflower crop corresponded to approximately half the doses estimated for the highest yields (Figure 2B). Attributing the value of 30 kg ha^{-1} for N and P_2O_5 doses in the production function (Figure 4B) leads to grain yield of 2,378 kg ha^{-1} (Table 1), which corresponds to 78% of the maximum production. Therefore, the reduction in N and P_2O_5 doses from 120 to 30 kg ha^{-1} would reduce grain yield by 648 kg ha^{-1}, but on the other hand there would be an increment of R$ 176.00 in net revenue (Table 1).

When doses of 30 kg ha^{-1} of N and 30 kg ha^{-1} of P_2O_5 were substituted in the regression equations presented in Figure 3, the estimated critical contents of P in the plant and in the soil were 2.84 g kg^{-1} and 6.75 mg dm^{-3}, respectively. These values can be used in the nutritional diagnosis of sunflower in areas with alkaline soils, and guide the recommendations of phosphate fertilization based on soil analysis.

Other field studies are necessary, including in different classes of soils that occur in the region, to adjust the recommendations of fertilization for the crop and the identification of critical contents of N and P in the plant and

Table 1. Gross revenue, expenditure with fertilizers and net revenue of the sunflower crop as a function of N and P_2O_5 doses applied to alkaline soil at the Apodi Plateau, RN, Brazil

N dose	P_2O_5 dose	Estimated yield [1]	Gross revenue	Expenditure with fertilizers	Net revenue
kg ha^{-1}			R$		
30	30	2,378	1,070	155	914
30	60	2,562	1,153	231	921
30	90	2,670	1,201	306	894
30	120	2,701	1,215	382	832
60	30	2,487	1,119	235	883
60	60	2,670	1,201	311	890
60	90	2,778	1,250	387	863
60	120	2,809	1,264	462	801
90	30	2,595	1,167	315	852
90	60	2,779	1,250	391	859
90	90	2,886	1,299	467	831
90	120	2,917	1,312	542	770
120	30	2,703	1,216	396	820
120	60	2,887	1,299	471	827
120	90	2,995	1,347	547	800
120	120	3,026	1,361	622	738

[1] Yield estimated by the multiple linear regression model

in the soil. Despite that, the obtained results indicate that the recommendation of fertilization with doses of 30 kg ha^{-1} of N + 30 kg ha^{-1} of P_2O_5 can be adopted for sunflower cultivation in the Apodi Plateau region.

Conclusions

1. The doses of 30 kg ha^{-1} of N + 30 kg ha^{-1} of P_2O_5 are economically viable for the production of sunflower grains in alkaline Haplic Cambisol at the Apodi Plateau.

2. Critical levels for the crop are 28.2 g kg^{-1} for leaf N content, 2.84 g kg^{-1} for leaf P content, and 6.75 mg dm^{-3} for available P content in the soil extracted by Mehlich-1.

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