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Full Length Research Paper

Influence of different nitrogen and phosphorus pentoxide levels on eggplant yield

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The balanced fertilization is crucial for obtaining a good plants growth and achieve good productivity indices. The aim of this study was to evaluate the performance of eggplant (*Solanum melongena* L.) under different doses of nitrogen (N) and Phosphorus pentoxide (P_2O_5) performed separately. The study was conducted in 5 liter-pots arranged in a completely randomized design, consisting of 5 doses (0, 50, 100, 150 and 200 kg ha^{-1}) of N and P_2O_5 with 5 replications in a greenhouse, located at latitude 22° 13' S and longitude 54° 48' W. The variables analyzed were: root fresh mass (RFM) and root dry mass (RDM), shoot fresh mass (SFM) and shoot dry mass (SDM), fruit weight (FW), number of fruits (FN) per plant, stem diameter (SD) and plant height (PH). Application of N had significant effects on all variables studied, except for SD. Application of P_2O_5 had significant effects on most variables, except for PH, SFM and FW. N applications affected yield more than P_2O_5 due to FN and FW. The dose of 100 to 150 kg ha^{-1} both for N and P_2O_5 provided the best results.

Key words: Soil fertility, plant nutrition, horticulture, Solanaceae.

INTRODUCTION

The eggplant (*Solanum melongena* L.) is an annual vegetable crop that belongs to the family Solanaceae and is native to India. It is an economically important crop in Africa, Asia, Central America and it is also cultivated in some warm temperate regions of the South America and Mediterranean (Aminifard et al., 2010).

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The eggplant has shown increasing importance among vegetables due to the wide popularization of its nutritional value (Zenia and Halina, 2008). This plant is well adapted to the tropical climate, and its development is influenced by the availability of several nutrients, especially nitrogen (N) and phosphorus (P) (Swiader and Morse, 1982).

Nitrogen deficiency in eggplant crop leads to stunted and chlorotic leaves caused by the formation of poor photosynthesizing that leads to early flowering and shortening of the growth cycle. The presence of N in excess promotes the development of organs above ground, with plenty of dark green tissue (high chlorophyll) of soft consistency and reduced root growth. With that it increases the risk of lodging and reduces plant resistance to adverse climatic conditions and foliar diseases (Bozorgi, 2012).

Nitrogen at appropriate levels is essential to plant growth due to its structural function in proteins and nucleic acids, which are the basic components of plasma and chlorophyll, both indispensable for the plant to perform photosynthesis (Taiz and Zeiger, 2004).

P deficiency induces abscission of flowers, consequently reducing the yield (Ribeiro et al., 1999). This nutrient plays an important role in energy transfer in cells, respiration and photosynthesis, and is a structural component of nucleic acids, as well as various coenzymes, phosphoproteins and phospholipids (Amiri et al., 2012).

Some authors studied the application of N eggplant as Kamili et al. (2002) studied the application of N in eggplants and observed that there was an increase in plant height (PH) with increased rates of N. Haag and Homa (1981) observed a significant decrease in the diameter of the eggplant stem when N was absent. Prabhu et al. (2006) studied the effect of different levels of nitrogen and phosphorus on culture of eggplant and found that the total yield per hectare was significantly increased with increasing doses of N and P. The highest yield was obtained from 200:100 kg NP ha^{-1}. In that sense, the doses of fertilizers applied to the soil by means of fertilization should foster the growth and yield, but excessive application of fertilizers can lead to toxicity or interfere with the absorption of other nutrients (Kehinde et al., 2011).

Knowledge of nutrient requirements of the plant is important in determining the amounts of nutrients to be applied. This is because the absorption of nutrients is differentiated according to plant phenology, being intensified with the flowering, fruit formation and growth. Thus, the study aimed to evaluate the performance of eggplant, fertilized with different doses of phosphorus and nitrogen applied separately.

MATERIALS AND METHODS

The work was installed in a protected environment at Faculdade Anhanguera in Dourados (FDO) in the year 2012. The city of Dourados is located at latitude 22° 13' S and longitude 54° 48' W and altitude of 430 m. The climate, according to Köppen (Mato Grosso Do Sul, 1990) is humid mesothermal type Cwa, with annual average temperatures and precipitation ranging from 20 to 24°C and rainfall of 1250 to 1500 mm, respectively.

The experiment consisted of nitrogen and phosphorus fertilization on an eggplant crop performed separately and arranged in a completely randomized design with 5 treatments and 5 replications. Doses were 0, 50, 100, 150, and 200 kg ha^{-1} of P_2O_5 and N. Each plot consisted of one plant per pot with capacity of 5 L, in which 3.5 kg of soil classified as clayey Haplorthox were placed, with the following chemical characteristics: pH 6.0 in water, 28.2 g dm^{-3} of organic matter, 26.0 mg dm^{-3} of P; and 6.4, 50.3, 18.0, mmol dm^{-3} of K, Ca, and Mg, respectively, being considered soil of good fertility, being nutrients at satisfactory levels.

The seedlings were grown in trays with 72 cells containing commercial substrate, by sowing one seed per cell of variety Embu (ISLA Sementes Ltda®). While driving the seedlings there was no fertilization. After 15 days of the emergence, the plants were transplanted to the pots, with one plant per pot, and the doses of N were applied as ammonium sulphate ($(NH_4)_2SO_4$) - 21% of N and P in the form of superphosphate (SS) - 18% P_2O_5 according to the treatment.

The variables analyzed were: root fresh mass (RFM) and root dry mass (RDM) (g), shoot fresh mass (SFM) and shoot dry mass (SDM), fruit weight (FW), number of fruits (FN) per plant, stem diameter (SD) and PH. Evaluations of PH and SD were performed at intervals of 10 days after transplantation and the number and weight of fruit was considered the first harvest after 120 days from the transplantation to the pots.

Seedling height was obtained with a graduated ruler (± 1 mm) measured from the ground level to the insertion of the last leaf. The SD was measured with the aid of a digital caliper (± 0.1 mm) obtained from the average of two orthogonal measurements. FW was determined using an analytical scale with precision of 0.0001 g.

For the evaluation of fresh and dry mass at the end of the experiment, the plants were separated into root, and above-ground organs (stems and leaves), and then dried at 65°C with forced air circulation for a period 48 h, until constant weight.

Data were subjected to analysis of variance (ANOVA; $P < 0.05$) to determine the significant effect of treatments. Regression analyses were conducted to test the effects of doses on the evaluated characteristics. The statistical software SISVAR 5.1 was used (Ferreira, 2007).

RESULTS AND DISCUSSION

The results of the ANOVA showed significant effects for most variables analyzed ($p < 0.05$) for doses N, except for the variable DC. The results were similar for the doses of FW. P_2O_5 levels for most variables, except for PH, SFM and

Nitrogen

PH presented an increasing linear response to the increase of nitrogen doses (Figure 1), in which the maximum dose applied promoted an estimated maximum value of 68 cm. Oliveira et al. (2012) studied the initial growth of eggplant using biomass of *Tefhrosia cândida* to cover the soil with and without nitrogen fertilization and found greater PH with nitrogen fertilization regardless of the doses.

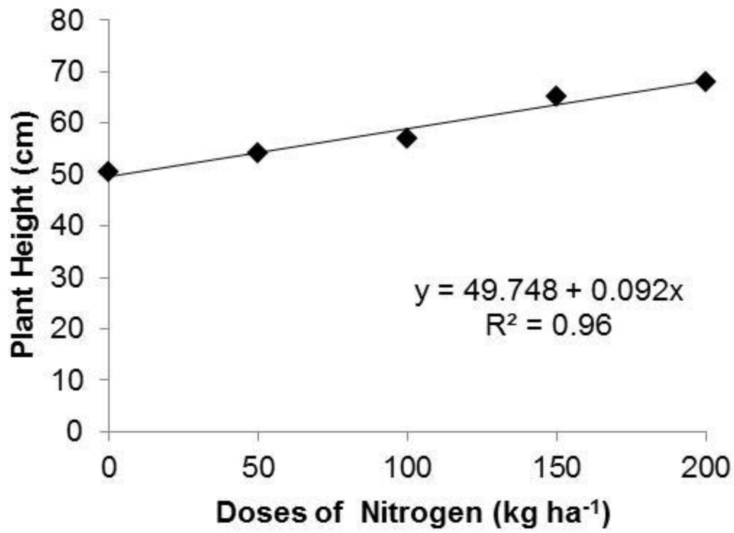

Figure 1. Plant height (PH) according to the doses of N in the eggplant crop.

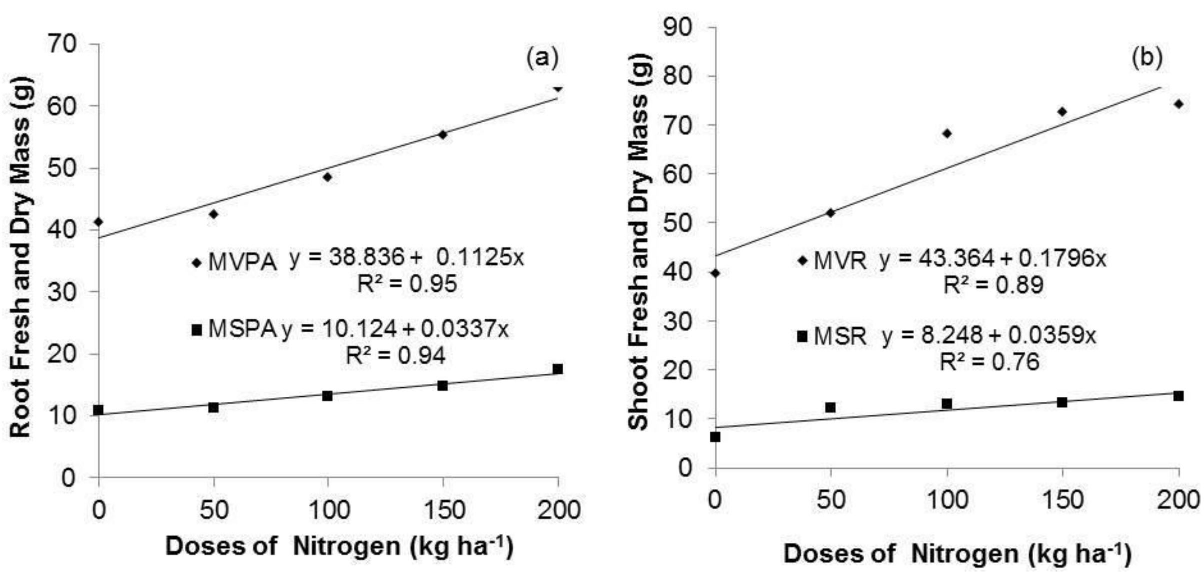

Figure 2. Shoot fresh and dry mass (a) and root fresh and dry mass (b), according to the doses of N in the eggplant crop.

When evaluating components of eggplant production in Iran, Bozorgi (2012) measured a height of 111.5 cm for 90 kg ha $^{-1}$ of nitrogen, such height is almost twice that found in this work. One of the factors that probably contributed to that difference is the time of measuring. Bozorgi (2012) reported that in his study the measurement was made at the peak of fruiting, while in this test it was performed at the beginning of fruiting, and the climatic condition of northern Iran (Bwk) is also different from that of the place in which this study took place (Cwa).

SFM and SDM increased linearly with increasing doses of nitrogen (Figure 2a), in which the maximum dose promoted a maximum value of 59 and 15 g, respectively. Cardoso et al. (2008) studied the application of cattle manure (CM) and magnesium termophosphate (MT) in the fertilization of eggplant and found a value of 50.28 g plant^{-1} for the SDM by the combination of higher doses of N and P supplied by the fertilizers, respectively. Largest increase in the dry mass of the eggplant was also verified by Oliveira et al. (2012) with nitrogen and ground cover with *T. cândida*. Coutinho Neto et al. (2010) also

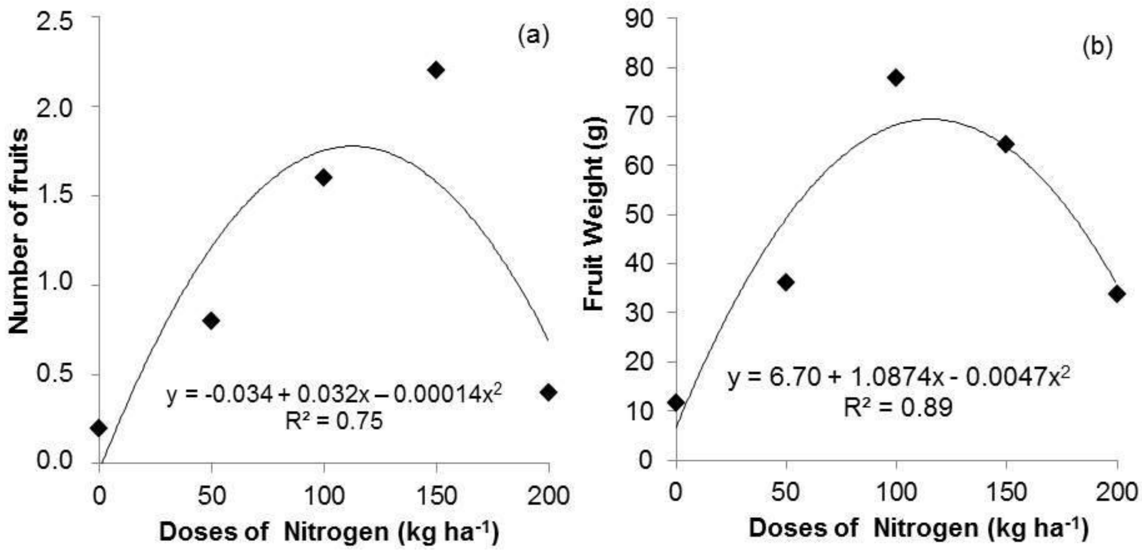

Figure 3. Fruit weight (a) and number of fruits (b), according to the doses of N applied to the eggplant crop.

observed it when studying doses of N and K in a radish crop.

Silva et al. (2001), on a study on red pepper, found that the application of ammonium sulfate increased SDM. According to these authors, the result was due to the accumulation of nutrients, which results in increased biomass, stimulating vegetative growth. Pedrinho et al. (2007) evaluated the effect of nitrogen fertilization on biomass and cardioactive glycosides content of *Nerium oleander* L. and observed increasing linear effect parameters for fresh and dry mass, according to the amount of N applied.

The fresh and dry mass of both roots and shoots also showed increasing linear responses with increasing doses of N (Figure 2b), in which the maximum dose promoted a maximum value of 74.24 and 14.68 g, respectively. Cardoso et al. (2008) found a higher value for eggplant RDM (16.74 g plant^{-1}) with a combination of the maximum doses of CM and MT with quadratic and linear adjusts, respectively.

Silva et al. (2001), in a study on red pepper, reported that N fertilization did not increase RDM due to the effect of salinity with potassium chloride (KCl), and possibly also by the antagonism between the ammonium sulfate (NH_4SO_2) and chloride used as sources of nutrients. For the culture of radish, Coutinho Neto et al. (2010) found no significant effect on RDM under the effect of N doses.

FW (Figure 3a) showed a significant response to the quadratic model with the initial increase up to the dose of 100 kg ha^{-1} in which an average of 77.84 g fruit was promoted, followed by a decline curve for doses of 150 and 200 kg ha^{-1} of N. This effect occurred in accordance with the FN per plant (Figure 3b), probably caused by a toxic effect of ammonium sulfate.

According to Foloni et al. (2006), cover fertilization with ammonium sulfate, when not done to correct soil acidity in their study on cotton considerably impaired the accumulation of Ca, Mg and K in the shoots. According to these authors even fertilization with ammonium sulfate causes rapid drop in soil pH, and the acidity inhibits the production of NO_3^- in soils receiving application of NH_4^+. Ferreira et al. (2010) found a linear effect for the average mass of tomato fruit, due to the increase of nitrogen rates.

In a study on red, pepper Campos et al. (2008) evaluated different doses of nitrogen and found a quadratic effect for N. The largest FN per plant was (44) at a dose of 250 kg ha^{-1} of N. The increasing FN per plant with increasing levels of N is probably due to the fact that nitrogen is the element to be absorbed in larger quantities by plants of the family Solanaceae. N is fundamental to the growth and development of plants (Oliveira et al., 1999). In this sense, the same authors observed an increase in fruit yield per pepper plant, depending on the supply of N by means of fertigation.

According to Carnicelli et al. (2000), the reduction in the FN per plant at doses above that responsible for the maximum value for this characteristic may be related to the toxic effect of ammonium and low nitrification rate, reducing the absorption of other cations (K^+, Ca^{2+}, Mg^{2+}) by the plant. According to Filgueira (2000), some cultures resent excess of nitrogen, such as root or tuberous plants; nitrogen excess can cause excessive vegetative growth at the expense of the production of tubers or roots.

Ferreira et al. (2010) observed a linear effect for the FN per tomato plant according to the nitrogen doses. These responses in different surveys are possibly related to the hormone balance in the plant canopy. The increase in the availability of nitrogen to plants increases the synthesis of

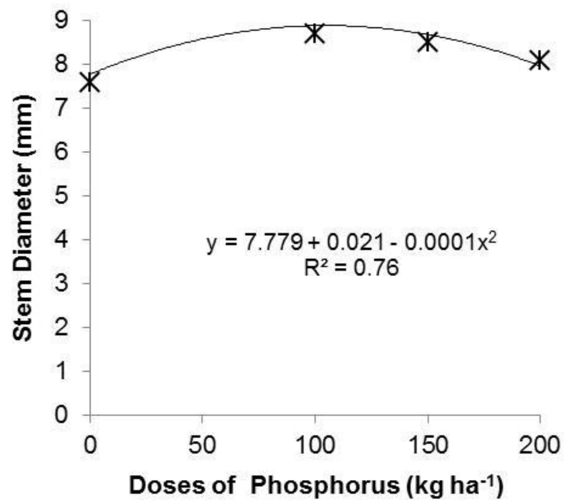

Figure 4. Stem diameter according to P_2O_5 levels in eggplants.

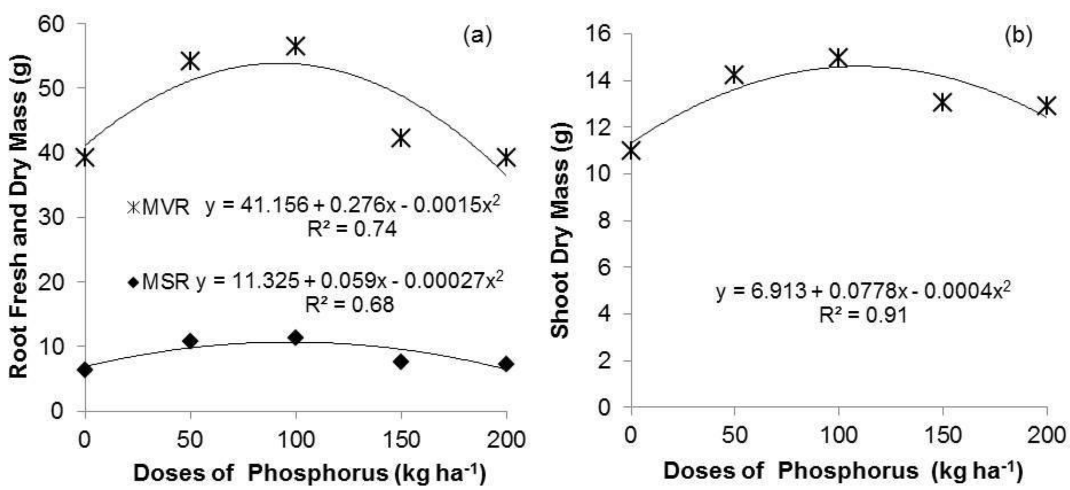

Figure 5. Root fresh and dry mass (a) and shoot dry mass (b), according to the doses of P_2O_5 in an eggplant crop.

hormone gibberellin at the apex of the shoots and leaves in expansion, being responsible for increasing fruitfulness.

The increase in the supply of nitrogen to plants may result in increased photosynthetic potential, what may lead to a greater production of carbon skeletons leaves, increasing the potential of the source and hence the supply to the drain (Ferreira et al., 2010).

With the results of this experiment it is possible to observe that N can increase eggplant production, what is not only due to the increase in average FW, but also to larger FN.

Phosphorus

In the evaluation of SD it was possible to observe a quadratic effect, with positive responses at doses of 50 and 100 kg ha^{-1} of P_2O_5 (Figure 4), the latter being the dose that best represents the results. Doses above 100 kg ha^{-1} did not correspond positively with a decrease in the SD. Zonta et al. (2010) verified a positive linear correlation with increasing doses of P_2O_5, in which the maximum dose used (3,000 kg ha^{-1}) of superphosphate promoted a maximum value of 25.73 mm SD. Filgueira (2003b) also claims that there is an increase in neck diameter; according to the author, the improvement in this feature can provide greater sustainability for the plant as well as higher sap flow, favoring the development of the plant and its fruits, what can lead to greater productivity, hence higher profitability to the producer.

The maximum weight of the RDM and RFM (Figure 5a) was obtained with 100 kg ha^{-1} at 120 days; higher doses obtained decrease in levels. Peryea (1990) reported that

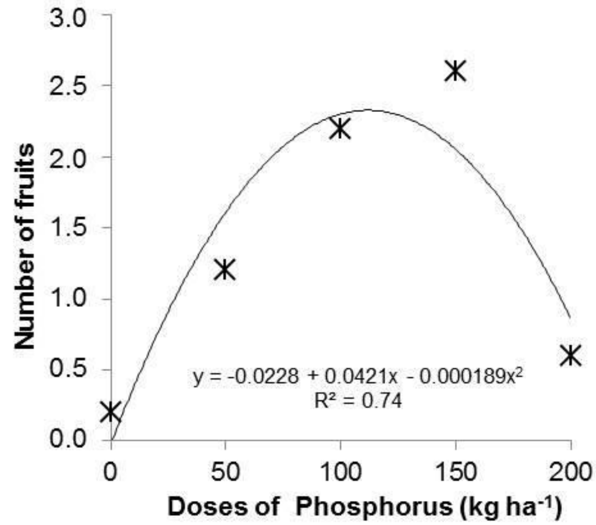

Figure 6. Number of fruits, according to the doses of P_2O_5 in the eggplant crop.

high doses of phosphorus can lead to toxicity, reducing root growth, which can account for a reduction in the RFM and RDM with increasing doses of phosphorus. Cardoso et al. (2008) found that the combination of higher doses of cattle manure and magnesium thermophosphate provided linear and quadratic adjusts, respectively, for the RDM of the eggplant (16.74 g plant^{-1}).

The SDM showed significant results, with little difference among the levels of phosphorus (Figure 5b); the dose of 100 kg ha^{-1} provided 14.98 g of eggplant SDM. Possibly from this dose, with the increased availability of P_2O_5 in the soil, absorption grew in proportions greater than the increase in SDM production, resulting in a reduction of the amount of dry mass. High concentrations of P_2O_5 in the tissues may reduce photosynthesis, due to the excessive export of trioses-P from the cytosol to the chloroplast, also reducing the intermediates of the calvin cycle and consequently the production of photoassimilates (Taiz and Zeiger, 2004).

Cardoso et al. (2008) found a higher value of SDM (50.28 g plant^{-1}) by a combination of higher doses supplied by fertilizers; P deficiency is detrimental to the growth of shoots. Moura et al. (2001) studied red pepper with different levels of phosphorus as fertilizer, and verified answers that fit the quadratic model. According to these authors, SDM increased with the supply of P_2O_5 up to near 250 mg of P_2O_5 kg $^{-1}$ of soil, in which the result is attributed to the efficiency in the use of phosphorus in shoot growth, and to the greater intensity of phosphorus redistribution from the older and inactive tissues to the younger under development.

The ratio of root/shoot decreased with the increase in P_2O_5 in the soil due to larger increases in SDM production than in RDM, according to Martinez et al. (1993) this behavior should not be generalized for all kinds of plants. When some nutrients limit plant growth, roots become drains relatively stronger for carbohydrates in comparison to the shoot, what leads to a reduction that affects the roots (Taiz and Zeiger, 2004). Other authors, such as Castro et al. (2012) report that the reduction in shoot growth in conditions of deficiency of P can be related to the decreased production of cytokinin in the roots, and the translocation of this reduction to the shoot, since this hormone is involved in leaf senescence and indirectly on stomatal closure.

The FN per plant (Figure 6) showed a significant response to the quadratic regression model, with the initial increase up to the dose of 150 kg ha^{-1}, with an average production of 2.6 fruits per plant, followed by the decline curve for the dose of 200 kg ha^{-1} of phosphorus. The dose of 150 kg ha^{-1} caused a reduction in the FN per plant, which may indicate that increasing phosphorus may have caused changes in the availability of other nutrients that are essential to crop development.

The fact that high doses of P_2O_5 reduce the FN is reported by Instituto da Potassa and Fosfato (1998). In that study the authors observed that soils with high phosphorus content may cause a zinc deficiency, because high levels of phosphorus may reduce the absorption of zinc by the plant. The increase of salinity, the toxicity and zinc deficiency induced by high concentrations of phosphorus are some of the causes of the reduction in the FN according to Peryea (1990) and Seno et al. (1996), respectively. However, Filgueira (2003b) states that Zn may present the phenomenon of "hidden hunger", which is not detected visually. Zonta et al. (2010) found a highly significant effect (p <0.01) with the application of superphosphate at the eggplant sowing to the FN, having a quadratic response to increased phosphorus fertilization. Doses above 2054 kg ha^{-1} of superphosphate provided an estimated value of more than 26 fruits $plant^{-1}$. Manfio (2007) observed that the FN per plant was 65% higher when compared to the absence of P_2O_5, which indicates that phosphorus was effective in raising the FN in the eggplant.

Conclusion

The eggplant crop presented higher performance for most of the variables in relation to nitrogen, for which the dose with 100 to 150 kg ha^{-1} for the N source used in this work showed the best results. Doses which were higher than that led to lower yields in addition to increasing the cost of production.

The performance of the eggplant according to the levels of phosphorus applied was not different from that obtained with the application of nitrogen; however, the results obtained by the application of nitrogen were most satisfactory, since it showed differences for the variables number and weight of fruits.

Conflict of Interests

The authors have not declared any conflict of interests.

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