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RESEARCH ARTICLE

# GROWTH AND DEVELOPMENT OF SOYBEAN ACCORDING TO LIMESTONE AND PHOSPHORUS DOSES

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## ABSTRACT

In tropical soils, the correction of soil acidity may help increase the efficiency of phosphate fertilization. In this sense, the aim of this study was to evaluate the growth and development of soybean plants (*Glycine max*) under different doses of limestone and phosphorus in a dystrophic Yellow Latosol. The study was performed in a greenhouse of the Federal University of Piauí, from October to November, 2014. The experiment was performed in a completely randomized design, with three replications and the treatments were arranged in a 4x5 factorial scheme, constituted by the combination of liming (0, 1.5, 6.0 and 12 Mg ha-$^{1}$) and doses of phosphorus (0 , 100, 200, 300 and 400 kg ha$^{1}$ de $P_2O_5$) At 50 days after sowing, the following variables were evaluated: plant height, leaf area, stem diameter, fresh matter and dry matter of plants. The combined application of approximately 6 Mg ha$^{-1}$ of limestone and 260 kg ha$^{-1}$ of $P_2O_5$ provides the highest growths in soybean plants. The soil pH increases with the limestone dose increase, reaching values in the range of 6 to 6.5 with the application of 12 Mg ha$^{-1}$ of limestone. The interaction between liming and phosphate fertilization was positive for the soybean growth and development.



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## INTRODUCTION

The soybean crop (*Glycine max* (L.) Merrill) has great economic and social potential, and stands out over the years among the most exploited crops in all segments of the agricultural activity in Brazil, corresponding to 57% of all cultivated area in the country (Conab, 2016). Among the macronutrients essential to the development and high yield of soybean, phosphorus has a prime position, so adequate levels of this nutrient in the plant become necessary (Neto *et al*., 2011). Phosphorus is the most limiting nutrient of biomass productivity in tropical soils (Oliveira Júnior *et al*., 2008) and plays a key role in all metabolites related to energy acquisition and utilization (Prado *et al*. 2010). This nutrient deficiency in the soil decreases plant growth and yield potential at early reproductive stages (Filho *et al*., 2013), reflecting the negative impact on productivity. However, a good supply of this nutrient to the plant provides significant increases in soybean production (Prado *et al*., 2010).

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Most of the soils, especially those in the Cerrado region, do not have adequate levels of phosphorus, culminating in the need to raise the levels immediately or gradually (Neto *et al*., 2010). Phosphorus deficiency in tropical soils is higher due to acid pH and the presence of highly weathered minerals such as crystalline and amorphous oxides of Fe and Al (Broggui *et al*., 2010). For making this nutrient available to the plants, large quantities of limestone and phosphate fertilizers are required, since some of these soils may adsorb the nutrient content (Bonfim-Silva *et al*., 2014). Many studies show the positive interaction between liming and the availability of phosphorus to plants, in which increasing soil pH values lead to a better efficiency of phosphorus use by plants (Martins and Pitelli, 2000; Viviane *et al*., 2010; Negreiros, 2014; Marin *et al*., 2015). This occurs because limestone application neutralizes the exchangeable $Al^{+3}$ due to the increase in pH, and provides decrease in phosphorus retention, increasing its availability in solution (Moretto and Viecelli, 2012). Although tropical soils are characterized by the high degree of weathering and low levels of phosphorus available to plants, Brazil presents the greatest capacity to multiply current soybean production in these regions (Bastos *et al*., 2010).

Due to the limited information available about the interaction between liming and phosphating for first year of cultivation areas, the aim of this study was to evaluate the growth and development characteristics of soybean plants under different doses of phosphorus and limestone in cerrado soil.

# MATERIALS AND METHODS

**Location of the experimental area**

The study was performed in a greenhouse at the Federal University of Piauí - UFPI, in Bom Jesus, PI, from October to November 2014. According to Köppen classification, the climate of the region is type Aw tropical, characterized by being hot and humid and with average temperature of 24 ºC. It presents average annual precipitation around 1,100 mm, with rainfall concentrated in the period from November to March (Jacomine, 1986).

**Installation and conduction of the experiment**

The experimental units consisted of pots with 4 kg of soil (dry base), passed through a 2 mm sieve, with three replications, in a completely randomized design. The treatments were arranged in a 4x5 factorial scheme, consisting of the combination of liming (0, 1.5, 6.0 and 12 Mg ha$^{-1}$) with dolomitic limestone (RTNP 91%) and phosphorus doses (0, 100, 200, 300 and 400 kg kg ha$^{-1}$ of $P_2O_5$), using simple superphosphate (SSP, consisting of 18% of $P_2O_5$, 16% of Calcium and 8% of sulfur). . The control treatment was considered as a zero dose for limestone and $P_2O_5$.

It was used a Dystrophic Yellow Latosol soil (Embrapa, 2013), with loam-sandy clay texture from an area with native vegetation cover. After the collection, at depth of 0-0.20 m, the soil was dried, in a 2 mm mesh sieve and, later, led to analysis for determining the chemical composition. The results of soil chemical analysis are presented in Table 1.

Liming was performed 40 days before sowing the crop, in September 2014. The limestone was added and incorporated into the experimental units soil. Phosphorus doses, together with a single dose of potassium (150 kg ha$^{-1}$ of KCL), were applied at the time of sowing. For sowing, four soybean seeds (Intacta RR2 Pro) were used per pot at a depth of 0.05 m. At 15 days after sowing, the thinning was performed, maintaining 2 plants per pot.

**Analyzed variables**

At 50 days after sowing, when the plants were in stage V10, the following determinations were made: plant height; leaf area; stem diameter; fresh matter and dry matter of plants. The plant height determination was characterized as the distance from the soil to the insertion of the last expanded leaf. A digital pachymeter was used for the stem diameter. A leaf area meter model LI-3000 Meter Area was used to determine the leaf area (LA), with a subsequent reading and adjustment in equation (1):

$$AF = \frac{\sum SF}{AS} \qquad (1)$$

$LA$ =leaf area*;* $LS$ =leaf surface e $SA$ = soil area.

The fresh matter of the plants was determined by the mass of the plants cut at a height of 0.1 m from the soil surface.

After weighing, the plants were packed in paper bags and taken to the oven at 65°C for 72 hours. After drying the plants were weighed to determine the dry matter. After the growth evaluation of the shoot part of the soybean plants, from each pot, a soil sample was collected to determine the soil pH in each treatment.

**Statistical analysis**

The results were submitted to normality analysis by Shapiro-Wilk test and variance by F test ($p<0.05$) with the aid of the statistical program "R" version 3.1.2. The quantitative factor (corrective dose and $P_2O_5$) was analyzed with adjustments of multiple regression equations (surface response) through Sigmaplot 11.0 software.

# RESULTS AND DISCUSSION

A significant interaction between limestone doses and phosphorus was observed for plant height (PH), leaf area (LA), stem diameter (SD), fresh mass (FM) and dry mass (DM) of soybean plants (Table 2). All variables were affected by phosphorus and limestone doses, which, acted in an associated way, enabling the adjustment of a response surface model, from which their doses can be optimized, aiming the mean maximization of these variables (Figure 1 and 2). Phosphate fertilization and liming positively influenced the PH increase (Figure 1A). These results show that the maximum height of plants (80.51 cm) was obtained with the joint application of 6.18 Mg ha$^{-1}$ of limestone and 262 kg ha$^{-1}$ of $P_2O_5$. The PH increment at this dose is 81.89% higher than the control. The higher growth of the plant can be attributed to the addition of limestone and phosphorus that improved the chemical properties of the soil. The limestone contributed to increase pH (Figure 3) and consequently, increased the availability of phosphorus. These observations can be reinforced by studies carried by Negreiros (2014), who applied limestone and phosphorus sources in Piauí cerrado soil and observed an increase in the sum of bases (SB), saturation for bases (V), phosphorus contents, calcium and magnesium in the 0-20 cm soil layer.

Similarly, evaluating the effect of phosphate fertilization and liming on the interference relationships between soybean and capim-marmelada, verified that the use of liming with the increase of 70% in soil base saturation, showed an increase in plant height (13.33%) at 49 days after the beginning of the experiment (Martins and Pitelli, 2000). Neto *et al.* (2010) evaluating the phosphate fertilization in the soybean crop in an Oxisol in Piaui Southwest, observed that the dose of 95.60 kg ha$^{-1}$ of $P_2O_5$ in soil with elevation of 50% in the soil base saturation, provided an increase of plant height (14.91%) in relation to the control. At the same time, there is a decrease in plant height for limestone and phosphorus doses higher than the maximum (Figure 1A). This inversion between dose increase and reduction of plant growth is possibly related to the excessive pH soil increase, contributing to the unavailability of micronutrients, and also due to the toxic effect of phosphorus excess in the plant. Similar results were observed in other studies with a decrease in height of soybean plants with doses above 95.60 kg ha$^{-1}$ of $P_2O_5$ (Neto *et al*., 2010) and 140 kg ha$^{-1}$ of $P_2O_5$ (Valadão Junior *et al*., 2008). Thus, soybean responses to phosphate fertilization depend on the soil fertility status (Neto *et al*., 2010).

**Table 1. Chemical characterization of the Dystrophic Yellow Latosol, in the 0 - 0.20 m layer**

| pH | P | $K^+$ | $Ca^{2+}$ | $Mg^{2+}$ | $Al^{3+}$ | H+AL | SB | t | T | m | V | OC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | --- mg $dm^{-3}$ -- | | ------------------------- cmol $dm^{-3}$ ---------------- | | | | | | | ------- % ----- | | mg $dm^{-3}$ |
| 4.2 | 0.4 | 37.5 | 0.2 | 0.1 | 1 | 4.1 | 0.4 | 1.4 | 4.5 | 71.6 | 8.8 | 2.62 |

PH in water, P: phosphorus, $K^+$: potassium, $Ca^{2+}$: calcium, $Mg^{2+}$: magnesium, $Al^{3+}$: aluminum, H + Al: hydrogen + aluminum, SB: sum of bases, m: Saturation by aluminum, V: saturation for bases and CO: organic carbon.

**Table 2. Analysis of variance of the growth variables of soybean crop after the use of limestone and phosphorus doses**

| Variation Source | Mean Squares | | | | |
|---|---|---|---|---|---|
| | HP | LA | SD | FM | DM |
| Limestone doses | 760.55* | 70807.40* | 0.4ns | 21.43ns | 3.4* |
| Phosporum doses | 4122.3** | 685861.33** | 9.90** | 486.73** | 37.18** |
| Limestone x Phosphorum | 1000.73** | 67672.95** | 0.57* | 42.94** | 3.22** |
| C. V. (%) | 19.47 | 23.07 | 11.1 | 21.97 | 26.1 |

** Significant at 1%; * Significant at 5% and [ns] not significant. C. V. - coefficient of variation. PH: plant height, LA: leaf area, SD: stem diameter, FM: fresh matter and DM: dry matter of soybean plants.

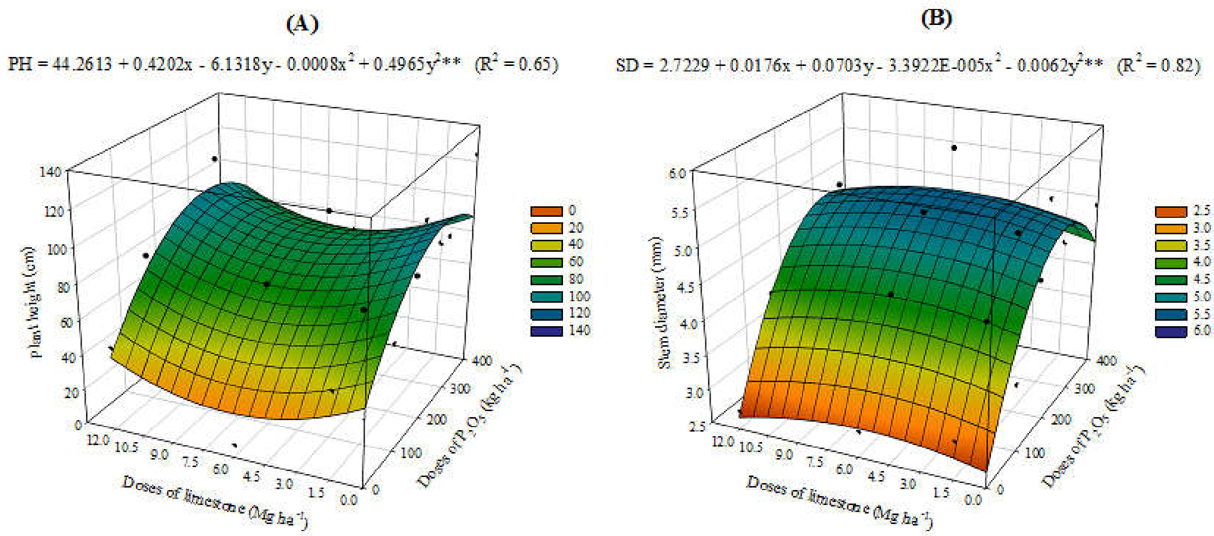


**Figure 1. Means for plant height - PH (A) and stem diameter – SD (B) of soybean according to doses of phosphorus (x) and limestone doses (y). ** Significant at 1%**

The SD of the soybean plants was positively influenced by the doses of limestone and doses of $P_2O_5$ (Figure 1B). The maximum stem diameter (5.6 mm) was reached with doses of 5.67 Mg $ha^{-1}$ of limestone associated with 259.42 kg $ha^{-1}$of $P_2O_5$ With the application of these doses there was an increment of the SD in 105.80% when compared to the control. A larger stem diameter is associated with a more pronounced development of the shoot and especially the root system, favoring the plant survival and development (Paiva *et al*., 2011). In addition, growth in diameter is directly related to liquid photosynthesis, which depends on accumulated carbohydrates and auxins and a favorable balance between liquid photosynthesis and respiration (Sousa *et al*., 2011). Phosphate fertilization and liming positively affected the LA increase (Figure 2A). The maximum leaf area of plants (805.86 cm) was obtained with the joint doses of 12 Mg $ha^{-1}$ of limestone and 279,70 kg $ha^{-1}$ of $P_2O_5$, promoting an increase of 413% in relation to the control. The increase of the leaf area with liming and phosphate fertilization in soybean was demonstrated by Martins and Pitelli (2000), who verified an increase of 32.31% by liming and 198.58% by 200 ppm of $P_2O_5$. Leaf area can be considered a productivity index, given the importance of photosynthetic organisms in organic production (Ferreira *et al*., 2014).

Thus, Marin *et al*. (2015) when evaluating the effect of phosphate fertilization on the production of soybean seeds, observed that plants that received increasing doses of phosphorus in soil corrected with one ton of limestone per hectare, originated plants able to maximize the number of grains per plant with increase in productivity. For FM and DM of soybean plants, there was a positive influence of phosphorus and limestone doses (Figure 2B and 2C). The maximum value of fresh mass (21.30 g) was reached with doses of 7.34 Mg $ha^{-1}$ of limestone in association with 301.75 kg $ha^{-1}$ of $P_2O_5$, providing an increase of 445.33% in relation to the control. The maximum dry mass (5.76 g) was obtained with the joint doses of 5.56 Mg $ha^{-1}$ of limestone and 257.50 kg $ha^{-1}$ of $P_2O_5$, providing an increase of 462.88% compared to the control. Positive results for the weight of shoot dry mass of the soybean shoot were observed at 49 days after the beginning of the experiment, with a 22.08% increase due to the liming effect (Martins and Pitelli, 2000). Viviane *et al*. (2010) verified that the increase in pH in CaCl2 of the soil promoted an increase in the shoot dry mass yield of soybean for both studied soils. For the Dystroferric Red Latosol, the response was linear, with a dry mass increase of about 11% between the original pH (5.6) and pH 7.0, while in the Red Latosol Dystrophic the response

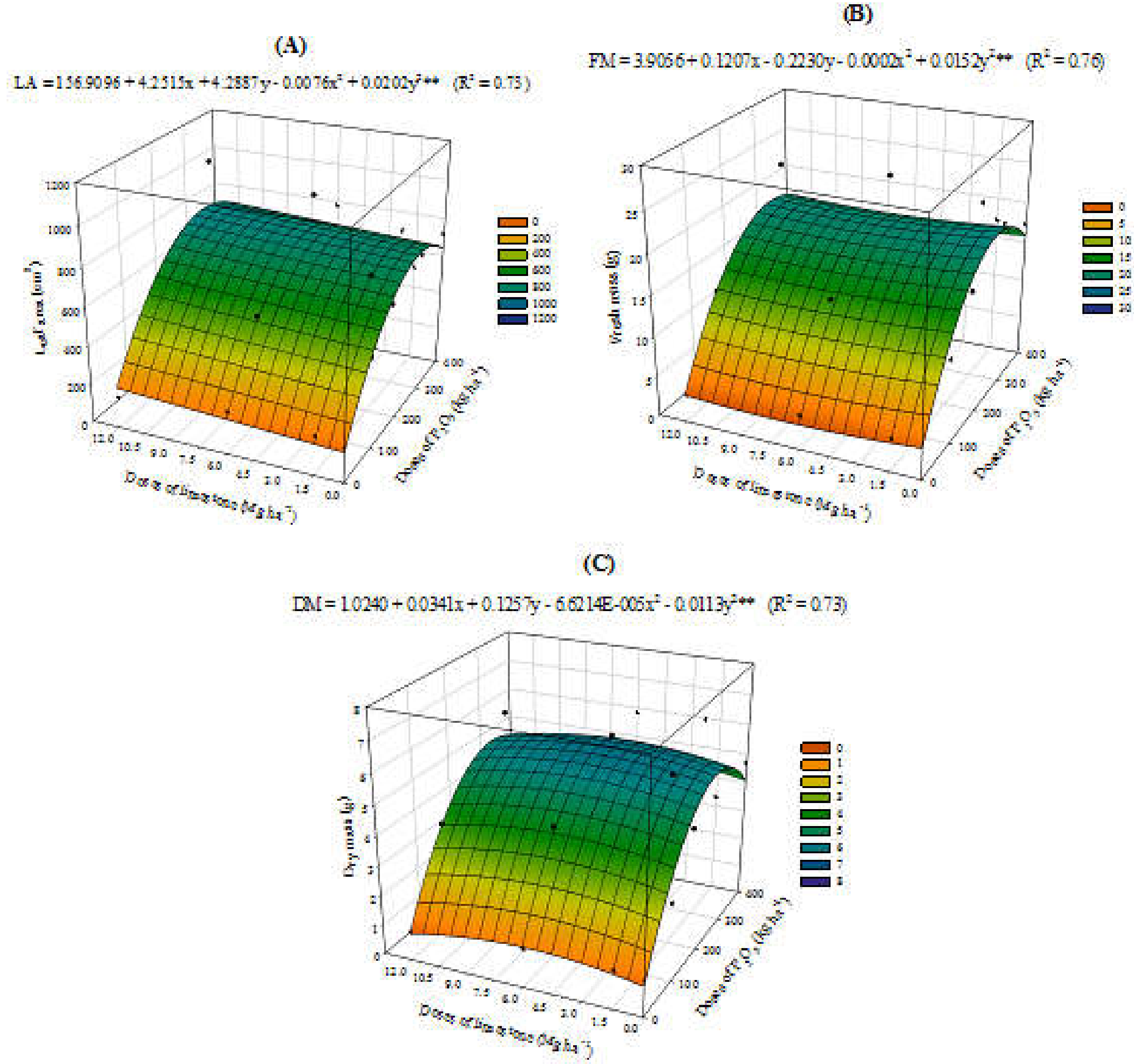


**Figure 2. Means for leaf area - LA (A), fresh mass - FM (B) and dry mass - DM (C) of soybean according to doses of phosphorus (x) and limestone doses (y). ** Significant at 1%**

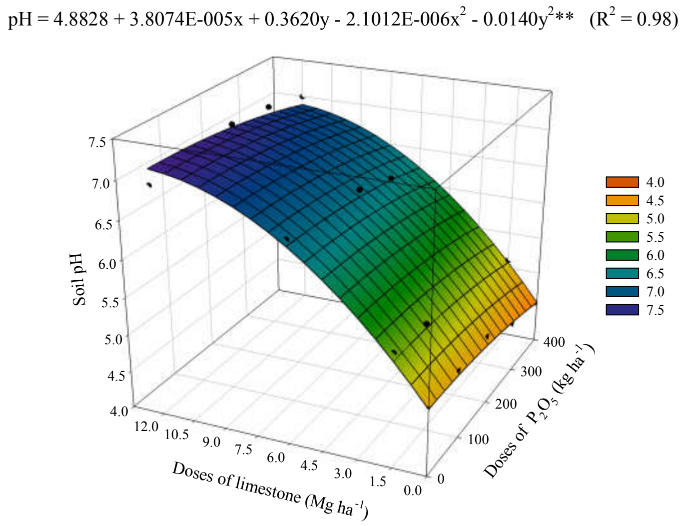


**Figure 3. pH values of the soil according to phosphorus doses (x) and limestone doses (y). ** Significant at 1%**

to the soil pH increase was quadratic, resulting in an increase of 18% in the dry mass. The production of fresh and dry mass increased as a consequence of the increments promoted in other developmental components, such as height, stem diameter and leaf area. These results of plant growth can be justified by the greater availability of phosphorus in the soil due to the application of limestone and phosphorus. A study performed by Negreiros (2014), with the interaction of limestone and phosphorus applied to the soil, provided a higher soil phosphorus content in the depth of 0-40 cm. When phosphorus is available to plants in adequate amounts, it promotes greater growth and greater leaf area, causing greater solar radiation uptake and increased photoassimilate production (Bonfim-Silva *et al*., 2011). The soil pH was significantly affected by the application of limestone and phosphorus to the soil (Figure 3). According to the results, pH increased with the limestone dose increase, reaching maximum value (7.21) with the application of 12 Mg $ha^{-1}$ of limestone. However, the pH reduced with the phosphorus dosage increasing. Negreiros (2014), also found that the liming practice contributed to the increase of pH and reduction of the acidity components, $Al^{3+}$ (aluminum), H + Al (potential acidity) and m (aluminum saturation). Natale *et al*. (2007) also verified the positive effects that liming promotes in the improvement of soil chemical attributes related to acidity, increasing pH, $Ca^2$, $Mg^{2+}$, SB and V contents and decreasing H + Al, up to 60 cm depth (in the line spacing and in the crop line).

The application of 6 Mg $ha^{-1}$of limestone was enough to maintain the soil pH at the ideal level for the crop development (between 6 and 6.5), because at this level, there is an ideal nutrient availability balance for the plants. Thus, providing a better development and greater productivity. According to Prochnow *et al*. (2004), in general, the availability of P is higher in soils with pH in the range of 5.5 to 7.0. In a study performed by Brevilieri (2012) about phosphorus fertilization in soybean cultivation on a Red Latosol, it was verified that the use of 180 kg $ha^{-1}$ of $P_2O_5$ promoted maximum productivity (1860.5 Kg $ha^{-1}$). The higher doses of limestone cause the overliming phenomenon that happens when excessive doses of limestone are applied to the soil, a fact that limits the development of the crop and the availability of cationic micronutrients in the soil (Silva *et al*., 2015).

**Conclusion**

The interaction between liming and phosphate fertilization is positive and favors the soybean growth and development.
The combined application of approximately 6 Mg $ha^{-1}$ of limestone and 260 kg $ha^{-1}$ of $P_2O_5$ provides the highest growths in soybean plants. The soil pH increases with the limestone dose increase, reaching values in the range of 6 to 6.5 with the application of 12 Mg $ha^{-1}$ of limestone.

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