Effects of limestone and organic fertilizer on cassava yield and on chemical and physical soil properties

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ABSTRACT

Cassava has a high yield potential that can be achieved with adequate liming and fertilization of the soil. The objective of this study was to evaluate the effect of organic fertilizer application, in association or not with liming, on yield and morphological characteristics of cassava roots and on chemical and physical properties of the soil. The experiment was arranged in the split plot design. The plots corresponded to limestone rates (0 and 2.5 t ha^{-1}) and the sub-plots to chicken manure rates (0, 4, 8, and 12 t ha^{-1}). Yield showed no response to limestone application, but responded to manure, producing 43 t ha^{-1} of roots at the rate of 8 t ha^{-1}. The treatments had no influence on soil density and total porosity. The addition of manure increased the concentrations of P and K, while the addition of limestone increased Ca and Mg in the soil. The pH was affected only by limestone. Therefore, limestone does not affect crop yield and soil physical properties up to the amount used. Use of chicken manure up to 8 t ha^{-1} increased yield. Limestone and manure affect soil fertility in different ways.

Keywords: *Manihot esculenta* Crantz; chicken manure; root length; soil density; nutrient.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) crop has great importance in the tropics because it is a readily available food, easy to grow, with high capacity of transformation, and can be stored as food for several years (Nassar *et al*., 2009). It is a species native to Brazil (Valle, 2005) and is cultivated in all states of the country (IBGE, 2017). Its roots rank fifth among the world's most produced food behind only rice, wheat, potatoes, and corn (International Potato Center, 2010).

Due to its high yields, the crop extracts a large quantity of nutrients from the soil (Ternes, 2002), thus, the adequate amounts of nutrients is essential for cassava to express its yield potential.

The response of cassava to fertilization varies according to the soil fertility. The crop responds well to fertilization when cultivated on low fertility soils, while it may not present increase in yield with the application of fertilizers to an already medium to high fertility soil (Lorenzi, 2003).

Acidity or alkalinity of soils are the factors that most affect nutrient availability to plants (Caires, 2013). Therefore, the determination of the soil acidity and its amendment through liming allows greater nutrient utilization from fertilizer applications by cultivated plants.

Mineral or organic fertilizers can be used to amend soils, and the latter has greater advantages, with large beneficial effects on the chemical, physical, and biological properties of the soil (Ourives *et al*., 2010).

Odedina *et al*. (2011) compared cassava root yield between manure sources and NPK fertilizer and found that the use of poultry manure resulted in 44% and 29%

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increase of yield over the control without any source of fertilizer and over the treatment with NPK, respectively.

Mathias & Kabambe (2015) studied the effects of cattle manure rates on cassava yield and found 26% increase in yield at the rate of 5 t ha^{-1} compared with the non-application of manure.

In sweet-potato, Rós *et al*. (2014) studied the effect on yield of chicken manure applied to the soil up to 12 t ha^{-1} and obtained a higher yield of tuberous roots (23.6 t ha^{-1}) with the rate of 5.8 t ha^{-1} manure. It is of note that the use of manure at this rate resulted in 32% increase of yield, which can be explained by the physical and chemical improvements in the soil.

The increase in crop yield with application of manure to the soil is often related to improvements in soil chemical (Odedina *et al*., 2011) and physical properties (Mecabô Junior, 2013). The addition of organic fertilizers can raise the pH, with consequent increase in cation exchange capacity and nutrient release (Menezes & Silva, 2008, Pires *et al*., 2008). The manures are sources of Ca, Mg, S, and micronutrients, as well as important nutrients for soil fertility maintenance (Odedina *et al*., 2011).

The benefits to soil physics by the application of manure include increased macroporosity, reduced soil density, and maintenance of aggregate stability (Mecabô Júnior, 2013). The organic matter favors increased total porosity and reduced soil penetration resistance (Magalhães, 2017)

Silva *et al*. (2012) argued that the application of cattle manure to the soil supplies and makes nutrient available to yam plants, improves the soil cation exchange capacity, and hence increases crop yield. Alves *et al*. (2008) pointed out that these effects are stronger in low CEC soils.

Considering the hypothesis that the application of limestone and organic fertilizer favors cassava crop yield and improves physical and chemical properties of the soil, the objective of this study was to evaluate the effect of the organic fertilizer (laying hen manure), in association or not with liming, on the yield and morphological characteristics of cassava roots and on chemical and physical properties of the soil.

MATERIAL AND METHODS

The study was carried out in the municipality of Presidente Prudente, São Paulo, located at 22º 11' S latitude and 51º 23' W longitude, and 424.29 m altitude. The experiment was conducted in a transition area between two soil types, Neosol and Argisol. The chemical analysis of the soil was performed before the land preparation for the experiment setup and resulted in: pH ($CaCl_2$) = 4.8; organic matter = 11.1 g dm^{-3}; P (resin) = 4.8 mg dm^{-3}; K = 2.3 mmol$_c$ dm^{-3}; H + Al^{+3} = 23.8 mmol$_c$ dm^{-3}; Ca^{+2} = 14.3 mmol$_c$ dm^{-3}; Mg^{+2} = 4.5 mmol$_c$ dm^{-3}; CEC = 44.9 mmol$_c$ dm^{-3}; and V% = 47%.

The experiment was arranged in a split-plot design, with eight replications. The plots consisted of two limestone rates (0 and 2.5 t ha^{-1}) and the subplots consisted of 4 chicken manure rates (0, 4, 8, and 12 t ha^{-1}). Limestone characteristics were: CaO = 36%; MgO = 12%, NP = 94.2; RTNP = 85%. Chicken manure was stored under plastic cover in an aerated area for 90 days prior to use. Manure chemical composition was as follows: N – 2.21%, P_2O_5 – 7.9%, K_2O – 3.5%, Ca – 13.6%, Mg – 0.8%, S – 0.5%, MO – 33.3% and C – 18.38%.

Limestone was broadcast on plowed soil and incorporated with leveling disk harrow, 40 days before the cassava planting. Manure was broadcast and incorporated with a new plowing and, finally, land leveling was carried out with a leveling disk harrow, 10 days before planting.

Stem cuttings about 0.2 m in length taken from the middle third of plant stems of the cassava cultivar IAC 576-70, 12 months of age were planted at 0.1 m depth.

Each experimental plot comprised an area of 28.8 m^2, with four rows and 10 plants each spaced 0.9 m between plants and 0.8 m between rows. The net plot consisted of the middle two rows in each plot, not using the plants at the ends of the rows. Cultural operations in the experimental area included manual weeding during the whole cycle of the crop.

Planting was carried out on 05/15/2015 and harvest was carried out 330 days after planting. Total yield (roots with diameter $\geq$ 0.03m and length $\geq$ 0.10m) and commercial yield (roots with diameter $\geq$ 0.05m and length $\geq$ 0.15m) were evaluated. Fresh mass, root length, and diameter of each root were also measured.

Soil samples were taken from the plots at 0-0.20m depth to evaluate the chemical properties at harvest (11 months after planting) and samples with undisturbed structure (1 per plot) were collected from the middle portion of the 0-0.30m depth to evaluate soil physical properties of the soil eight months after planting. Soil properties evaluated were: active acidity (pH), organic matter (OM), phosphorus (P), calcium (Ca), magnesium (Mg), potassium (K), base sum (BS); cation exchange capacity (CEC); soil density (SD) and total porosity (TP).

The following methods of analyses were used: pH in $CaCl_2$; P, Ca, Mg, and K by ion exchange resin, and organic matter by oxidation, according to Camargo *et al*. (2009). CEC and BS were calculated. SD was determined by the volumetric ring method, in which the soil sample mass dried at 105 °C is related to the sum of the volumes occupied by the particles and the pores, while TP was determined by the ratio between soil density (SD) and particle density (PD). Particle density (PD) is calculated by the volumetric flask method. Physical attributes were determined according to Embrapa (1997).

Results were analyzed by analysis of variance and means were compared by the Tukey test at 5% of probability or adjusted to polynomial regression equations. The model was selected based on the significance of the F test and the highest values of the coefficient of determination (R^2). The statistical significance was tested at 5% probability of error.

RESULTS AND DISCUSSION

No interaction was found between limestone application and chicken manure rates for any of the soil evaluated properties.

There was no difference between the treatments with and without limestone, and the results for total yield, commercial yield, length, diameter, and individual fresh root mass were 39.9 t ha^{-1}, 35.6 t ha^{-1}, 24.8 cm, 4.8 cm, and 410.4 g, respectively. Otsudo & Lorenzi (2004) and Souza *et al*. (2009) point out that the use of limestone has not promoted significant increases in cassava yield due to the tolerance of the crop to soil acidity. However, increased crop yield was reported by Campos *et al.* (2004) as being probably due to the higher acidity and lower fertility of the soil used in their study.

Total and commercial yields showed an estimated quadratic response to application of manure, with maximum points close to 8 t ha^{-1} of the fertilizer. The total and commercial yields obtained at this rate were 45 and 43 t ha^{-1}, respectively (Figure 1). Amanullah *et al*. (2006) also reported increase in yield of cassava roots with application of poultry manure (10 t ha^{-1}) and attributed the yield gain to improvements in soil physical properties and slow and constant availability of nutrients during the crop growing season. According to Amanullah *et al.* (2007), application of poultry manure to cassava provides good biomass production and better nutrient absorption, resulting in higher yield of tuberous roots.

The estimated yield quadratic response was also reported for other crops. Rós *et al.* (2014) reported that sweet potato fertilized with chicken manure up to the rate of 12 t ha^{-1} presented maximum commercial yield of tuberous roots (23.6 t ha^{-1}) at the rate of 5.8 t ha^{-1}, with decrease in yield at higher rates of manure. Oliveira *et al*. (2001) verified that the addition of chicken manure to yam crop promoted yield increase up to the rate of 6.6 t ha^{-1} and yield reduction at higher rates. Therefore, the use of excessive amounts of organic fertilizers results in a decrease of crop yield. Primavesi (2002) argued that excess NPK reduces nutrient absorption and can reach toxic levels, causing imbalance in the absorbed and metabolized macro and micronutrient concentrations, which results in yields lower than the plant potential when there is a balance between the rates of absorption and metabolization.

However, Rós *et al*. (2014) studying the same cassava variety as the present study, found that the rates up to 18 t ha^{-1} did not reduce yield, which indicates that for the those environmental conditions the amount of manure was not capable of damaging the crop.

Length and root mean diameter showed linear behavior. However, with increasing manure rates, the length decreased from 26.8 cm at the rate 0 to 22.7 cm at the rate 12 t ha^{-1} (Figure 2A), while the diameter increased from 4.7 cm at the rate 0 to 4.9 cm at the rate 12 t ha^{-1} (Figure 2B). The fresh root mass showed no change, with mean value of 410.4 g.

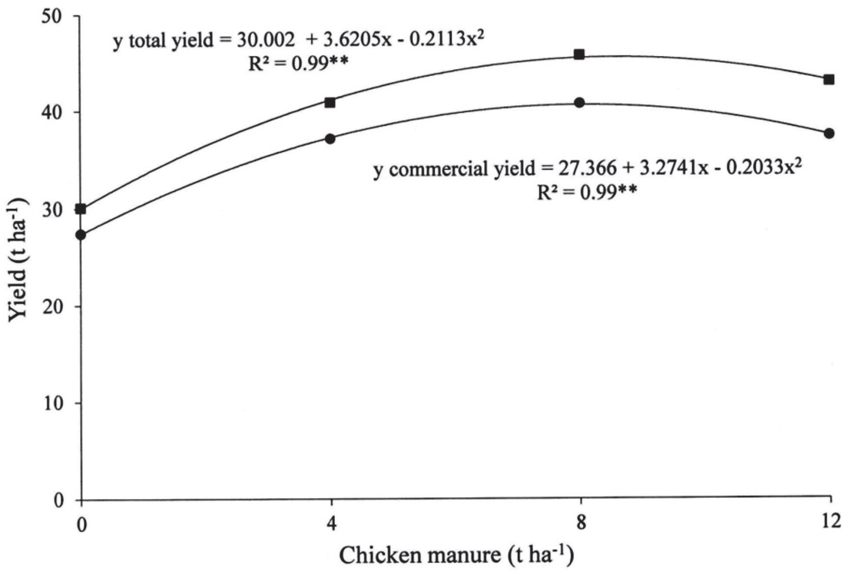

Figure 1: Total and commercial yields of cassava roots. ** Significant at 1% by test F.

The yield increase of cassava roots reported by Rós *et al*. (2014) occurred due to the increase in the number of roots per unit of plant, without any difference in individual mean fresh mass of roots. Thus, it is likely that, in the present work, the addition of manure to the soil, up to the rate of 8 t ha^{-1}, also resulted in an increase in the number of roots with similar mean fresh mass per plant unit.

No interaction was found between limestone treatments and manure application rates as well as application of limestone and manure caused no change in soil density (1.57 Mg m^{-3}) and total soil porosity (0.4 m^3 m^{-3}). Rós *et al*. (2014) found that application of manure up to the rate of 18 t ha^{-1} to a Argisol, sandy texture, reduced soil density and increased porosity. The difference from this study may be attributed to the type of soil and the rate used, since it is expected that reduction in soil density would occur only with the continuous application of manure (Arriaga & Lowery, 2003). Dortzbach (2009) studied the influence of pig slurry, deep-litter, and urea on physical attributes of an Argisol, and even with the continuous application over five years, they found no changes in soil density, total porosity, macroporosity, microporosity, and water retention.

No interaction was found between limestone treatments and manure application for any of the soil chemistry characteristics studied.

There was no change in the soil pH at harvest as a result of manure application. This is because the pH usually increases when there is a continuous application of organic fertilizer (Mitchell & Tu 2006; Galvão *et al*. 2008). However, the pH varied as a function of the application (pH = 5.46) or not (pH = 4.86) of limestone, and, as expected, the application of limestone raised the pH of the soil. Dos Anjos *et al.* (2011) also confirmed the increase in soil pH, even when it was measured at 27 months after the limestone application.

The organic matter concentration showed no change in function of application of limestone and manure, with a mean of 11.83 g dm^{-3}. This result differed from reports by Rós *et al.* (2014), in which the application of chicken manure resulted in increased organic matter in the soil. This difference is probably related to the amount of manure used (up to 18 t ha^{-1}).

Phosphorus and potassium were not influenced by limestone application, but their concentrations increased with increase in the rate of manure used. These results indicate that these nutrients were supplemented by manure at rates higher than the plant requirements, resulting in significant increases in their concentrations. P concentration presented an adjusted response according to the linear model, showing increase in the concentration with the increase in manure rate (Figure 3A). At the rate 0,

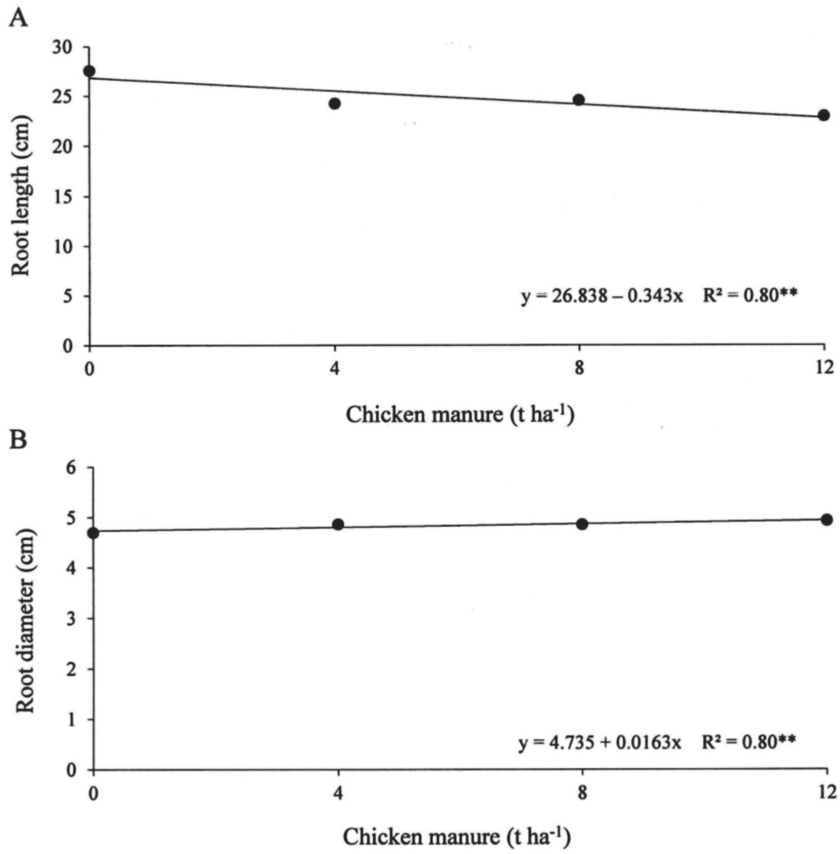

Figure 2: Length (A) and mean diameter (B) of roots. ** Significant at 1% by test F.

the estimated mean was approximately 5.55 mg dm^{-3} and reached about 18.37 mg dm^{-3} with the application of 12 t ha^{-1} of manure, resulting in a 230% increase. Rós *et al*. (2014), working with sweet potato, also used chicken manure up to 12 t ha^{-1}, but the soil P concentration increased in 1313%, which is related to soil and crop conditions of their study. Reduction in P adsorption in the soil is due to the carboxylic and phenolic functional groups present in the organic matter responsible for blocking the positive charge sites of Fe and Al oxides, which are P adsorption sites (Hue, 1991). Silva & Menezes (2007) found that cattle manure applied to cassava crop increased extractable P in the soil. Moreover, in the case of cassava, there is a significant response to P application, as Brazilian soils are generally low in its concentration (Mattos *et al*., 2002; Pereira *et al*., 2012).

Potassium is the nutrient absorbed in greater amounts by cassava (Otsubo & Lorenzi, 2004), it is, thus, essential for the crop to show high productivity. The K concentration also presented an adjusted response according to the linear model, showing increase in its concentration with the increase in manure rate (Figure 3B). At the rate 0, the estimated mean was approximately 2.23 $mmol_c$ dm^{-3} and the application of the highest rate increased to about 3.00 $mmol_c$ dm^{-3}, resulting in a 35% increase. At harvest, the K concentration was higher than the concentration at planting, therefore, although the crop absorbed a great quantity of this nutrient, the manure provided K concentrations higher than the necessary to the crop. In their work with cassava, Rós *et al*. (2014) found that the application of up to 18 t ha^{-1} did not raise nutrient concentration in the soil at the time of harvest, which may be related to the pre-existing K concentration in the soil (3.1 $mmol_c$ dm^{-3}).

Calcium and magnesium concentrations were not influenced by manure, but increased with limestone application (Table 1), that is, the amounts added of these nutrients to the soil by manure and that became available to the plants were used by the cassava crop. On the other hand, supply of calcium and magnesium by liming is common practice to raise the concentrations of these macronutrients in the soil, as the acidity correctives have Ca and Mg in their composition.

Increasing Ca and Mg concentrations with limestone application also increased the Base Sum (BS) (Table 1). Cation exchange capacity (CEC) was not significantly influenced by the application of limestone or manure, with mean value of 45.1 $mmol_c$ dm^{-3}. This result differs from Alleoni *et al*. (2005) and Bambolim *et al*. (2015) who reported that the application of limestone increased CEC. However, by holding the CEC value and increasing the BS, the Base Saturation (V) increased with the limestone application (Table 1). Dos Anjos *et al*. (2011) also found that Base Saturation measured at 12 months after the

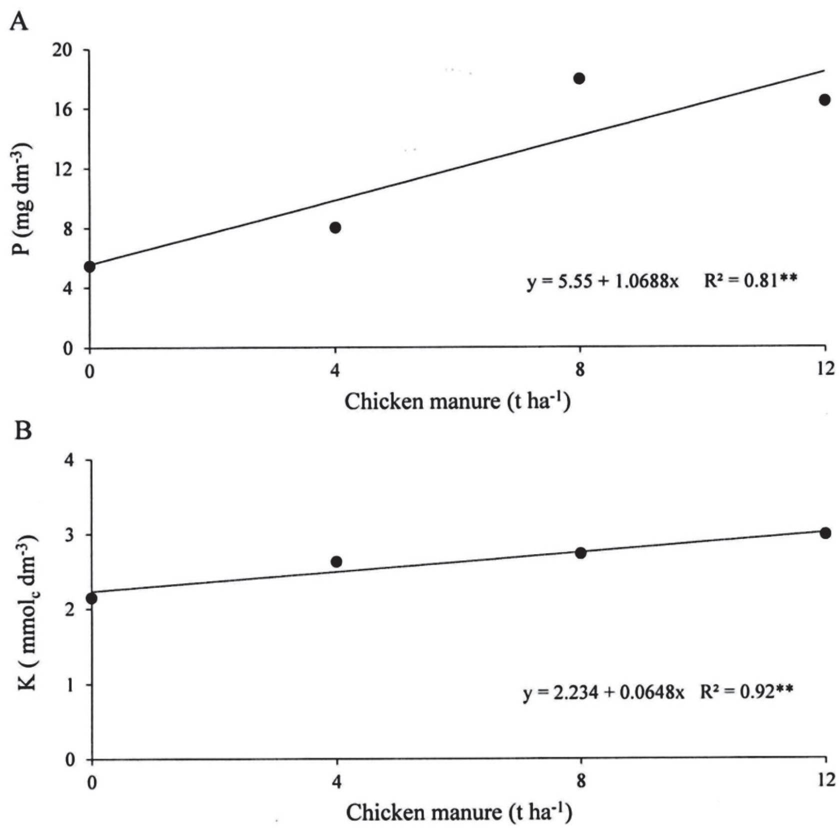

Figure 3: P (A) and K (B) concentrations in soil. ** Significant at 1% by test F.

Table 1: Calcium and magnesium concentrations, Base Sum (BS), and Base Saturation (V) as a function of limestone application to the soil

Treatment	Ca	Mg	BS	V
	mmol$_c$ dm^{-3}			%
With lime	21.9 A	6.0 A	30.4 A	64.9 A
Without lime	15.3 B	4.3 B	22.3 B	50.8 B
CV (%)	14.98	10.25	14.68	9.09

Means followed by the same letter in the column are not significantly different by the Tukey test at 5% probability.

application of limestone in an orange orchard was higher than the control without limestone application. It is of note that Base Saturation, according to Natale *et al*. (2007), reflects in general the benefits of liming such as increase of pH, Ca^{2+}, Mg^{2+}, and Base Sum and decrease of Al^{3+} and H + Al.

CONCLUSIONS

Under the conditions of the present study, the cassava crop showed no response to limestone application, maintaining yield and root characteristics independent of the application of the acidity corrective.

The crop responded to soil fertilization, increasing total and commercial yields with application of chicken manure up to the rate of about 8 t ha^{-1}. The use of manure promoted changes in length and diameter of tuberous roots.

No difference was found in the physical properties soil density and total porosity due to the application of limestone and manure to the soil. Chicken manure application increased P and K concentrations, while limestone application increased Ca and Mg concentrations. The pH was influenced only by limestone.

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