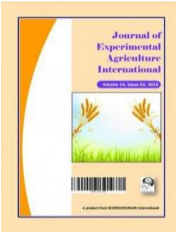

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Chemical Soil Attributes, Accumulation of Foliar Macronutrients and Productivity of the 'Vitória' Pineapple Plant Fertilized with Urea and Chicken Manure

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Authors' contributions

This work was carried out in collaboration between all authors. Author FAPL designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors WEP, TJD and YHL managed the analyses of the study. Authors JGM and MLMV managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The pineapple plant cultivar 'Vitória' is resistant to Fusarium and it presents similar characteristics to the cultivars 'Pérola' and 'Smoot Cayene'. However, the expansion of this new cultivar depends on the development of research on several aspects, among them, fertilization. In this context, the experiment was carried out with the objective of evaluating soil fertility, foliar macronutrient contents and productivity in 'Vitória' pineapple plant in function of nitrogen fertilization with urea and chicken manure. The experiment was conducted under randomized block design, with four replications.

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Treatments consisted of five doses of N, in two sources of organic fertilization (chicken manure) and mineral (urea), totaling nine combinations generated through the Central Composite Matrix of Box: T1 , 44 and 2.91; T 2 , 152 and 0; T 3 , 0 and 10; T 4, 44 and 17.1; T 5 , 260 and 2.91; T6 , 152 and 10; T7 , 152 and 20; T8 , 304 and 10; and T9, 260 and 17.1 g plant^{-1}. At 6 months after planting the chicken manure decreased H + A1, Mg and CEC levels, and at 23 months after planting increased soil P, SB e CEC levels. In the two seasons, Urea has reduced pH and it reduced Mg, SB and CEC contents at six months after planting. Doses of urea between 10 and 12 g plant^{-1} are recommended in order to maximize the productivity of the pineapple plant.

Keywords: Ananas comosus; plant nutrition; soil fertility.

1. INTRODUCTION

Pineapple culture requires high quantities of nutrients for its development and production. However, nutrient levels in the producing regions of pineapple are insufficient to fulfill nutritional needs [1]. In addition, the amounts of nutrients absorbed by the crop are very high when compared to other crops [2].

According to the objective of the production, it is necessary to establish a judicious fertilization program, either with organic or mineral fertilization, to guarantee the high pineapple plant productivity [3,4]. Due to the high nutritional demand, and factors like the edaphoclimatic conditions, adopted management practices, cultivar, system and the planting density [5,6].

The 'Vitória' has similar agronomic characteristics in relation to ‘Pérora’ and ‘Smooth Cayenne’ utilized as reference, besides being resistant to the major illness of pineapple fruit, the *Fusarium*, which is the main cause of yield losses [7]. However, the increase in crop yield depends on several factors, including nutrient supply; therefore, it is necessary to study the nutritional aspects of this cultivar in order to satisfy its requirements.

About nutritional aspects, nitrogen (N) is one of the most important macronutrients for plants, because it is part of a series of necessary compounds for plant development, such as the composition of chlorophyll molecules, nitrogenous bases of nucleotides, amino acids, proteins (among which the ribulose enzyme 1, 5-biophosphate carboxylase oxygenise - Rubisco, in the Calvin cycle, catalysts of the photosynthetic reduction of CO_2) and several compounds of the secondary metabolism. To be part of these substances, N is generally absorbed from the rhizosphere by the roots, where it it is mainly in the available forms of ammonium (NH_4^+-N) or nitrate (NO_3^--N) [8,9].

Nitrogenous organic sources have become a common practice, especially for small farmers, for providing organic matter, macro- and micronutrients and by its low cost. Associated with mineral fertilization, organic fertilization can increase farmers’ efficiency, by promoting benefits in the physical, chemical and biological soil aspects, improving physical structure for plant growth, increasing water and nutrients holding capacity, and improving plant health due to the greater diversity and activity of soil microorganisms [10].

Among the fertilization organic sources, stands out the chicken manure which normally presents high levels of nutrients, such as N, phosphorus (P), potassium (K) and calcium (Ca), higher than cattle manure, another source of organic fertilizer [11]. Moreover, because it is a byproduct of poultry activity it can be obtained at fowl run and poultry farms, with a low cost acquisition. However, for most crops, it does not have a recommended dose to be used as fertilizer.

Considering that the utilization of new varieties and the nutritional improvement are necessary on aspects for pineapple plant, the present study was carried out with the aim of assess the soil chemical attributes, the macronutrient contents in the leaf and the productivity of 'Vitória' pineapple fertilized with doses of two nitrogenous sources: mineral in the form of urea and organic in the form of chicken manure.

2. MATERIALS AND METHODS

The experiment was conducted in the experimental area of Quandu Itapororoca Farm, located approximately 11 km from the municipality of Itapororoca, state of Paraíba, Brazil. The prevailing climate in the region is As' type, hot and humid with fall-winter rains, drought period of five to six months, average temperature varying from 22 to 26ºC and an annual rainfall of 1,500 mm. Rainfall data were collected in the city of Araçagi, state of Paraíba, Brazil, located approximately 15 km from the experimental area (Fig. 1).

The experimental design was a randomized block design, with four replications. The treatments consisted of five doses of N, in two sources: organic as chicken manure and mineral as urea, totaling nine combinations generated through the Central Composite Matrix of Box: T 1 - 44 and 2.91; T 2 - 152 and 0; T 3 - 0 and 10; T 4-44 and 17.1; T5 -260 and 2.91; T6 -152 and 10; T7 - 152 and 20; T8 -304 and 10; and T9 - 260 and 17.1 g plant^{-1}. According to Silva et al. [12], N doses were defined based on the recommendations of N for pineapple. The soil of the experimental area was classified as Yellow Red Argisol and before the installation of this experiment samples of the 0-40 cm layer were collected and characterized by their physical and chemical attributes (Table 1).

The planting was carried out in the second month of the year, with pineapple plants of the 'Vitória', produced by '*in vitro*' cultivation. The plants were planted in raised bed in the system of double rows, spaced 0.9 x 0.40 x 0.40 m, resulting in a density of 38.400 plants ha^{-1}.

Fertilization consisted of application of 154 kg of P_2O_5 ha^{-1} were applied. Potassium addition was not necessary because it presented an adequate content (74.28 mg kg^{-1}). Nitrogenous fertilization was carried out under cover, split into three applications, the first one was at two months after the transplanting of plants, being composed of 50% of the urea doses and 50% of the chicken manure doses, the second one was applied six months after transplanting, and consisted of 50% remaining dose of chicken manure, and the third N dose was applied eleven months after transplantation the plants, composed of remaining 50% of urea doses. During the experiment, the usual cultural practices were performed aiming to guarantee good cleaning conditions and sanity of the plants. Weed control was carried out with the use of the Diuron herbicide, in a post-emergence and through manual weeding, with the aid of hoes. Irrigation was done during periods of absence of rainfall by the conventional sprinkler method.

At 6 and 23 months after planting, soil samples were collected at depth of 0-20 cm, taking in each plot a composite sample from 3 simple samples collected between plants of the useful area. The samples were air dried, sieved at 2 mm mesh for further determination of the pH and the contents of P, K^+, Na^+, Ca^{2+}, Mg^{2+} and organic matter according to Embrapa - Empresa [13]. The leaf D. was also collected, washed, cut, dried in a forced air circulation oven at 65ºC until constant weight and milled in a Wiley mill. In these plant samples the N, P and K contents were determined according to the methodology of Tedesco et al. [14]. At the end of the pineapple growth, pineapple fruits were harvested and weighed to calculate the productivity (t ha^{-1}).

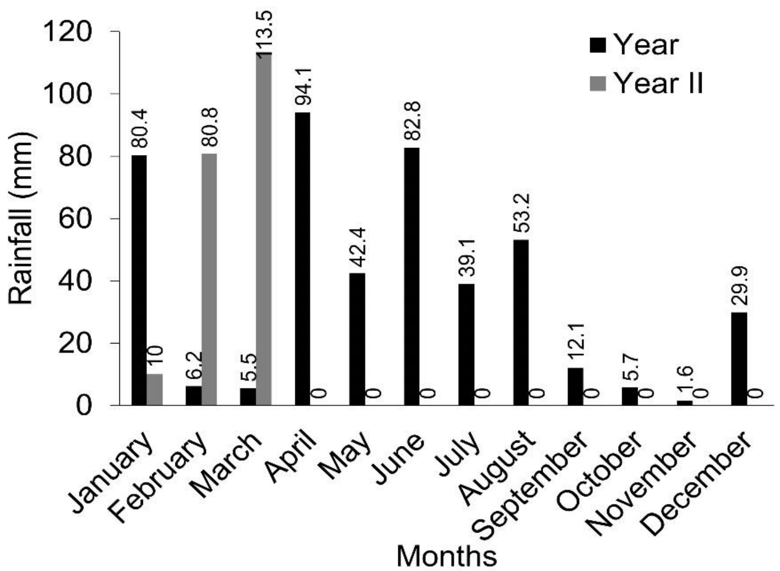

Fig. 1. Rainfall during the experiment conduction

Table 1. Soil chemical attributes before the experiments in the layer 0-40 cm and the chicken manure

Attributes of soil	Values	Attributes of chicken manure	Values
pH	5.5	pH	7.3
P	3.3 mg kg-1	P	13.7 g kg^{-1}
K^+	74.28 mg dm^{-3}	K^+	46.5 g kg^{-1}
Na^+	0.2 $cmol_c$ dm^{-3}	S	0.35 g kg^{-1}
Ca^{2+}	3.1 $cmol_c$ dm^{-3}	OC	349.2 g kg^{-1}
Mg^{2+}	1.3 $cmol_c$ dm^{-3}	Mg^{2+}	5.5 g kg^{-1}
Al^{3+}	0.2 $cmol_c$ dm^{-3}	N	34.5 g kg^{-1}
H^++Al^{3+}	11.2 $cmol_c$ dm^{-3}	Relation C:N	34.5 g kg^{-1}
SB	4.75 $cmol_c$ dm^{-3}	Humidty	38.7%
CEC	16.0 $cmol_c$ dm^{-3}	OM	602.2 g kg^{-1}
V	29.7%		
m	4.04%		
O.M.	8.7 g kg^{-1}		

pH= ionic potential of hydrogen; P = phosphorus, Mehlich^{-1}; K^+= potassium, Mehlich^{-1}; Na^+=sodium, KCl 1 mol/L; Ca^{2+}= calcium, KCl1 mol/L; Mg^{2+}= magnesium,KCl1 mol/L;SB = sum of exchangeable bases (Ca^{2+}+ Mg^{2+}+ K^+); H^++ Al^{3+}=potential acidity, Ca acetate 0.5 mol/L, pH 7.0; Al^{3+}= exchangeable aluminum by Ca acetate 0.5 mol/l, pH 7.0; CEC = exchangeable capacity of cations [SB + (H^++ Al^{3+})];V = saturation percentage by exchangeable bases [V= (SB/CEC)100];N = nitrogen; OC= organic carbon, Walkley-Black method; OM=soil organic matter, Walkley-Black method

All results were submitted to variance analysis (ANOVA), polynomial regression analysis for the N doses, being chosen the mathematical model with the coefficient of determination (R2) above 40%. For the variables that presented two periods, the joint analysis was performed. The Principal Component Analysis (PCA) was also performed. The SAS software was used to perform these analyses [15].

3. RESULTS AND DISCUSSION

The doses of chicken manure significantly influenced the content of soil Al3+, H + Al, P, Mg, SB and CEC and P concentration in the leaves. The urea doses reduced significantly the pH, Mg concentration in year 1, SB and CEC in the soil and leaf P and productivity (only significant for urea treatment).

Soil pH was not influenced by chicken manure and, presented an average value of 5.4 and 5.0 at 6 and at 23 months after planting, respectively. This may have occurred due to the organic matter contained in the chicken manure that was responsible for the maintenance pH in the two collection seasons, since the addition of organic matter results in an increase or a reduction of soil pH, depending on the predominance of processes which consume H + [16]. In this context, [17], studying impacts of fertilization with chicken manure also did not observe changes in soil pH.

The urea doses linearly decreased the pH in the two soil collect seasons (Fig. 2A), obtaining the highest pH (5.6) without urea addition in the first time of soil sampling. In the second date, it was observed that the highest pH value was obtained with the addition of 3 g of urea and the lowest pH (4.9) with the highest dose of urea (20 g). In the present work, the lowest values of pH with the use of highest urea dose can be explained by the fact that the higher presence of N in the soil increases the carbonic acid concentration, due to the greater microbial activity, which are dissociated and release H+ ions, reducing soil pH as in [18,19], promoting higher concentrations of acids, and consequently more acidic pH. What was also observed by Silva et al. [20] when evaluating urea doses in 'Vitória' pineapple plant, and was verified a similar effect on soil pH with doses increased.

According to Matos and Sanches [21], the pine-apple plant is a plant well adapted to acid conditions, preferring soils with pH between 4.5 and 5.5. Therefore, despite the variations observed, soil pH values for all treatments remained within the range considered adequate for the crop.

Chicken manure decreased the soil aluminum content at 23 months after planting 'Vitória' pineapple, with data adjustments to the linear regression model. The lowest estimated aluminum content was 0.05 $cmol_c$ kg^{-1}, obtained with the maximum dose of chicken manure (304 g plant $^{-1}$). After six months of plant growth there was no influence of the doses of chicken manureThe aluminum in the soil was not influenced by the urea doses (Fig. 2 B).

The reduction of aluminum content with doses of chicken manure increased probably occurred due to the complexing capacity of organic matter, since Al_3^+ is the second metal ion more complexed by functional groups of organic matter [22]. The organic acids interact with the present elements in the soil solution and they form organic complexes with Al, Ca, and Mg, thus raising the potential for acidity neutralization and mobility of exchangeable cations in the soil [23].

H + Al contents were influenced only by chicken manure doses only after six months of planting, with adjustment to the linear regression model, decreasing by raising the doses. The lowest value of 1.09 cmolc dm^{-3} was obtained with a dose of 304 g plant^{-1} of chicken manure (Fig. 3A). The potential acidity decreased by raising chicken manure doses, probably due to the increase of electric charges in the soil by the addition of organic matter [24].

Soil P content increased with the increase of the doses of chicken manure after 23 months of planting of 'Vitória' pineapple (Fig. 3B). This increase of soil P concentration with the increased chicken manure doses may have been due to organic acids being efficient in increasing P availability by blocking the adsorption sites, making P more available in the soil solution [25].

Magnesium concentration was adjusted to the linear regression model at six months after planting, as a function of the doses of chicken manure and urea. It was found that the highest Mg contents (1.08 and 1.3 cmolc.dm^{-3}) were obtained without the addition of chicken manure and urea, respectively (Figs. 4A and 4B). At 23 months after planting there were no significant models for chicken manure and urea. The reduction in Mg content in the soil may have occurred due to the competition of NH_4^+ with Mg+ by the soil adsorption sites, decreasing soil Mg content as the N doses increase in the two sources used [16].

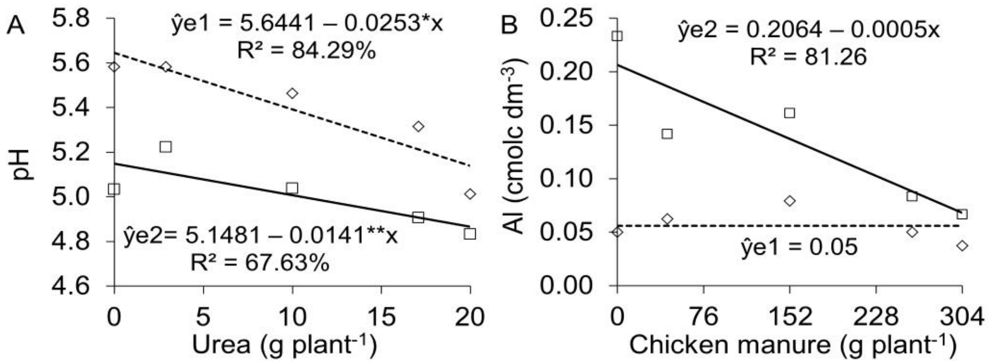

Fig. 2. pH (A) and soil aluminum (Al) concentration (B) under pineapple cultivation as a function of fertilization with chicken manure and urea in two seasons

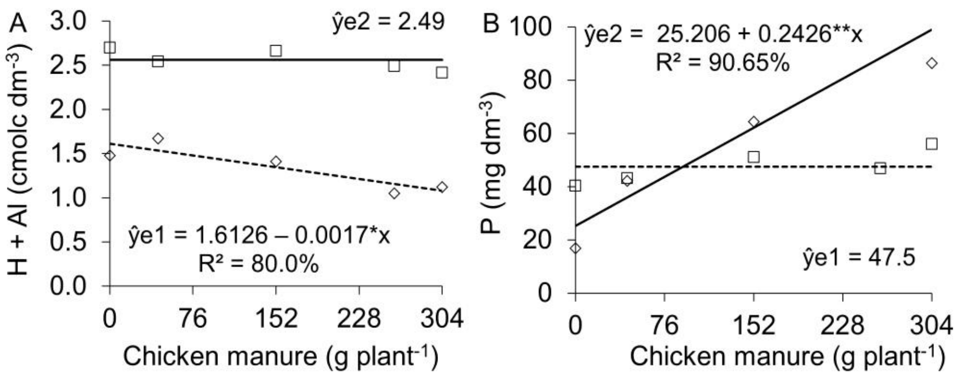

Fig. 3. H + A in the soil (A) and phosphorus content (B) under pineapple cultivation as a function of fertilization with chicken manure

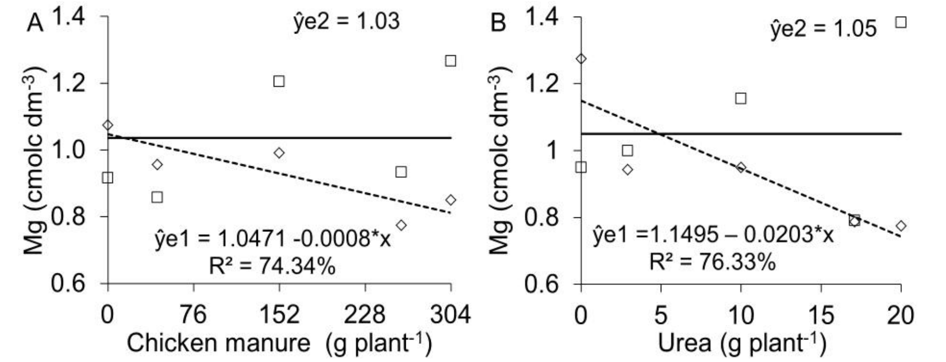

Fig. 4. Magnesium content in soil under pineapple cultivation as a function of fertilization with chicken manure (A) and urea (B) in two seasons

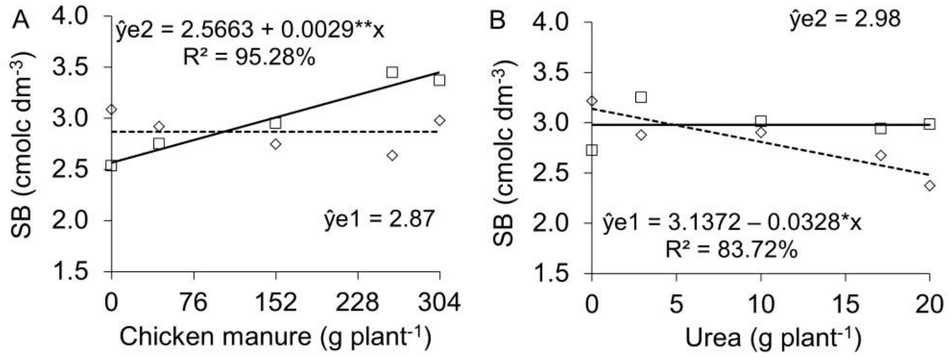

Fig. 5. Sum of bases (SB) in the soil under pineapple cultivation as a function of fertilization with chicken manure (A) and urea (B) in two seasons

The sum of bases was influenced by chicken manure and urea doses at 23 and 6 months, respectively. At six months, there was an increase in the sum of bases with chicken manure doses increase, a maximum value of 3.45 cmolc dm^{-3} was obtained from the chicken manure dose of 304 g $plant^{-1}$. At 23 months there was a decrease in sum of base with urea increasing doses, yielding the smallest value of 2.48 cmolc dm^{-3} in the dose of 20 g $plant^{-1}$ (Figs. 5A and 5B).

Cations exchange capacity was affected by both doses urea and chicken manure. At six months after planting there was a decrease in soil CEC with the increase of organic fertilizer and the increase of urea doses. At 23 months after planting there was an increase in soil CEC especially for chicken manure. Urea doses influenced CEC at 23 months after planting (Fig. 6 A) and (Fig. 6 B).

The increase of CEC and SB with the elevation of chicken manure doses occurred due to the fact that this input has in its composition cations such as K (46 g kg^{-1}) and Mg (5.5 g kg^{-1}) besides negative charges added by organic matter, attracting and adsorbing the cations.

Probably CEC of the soil decreased with the increase of the doses of chicken manure due to the increase of the electrical charges have had reduced the soil potential acidity. Thus, the increase of urea doses may have increased the ammonium content (NH_4^+), thus competing for charges from soil and decreasing the sum of bases and soil CEC [16].

Nitrogen content in the leaf was influenced only by the urea doses after six months of growth, reaching a maximum content of 17.3 g kg^{-1} in the dose of 20 g of urea (Fig. 7). This value is in the interval 15 - 17 g kg^{-1} considered suitable for pineapple [26].

Concentrations of N for all treatments at 6 months and at 23 months after planting were above the threshold value considered by Malézieux and Bartholomew (2003), of 8.7 g kg^{-1} for the growth of new tissues. On the other hand, Malavolta et al. [27] stated that contents above

12 g kg^{-1} are considered adequate for plant supply.

At 23 months after planting, the increase in the doses of chicken manure increased leaf P linearly, reaching a maximum content of 1.9 g kg^{-1} for the highest dose of 304 g plant^{-1} (Fig. 8A). Urea doses have reduced the P concentration in the leaves, sort of 0.03 g kg^{-1} to each gram of urea added per plant, as a result the highest P content was obtained without addition of urea (Fig. 8B).

In this present work, the reduction in leaf contents of P may have occurred due to the dilution effect, as a consequence of leaf stretching D, generated mainly by the addition of N in the form of urea, a reason pointed out by Spironello et al. [28].

However, Nightingale [29] attributes to the high levels of nitrate in the soil, due to the addition of nitrogen fertilizer, the cause of the pineapple reduction in P absorption. This trend was observed by Ramos et al. [30] when they verified that the deficiency of N increases the leaf P, K, Mg and B contents.

Similar results to this research were verified by Guarçoni and Ventura [31] evaluating doses of N in 'Gold' pineapple; [32] and [4] evaluating Nitrogen fertilization in 'Vitória' pineapple. Cavalcante et al. [33] also observed an increase in the Phosphorus content in the leaf dry matter of the pine tree, with an increase in the doses of chicken litter. It should be emphasized that the use of organic fertilizers can reduce P fixation because its absorption is disputed between the phosphate anion and the organic matter [34].

'Vitória' pineapple productivity presented quadratic behavior as a function of the urea doses. The estimated urea dose which promoted the highest productivity (47.4 t ha^{-1}) was 10.8 g plant $^{-1}$ (Fig. 9). According to Marques et al. [3], N is the nutrient that increases pineapple plant productivity, because it promotes the synthesis of amino acids and, consequently, of proteins, resulting in greater growth and production. In addition, N is indispensable for the use of carbohydrates inside the plant, contributing to increase the number and unit mass of leaves, vigor and total mass of the plant, characteristics that correlate positively with the mean weight of the infructescences and productivity [10,35].

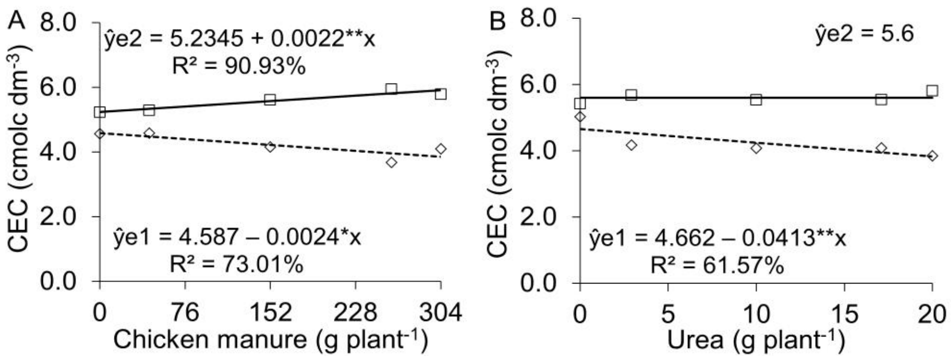

Fig. 6. Ability to exchange cations (CEC) in soil under pineapple cultivation as a function of fertilization with chicken manure (A) and urea (B) in two seasons

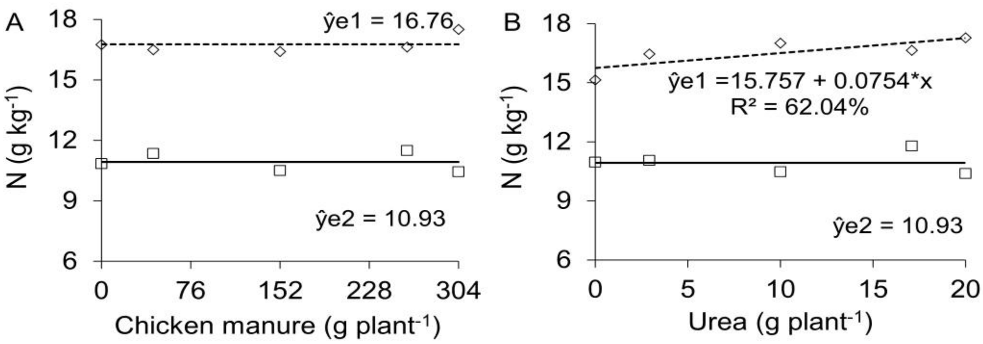

Fig. 7. Nitrogen (N) concentration in pineapple leaves as a function of fertilization with urea (B) in two seasons

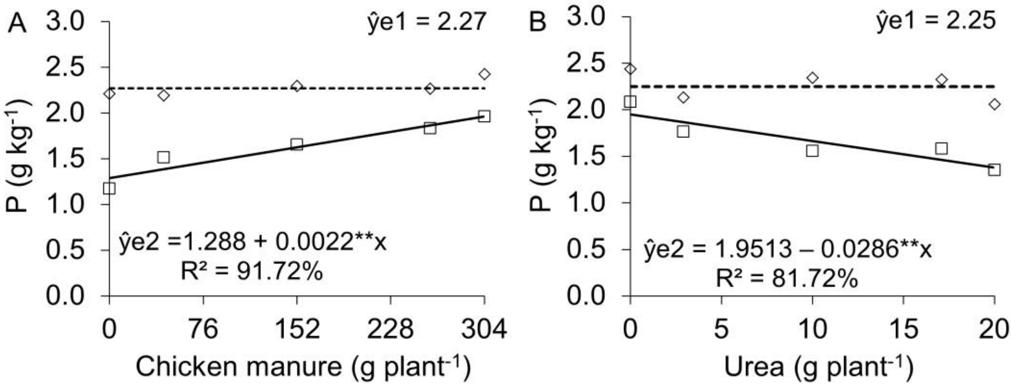

Fig. 8. Phosphorus (P) concentration in pineapple leaves as a function of fertilization with chicken manure (A) and urea (B) in two seasons

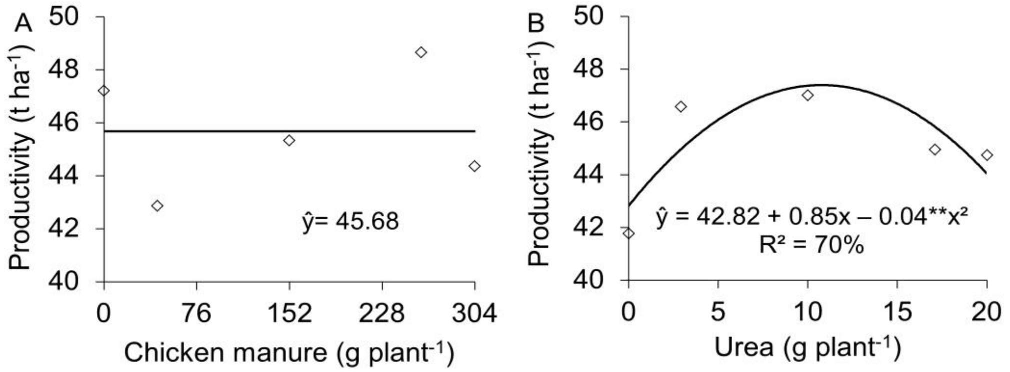

Fig. 9. Pineapple productivity as a function of chicken manure and urea fertilizations

Several authors have evidenced the effect of N on the production characteristics of pineapple plant. Guarçoni and Ventura [31] also verified in. 'Gold' a quadratic effect for pineapple yield, with a maximum yield of 65.4 t ha^{-1} with the application of 12.7 g plant $^{-1}$ of N. Spironello et al. [28], obtained a maximum crop yield of 72 t ha^{-1} with the application of 16.4 g $plant^{-1}$ of N for the cultivar Smooth Cayenne. For 'Vitória', [4] also verified the effect of N doses on crop yield, obtaining a maximum yield of 65.0 t ha^{-1} at the dose of 647.0 kg ha $^{-1}$.

4. CONCLUSION

Soil chemical attributes (H + Al, Mg and CEC) at six months after planting were reduced according to the increase in the addition of chicken manure and at 23 months after planting soil P concentration, SB and CEC increased with the addition of chicken manure .

As to urea application, reductions in pH in both dates of sampling and in Mg, SB and CEC contents after six months of growth were observed.

Urea doses about 10 g $plant^{-1}$ maximized the productivity of pineapple plant.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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