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Organic Fertilization in 'Pérola' Pineapple Increases Fruit Production and Physical and Chemical Characteristics

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Abstract

Pineapple is the third most cultivated tropical fruit in the world. However, few studies have focused on the cultivation using organic fertilization, especially in semiarid regions. Thus, this study aimed to evaluate growth, production and physicochemical traits of pineapple fruits produced under organic fertilization in the semiarid. The experiment was carried out at the didactic orchard of Federal Rural University of Semiarid, Mossoró, Rio Grande do Norte, Brazil. Four fertilization treatments were studied (chemical fertilizer, cattle manure, goat manure, poultry litter). At 18 months after planting, plant growth, physicochemical traits of fruits, and productivity were evaluated. Results showed that organic fertilization with poultry litter provides best results for physicochemical traits of fruits and productivity of 'Pérola' pineapple. Organic fertilization with poultry litter is most promising for plant growth, physicochemical traits of fruits, and productivity in 'Pérola' pineapple, therefore, the most suitable for cultivation in the semiarid region. The fruit firmness, central cylinder weight, and ratio SS/TA showed best values under chemical and goat manure fertilization.

Keywords: *Ananas comosus*, fruticulture, organic fertilizers, post-harvest, production

Introduction

Pineapple (*Ananas comosus* L.) belongs to the *Bromeliaceae* family, and it is the third most cultivated tropical fruit in the world (FAO 2019). Its center of origin is in South America, probably in the South and Southeast regions of Brazil, Argentina, and Uruguay (Melo et al. 2006). Costa Rica, Philippines, Brazil, Thailand, India, Indonesia, and Nigeria are the main producing countries. Brazil produces 1.61 million tons of pineapple per year, with average productivity of 24.08 thousand fruits per hectare, from 71.5 thousand hectares of harvested area. Rio Grande do Norte is among the main producing states, accounting for 68.83 thousand tons of fruits in 2019, which corresponded to 4.25% of the national production (FAO 2019, IBGE 2019).

The use of chemical and organic fertilizers in pineapple cultivation is a mandatory practice, since the crop is demanding of nutrients (Reinhardt et al. 2002). In addition, soils in semiarid regions are generally nutrient deficient, which results in reduced productivity if fertilization is not adequate.

Small producers generally do not apply inorganic fertilizers to crops, due to the high cost. However, organic materials used as fertilizer can supply the nutrient demand of pineapple plants. Several materials have been used as organic fertilizers, such as cattle, goat, and swine manures, poultry litter, and organic compost. Rich in carbon and nutrients, these materials can improve the characteristics of sandy soils and poor in organic matter, in addition to increasing the soil water retention capacity, which can reduce the amount of water available to plants.

Organic matter gradually degrades in the soil, releasing nutrients to pineapple, which directly influences the physicochemical quality of the fruits. Soluble solids content (°brix) and titratable acidity are among the physicochemical traits important for flavor and consumer

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acceptance of fruits and vegetables (Kurubas et al. 2019). Moreover, organic acids present in organic materials can improve the titratable acidity of fruits (Santos et al. 2014).

Studies have shown the benefits of using organic fertilizers for crop growing. (Santos et al. 2014) who studied the nutrition of pineapple crown sprouts, (Silva et al. 2014), who studied the decomposition and release of nutrients from organic sources, and (Irineu et al. 2018) studied the application of organic fertilizer in melons. Studies have shown the benefits of using organic fertilizers for crop growing, such as poultry litter in pineapple (Pereira et al. 2019), humic acids in pineapple crown sprouts (Santos et al. 2014), and biofertilizer based on bovine manure in melons (Irineu et al. 2018). The decomposition and nutrient release from poultry little and cattle manure have also been studied (Silva et al. 2014).

Although studies have shown the benefits of organic fertilization for crop growth and production, knowledge on the behavior of pineapples under edaphoclimatic conditions of northeastern Brazil is scarce, especially in the semiarid region. Thus, this work aimed to evaluate the use of organic fertilization on 'Pérola' pineapple growth, production, and physicochemical quality of fruits under semiarid conditions.

Material and Methods

The experiment was carried out between 2018 and 2019, in an experimental area at the Federal Rural University of Semiarid (UFERSA), Mossoró city, Rio Grande do Norte state, Brazil. Mossoró is located at the coordinates 5°11' S, 37°20' W, 18 m above the sea level. The climate of the region is BSwh according to the Köppen classification, which is hot and dry semiarid, with 27.50 °C average annual temperature, 68.9% average relative humidity, and 673.9 mm average annual rainfall (Sobrinho et al. 2013).

During the experiment, average temperature, average relative humidity and rainfall (**Figure 1**a, 1b), solar radiation and average wind speed (Figure 1c) were collected from the Automatic Weather Station (EMA) of UFERSA.

The experimental design was in randomized blocks with four treatments and four blocks, each unit consisting of 14 plants. The plants were fertilized with treatments: T1 = chemical fertilizer (NPK) and 3 organic sources (T2 = cattle manure, T3 = goat manure, and T4 = poultry manure), in which each organic source was applied 10 liters linear meter^{-1} in the once a year.

Pineapple seedlings were obtained by suckers from the 'Pérola' cultivar grown in a commercial area in the municipality of João Câmara, Rio Grande do Norte state, Brazil. Then, the offsets were cured for seven days exposed to sunlight at the didactic orchard of UFERSA.

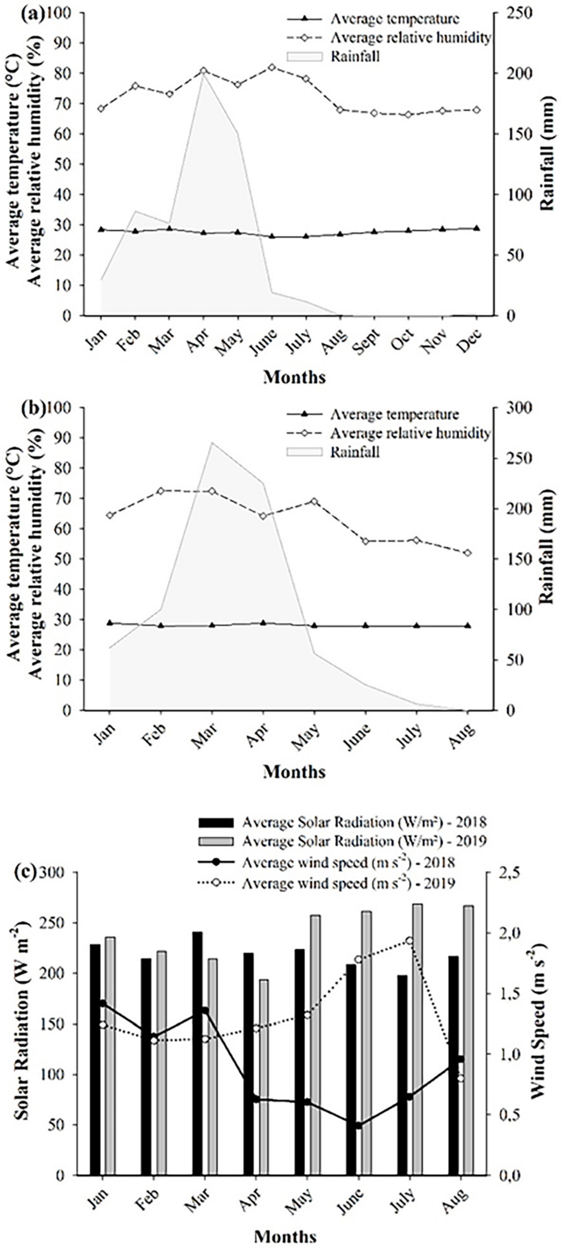

Figure 1. Climatic data collected during the experimental period (2018 and 2019). Average temperature and average relative humidity (Fig 1a, 1b), solar radiation and average wind speed (Fig 1c) under semi-arid conditions.

Before planting, the soil was prepared with plowing at 30 cm depth, followed by two harrows. Chemical fertilization was performed according to the chemical analysis of the soil in the experimental area (shown in **Table 1**) and the fertilization recommendation for irrigated pineapple in the semiarid region of Brazil (Souza and Oliveira 2021). Thus, 320 kg ha^{-1} nitrogen (as urea), 480 kg ha^{-1} potassium (as potassium chloride), and 80 kg ha^{-1} phosphorus (as simple superphosphate) were applied as six applications split to 0, 30, 90, 150, 210 and 270 days after planting.

Table 1. Physical and chemical analysis of the soil in the experimental area at 0-20 cm and 20-40 cm depth before planting the pineapple seedlings. Mossoró, Rio Grande do Norte state, Brazil

Sample (cm)	Sand	Silt	Clay	Texture	SWC (g kg-1)		AWC
	..........g kg^{-1}...........				33 kPa	1500 kPa	(%)
0 – 20	0.81	0.09	0.10	Loamy sand	60.60	34.50	2.61
20 – 40	0.71	0.06	0.19	Sandy loam	72.80	34.20	3.86

Sample (cm)	pH	SOM	P	K	Na	Ca	Mg	SB	t	CEC	N
	water	g kg^{-1}		.mg dm^{-3}			.cmol$_c$ dm^{-3}		g kg^{-1}		
0-20	8.02	4.68	18.2	115.6	210.2	1.90	0.20	3.31	3.31	3.31	0.42
20-40	8.65	1.48	29.4	16.7	38.4	1.90	0.40	2.51	2.51	2.51	0.28

SWC – Soil water content; AWC – available water capacity; SOM – soil organic matter; P and K were extracted by Mehlich 1; Ca and Mg were extracted by 1M KCl; SB – sum of bases; t – effective cation exchange capacity; CEC – total cation exchange capacity.

Regarding the organic fertilization, 10 liters linear meter^{-1} of each material (cattle manure, goat manures, and poultry litter) were incorporated into the soil. A sample of each organic material was taken for chemical analysis (shown in **Table 2**).

In January 2018, the seedlings were planted in furrows and double spaced at 90 × 40 × 40 cm. The experimental units were constituted in the form of beds containing 14 seedlings, 10 of which were considered a sampling unit, leaving the others as a border. Also, the beds were covered with black plastic mulching for weed control. A drip tape irrigation system was used, in which drippers spaced 40 cm supplied water at 1.6 L h^{-1} flow. The plants were irrigated throughout their growing season.

The phytosanitary treatments followed recommendations for the control of fusariosis (*Fusarium subglutinans*) with Benomil (60 g L^{-1}), and fruit borer (*Strymon basalides*) with Deltamethrin (25 g L^{-1}). Sprays were carried out weekly from 45 days after floral induction until fruiting. Floral induction was performed 12 months after planting in January 2019, by applying 50 mL per plant of 1% calcium carbide solution in the center of the leaf rosette using a backpack sprayer.

At 14 months after planting, plant height (cm), rosette diameter (measured between the largest leaves on opposite sides of the plant) (cm) and leaf length and width of leaf 'D' (cm) were determined with the aid of a measuring tape.

The harvest was carried out at the end of the experiment in august de 2019, when fruits were at the commercial maturation stage, showing green peel and skin yellowing at the base of the fruit. Then, fruits were transported to Physiology and Postharvest Laboratory at UFERSA for physicochemical evaluation.

For physicochemical evaluation, fruit weight (g) with and without crown and central cylinder weight (after separated from the pulp) were measured using a digital scale. Then, pulp yield was determined as a percentage of pulp, subtracting peel, crown, and central cylinder weights from the whole infructescence. From fruit weight, yield of each treatment was calculated as t ha^{-1}. Also, fruit diameter (at the center region) and length (with and without crown) were measured using a digital caliper and values were expressed as mm.

Firmness was determined using a digital texture analyzer (TA.XTExpress / TA.XT2icon, Stable Micro Systems) equipped with a 8 mm diameter tip at three equidistant points in the peel (at the upper, central, and lower regions of the fruit). Two readings were performed on opposite sides of the fruits of infructescence, and results were expressed as Newton (N).

Soluble solids (SS) was determined directly in the homogenized pulp using a digital refractometer (PR - 100 model, Palette, Atago Co, LTD., Japan), with duplicate readings and results expressed as °Brix (AOAC 2012). Titratable acidity (TA) was determined by titration, using 1.0 g pulp diluted with 50 mL distilled water in a 125 mL Erlenmeyer. Then, the solution was titrated in duplicate with 0.1 M NaOH until 8.1 pH and results expressed as g citric acid 100 g^{-1} fresh weight (AOAC 2012).

Data were tested for normality according to the Shapiro-Wilk test and for homogeneity of variances according to Bartlett test ($p<0.05$). Being normality and homogeneity assumptions met, data were submitted to two-way analysis of variance by the F test ($p<0.05$) followed by the Tukey test ($p<0.05$) to group means. All

Table 2. Chemical analysis of the organic materials used in the experiment with 'Pérola' pineapple. Mossoró, Rio Grande do Norte state, Brazil

Sample	pH	EC	SOM	N	P	K+	Na+	Ca^{2+}	Mg^{2+}
	H_2O	dS m^{-1}	%	g kg^{-1}		...mg dm^{-3}...		...cmolc dm^{-3}...	
Cattle manure	7.40	0.02	29.7	10.78	56.25	325.29	435.35	8.30	5.98
Goat manure	8.20	0.02	23.6	19.04	131.34	3553.33	892.45	7.78	7.36
Poultry litter	7.89	0.05	30.1	14.00	701.99	6367.35	2901.68	6.17	7.23

EC: electrical conductivity; SOM: soil organic matter.

statistical analyses were performed in R software (R Core Team 2020).

Results and Discussion

Plant growth variables: plant height (PH), leaf width 'D' (SW 'D') was significantly influenced by organic and conventional treatments (p<0.01). The diameter of the rosette, and leaf length 'D' were not affected by organic and conventional fertilization (p>0.01). Fertilization with poultry litter showed the highest PH and SW 'D' at 12 months of cultivation, being statistically superior to other organic sources and mineral fertilization (p<0.05) (**Table 3**).

Table 3. Average values of plant height (PH), leaf length 'D' (CPF'D') and leaf width 'D' (SW 'D') according to the organic and conventional production system in the pineapple crop ' Pérola'

Treatment	Plant height (cm)	Leaf width 'D'
Chemical fertilizer	79.87 b	66.06 b
Cattle manure	80.91 b	65.89 b
Goat manure	80.25 b	66.04 b
Poultry litter	92.46 a	77.45 a
CV	5.58	6.92
LSD	10.29	10.59

Means followed by different letters in the column differ significantly by Tukey test (p<0.05).

The type of fertilization significantly affects the diameter of the fruit diameter (D), weight with crown (WW+C), weight without crown (W-C), length without crown (L-C) (p<0.01), and length with crown (L+C) (p<0.05). Among the fertilization management used, poultry litter provided fruits higher in D, L-C, WW+C, and W-C. However, these did not differ statistically from goat manure (p>0.05). The poultry manure also provided greater L+C, however it did not differ statistically from the fertilization methods (p>0.05) (**Table 4**).

Table 4. Average values of fruit diameter (D), fruit weight with crown (WW+C), fruit weight without crown (W-C), fruit length with crown (L+C), and fruit length without crown (L-C) in ''Pérola' pineapple under organic and chemical fertilization

Treatment	D (mm)	WW+C (g)	W-C (g)	L+C (cm)	L-C (cm)
Chemical fertilizer	83.09b	0.47b	0.36 b	26.70ab	10.77b
Cattle manure	79.36b	0.51b	0.36 b	28.11ab	10.60b
Goat manure	87.02ab	0.56 ab	0.46ab	26.42ab	12.15ab
Poultry litter	93.26a	0.79a	0.68a	31.29a	15.16a
CV	5.14	19.85	22.68	9.30	11.85
LSD	9.86	0.25	0.23	5.78	3.17

Means followed by different letters in the column differ significantly by Tukey test (p<0.05).

For the physical and productive characteristics, the fertilization methods significantly influenced the peel weight (PW) and yield (PROD) (p<0.01) and the central cylinder weight (CCW) and pulp percentage (p<0.05). The crown length (CL) was not influenced by different organic and mineral sources applied (p>0.05). CCW was higher under chemical fertilization, however, it was not statistically different from fruits produced under fertilization with cattle manure, goat manure, and poultry litter (p>0.05) (**Table 5**).

Table 5. Average values of central cylinder weight (CCW), peel weight (PW), pulp percentage (%P), productivity (PROD), upper firmness (Firm), titratable acidity (TA), soluble solids content (SS) and ratio SS/TA of 'Pérola' pineapple under organic and chemical fertilization

Treatment	CCW (g)	PW (g)	%P	PROD(tha^{-1})
Chemical fertilizer	0.14a	0.04b	37.06b	18.16b
Cattle manure	0.11ab	0.05b	37.53b	19.86b
Goat manure	0.11ab	0.10 ab	43.91ab	21.86ab
Poultry litter	0.09ab	0.14a	53.91 a	30.60a
CV	33.04	33.33	16.50	19.86
LSD	0.07	0.06	16.37	9.72
Treatment	**Upper Firm (N)**	**TA g 100 g^{-1}**	**SS °Brix**	**SS/TA**
Chemical fertilizer	16.51 a	0.59b	11.55c	20.18ab
Cattle manure	9.82b	0.66ab	12.36bc	18.65b
Goat manure	8.07b	0.69ab	14.33ab	20.71a
Poultry litter	6.33 b	0.78a	14.65a	18.69b
CV	20.25	9.12	7.34	4.25
LSD	4.44	0.14	2.17	1.86

Means followed by different letters in the column differ significantly by Tukey test (p<0.05).

Incorporating poultry litter into the soil increased PW, %P, and PROD fruits which corresponded to increments of 71.42%, 31.25%, and 40.62%, respectively, compared to chemical fertilization in which it had the smallest means (p<0.05). Poultry litter was not statistically different from goat manure (p>0.05) (Table 5).

For upper firmness (FIRM), titratable acidity (TA), soluble solids (SS) and SS/TA ratio were significantly influenced by chemical and organic fertilization (p<0.01). Chemical and organic treatments did not significantly affect fruit firmness in center and lower position (p>0.05) (Table 5).

Fruit firmness at the upper region was higher under chemical fertilization than the treatments (cattle manure, goat manure, poultry litter) (p<0.05). The incorporation of poultry litter into the soil incremented the TA and SS content of the pineapple fruits compared to chemical fertilization (p<0.05). The SS / AT ratio was higher in fertilization with goat manure and chemical fertilization (p>0.05), with sweeter fruits compared to fruits produced by fertilization with cattle manure and poultry litter (p<0.05) (Table 5).

This result is due to the fact that the poultry litter has high nitrogen contents and presents a fast N release in a short period of time, providing a faster initial growth of the plant. Under the semiarid conditions, poultry litter decomposes faster in the first 30 days as compared to cattle manure, decreasing afterward, due to its lower C/N and lignin/N ratios (Silva et al. 2014). Nitrogen has great relevance on plant growth, acting specifically on developmental effects, such as increased plant height, number of emitted leaves and leaf length "D" in pineapple (Guarçoni M and Ventura 2011, Cardoso et al. 2013).

Poultry litter releases nitrogen, phosphorus, and potassium faster than the other organic fertilizers, such as cattle manure, as the levels of P and K were higher (Silva et al. 2014). Adequate N supply accelerates the vegetative growth and fruit size in pineapple plants (Cardoso et al. 2013). (Silva et al. 2012) observed an increase in fruit weight of 'Vitoria' pineapple as a response of higher nitrogen availability in the soil.

Drip irrigation associated with mulching increases soil moisture, mineralization rate of organic matter, and, consequently, the nutrient release from the organic materials, thus improving nutrient uptake by pineapple plants. Also, chemical analysis of the organic materials showed that phosphorus and potassium levels were higher in poultry litter than in the other fertilizer sources (Table 2), which may have contributed to better poultry manure response. Similar results for fruit length (12.6 cm) and diameter (8.8 cm) in irrigated 'Pérola' pineapple (Franco et al. 2014).

The smaller center cylinder provided by poultry litter is desirable, as both industry and consumers prefer fruits with CCW (Berilli et al. 2014). For fruit quality, (Andrade et al. 2015) found pulp percentages of 69.91% and 74.97% in 'Pérola' and 'Vitória' cultivars produced. (Silva et al. 2012) observed that fruit weight and productivity of 'Vitória' pineapple increased as a response to nitrogen availability in the soil. As stated by (Silva et al. 2014) and (Pereira et al. 2019), incorporating poultry litter into the 10-20 cm layer of the soil enhances K, P, and N release, essential nutrients for flowering induction and fruit development in pineapple. Therefore, the incorporation of poultry litter into the soil provides gains in peel weight, pulp yield, and productivity (PROD) (Ribeiro et al. 2011). What was observed in the present study, in which it PROD was above the national average productivity (24.6 t ha^{-1}) (FAO 2019), and that found by (Rios et al. 2018), 26.36 t ha^{-1}.

Under chemical fertilization, simple superphosphate contains 18 to 20% Ca content, which in association with N can improve fruit quality, particularly its firmness (Mditshwa et al. 2017). Firmness we obtained are in accordance with (Berilli et al. 2014), who found 5.6 N to 13.6 N on average for 'Vitória', 'Pérola', 'Gold', and 'EC-93' cultivars. Our results indicate that 'Pérola' pineapple produced in the semiarid is promising for the industry, due to firmness suitable for transport and shelf life, as well as its peel resistance is interesting for export.

Furthermore, results showed that the organically produced pineapples can be sweeter than those conventionally produced. It was also observed for other fruits such as jujube fruit, (Reche et al. 2019) and passion fruit (Oliveira et al. 2017).

The organoleptic properties of different fruits are strongly related to their soluble solids content, acidity and SS/TA ratio (Magwaza and Opara 2015). Studies have shown that, in addition to productivity, acidity and soluble solids content in pineapple are positively influenced by potassium fertilization (Guarçoni M and Ventura 2011).

The incorporation of poultry litter into the soil also increased nutrient supply, especially those nutrients related to organic acid metabolism, such as K, since this organic source had a high K content (Table 2). K is strongly associated with productivity and fruit quality, as it can increase the concentration of sugars in the fruits, possibly by controlling enzymatic activities and ATP formation.

Ratio SS/TA is an important variable for fresh consumption and industry. Values in this work are in accordance with (Berilli et al. 2011), (Berilli et al. 2014), and (Andrade et al. 2015), who studied the quality of 'Pérola' and three more pineapples cultivars for fresh consumption. The ratio SS/TA is one most used parameter to assess the infructescence taste and maturation. The SS and TA are important traits of fruit taste quality and consumer acceptance of fruits and vegetables (Kurubas et al. 2019).

Conclusion

Organic fertilization with poultry litter is most promising for plant growth, physicochemical traits of fruits, and productivity in 'Pérola' pineapple, therefore, the most suitable for cultivation in the semiarid region. The fruit firmness, central cylinder weight, and ratio SS/TA showed best values under chemical and goat manure fertilization.

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References

Andrade, M.G.S., Silva, S.M., Soares, L.G., Dantas, A.L., Lima, R.P., Souza, A.S.B., Melo, R.S. 2015. Aspectos da qualidade de infrutescências dos abacaxizeiros ‘Pérola’ e ‘Vitória’. *Revista AGROTEC* 36: 96–102.

AOAC. 2012. Official methods of analysis of AOAC International. *AOAC International* 19: 121-130.

Berilli, S.S., Almeida, S.B., Carvalho, A.J.C., Jesus Freitas, S., Berilli, A.P.C.G., Santos, P.C. 2011. Avaliação sensorial dos frutos de cultivares de abacaxi para consumo in natura. *Revista Brasileira de Fruticultura* 33: 592–598.

Berilli, S.S., Freitas, S.J., Santos, P.C., Oliveira, J.G., Caetano L.C.S. 2014. Avaliação da qualidade de frutos de quatro genótipos de abacaxi para consumo in natura. *Revista Brasileira de Fruticultura* 36: 503–508.

Cardoso, M.M., Pegoraro, R.F., Maia, V.M., Kondo, M.K., Fernandes, L.A. 2013. Crescimento do abacaxizeiro ‘Vitória’ irrigado sob diferentes densidades populacionais, fontes e doses de nitrogênio. *Revista Brasileira de Fruticultura* 35: 769–781.

FAO. Food And Agriculture Organization. 2019. Disponível em: https://www.fao.org/faostat/en/#data/QC/visualize <Acesso em: 12 Jun. 2019>

Franco, L.R.L., Maia, V.M., Lopes, O.P., Franco, W.T.N., Santos, S.R. 2014. Growth, production and quality of pineapple ‘pérola’ Under different irrigation depth. Caatinga 27: 132–140.

Guarçoni, M.A., Ventura, J.A. 2011. Adubação N-P-K e o desenvolvimento, produtividade e qualidade dos frutos do abacaxi ‘gold’ (MD-2). Revista Brasileira de Ciência do Solo 35: 1367–1376.

IBGE. Instituto Brasileiro De Geografia e Estatística. 2019. Disponível em: https://sidra.ibge.gov.br/tabela/1612 <Acesso em: 12 Jun. 2019>

Irineu, T.H.D.S., Figueredo, L.F., Figueredo, J.P., Silva, J.N., Paiva, J.R.G., Andrade, R. 2018. Agronomic efficiency of ‘Cantaloupe’ melon under different water blades and organic fertilization. *Comunicata Scientiae* 9: 421–429.

Kurubas, M.S., Maltas, A.S., Dogan, A., Kaplan, M., Erkan, M. 2019. Comparison of organically and conventionally produced Batavia type lettuce stored in modified atmosphere packaging for postharvest quality and nutritional parameters. *Journal of the science of food and agriculture* 99: 226–234.

Magwaza, L.S., Opara, U.L. 2015. Analytical methods for determination of sugars and sweetness of horticultural products—A review. *Scientia Horticulturae* 184: 179–192.

Mditshwa, A., Magwaza, L.S., Tesfay, S.Z., Mbili, N. 2017. Postharvest quality and composition of organically and conventionally produced fruits: A review. *Scientia Horticulturae* 216: 148–159.

Melo, A.S., Aguiar Netto, A.D.O., Neto, J.D., Barbosa Brito, M.E., Almeida Viégas, P.R., Soares, M.L.T, Fernandes, P.D. 2006. Vegetative development, fruits yield and optimization of pineapple cv. Pérola with different levels of irrigation. *Ciencia Rural* 36: 93–98.

Oliveira, A.B., Almeida, L.M.M., Moura, C.F.H., Siqueira, O.L., Souza, K.O., Filho, E.G., Urban, L., Miranda, M.R.A. 2017. Effects of organic vs. conventional farming systems on quality and antioxidant metabolism of passion fruit during maturation. *Scientia Horticulturae* 222: 84–89.

Pereira, L.F.A., Pereira, W.E., Dias, T.J., Moura, J.G., Véras, M.L.M., Leal, Y.H. 2019. Chemical Soil Attributes, Accumulation of Foliar Macronutrients and Productivity of the ‘Vitória’ Pineapple Plant Fertilized with Urea and Chicken Manure. *Journal of Experimental Agriculture International* 25: 1–10.

R Core Team. 2020. R: A Language and Environment for Statistical Computing. *R Foundation for Statistical Computing* 8: 9.

Reche, J., Hernández, F., Almansa, M.S., Carbonell-Barrachina, A., Legua, P., Amorós, A. 2019. Effects of organic and conventional farming on the physicochemical and functional properties of jujube fruit. *LWT* 99: 438–444.

Reinhardt, D.H., Renato, J., Cabral, S.F., Souza, S., Sanches, F. 2002. Pérola and Smooth Cayenne pineapple cultivars in the state of Bahia, Brazil: growth, flowering, pests, diseases, yield and fruit quality aspects. *Fruits* 57: 43–53.

Ribeiro, D.G., Vasconcellos, M.A.S., Araújo, A.P. 2011. Contribuição do sistema radicular de mudas micropropagadas na absorção de nitrogênio de abacaxizeiro cultivar Vitória. *Revista Brasileira de Fruticultura* 33: 1240–1250.

Rios, E.S.C., Mendonça, R.M.N., Cardoso, E.D.A., Costa, J.P., Melo, S.S. 2018. Quality of ‘Imperial’ pineapple infructescence in function of nitrogen and potassium fertilization. *Revista Brasileirade Ciencias Agrarias* 13: 1–8.

Santos, P.C., Silva, M.P.S., Freitas, S.D.J., Berilli, S.D.S., Altoé, J.A., Silva, A.D.A., Carvalho, A.J.C. 2014. Acidos húmicos e brassinosteroide no crescimento e estado nutricional de rebentos de coroas de abacaxi. *Revista Brasileirade Ciencias Agrarias* 9: 532–537.

Silva, A.L.P., Silva, A.P., Souza, A.P., Santos, D., Silva, S.M., Silva, V.B. 2012. Resposta do abacaxizeiro ‘Vitória’ a doses de nitrogênio em solos de tabuleiros costeiros da Paraíba. *Revista Brasileira de Ciência do Solo* 36: 447–456.

Silva, V.B., Silva, A.P., Dias, B.O., Araujo, J.L., Santos, D., Franco, R.P. 2014. Decomposição e liberação de N, P e K de esterco bovino e de cama de frango isolados ou misturados. *Revista Brasileira de Ciencia do Solo* 38: 1537–1546.

Sobrinho, J.E.V., Pereira, C., Duarte, O.A.W., Santos, O., Silva, N.K.C., Maniçoba, R.M. 2013. Climatologia da precipitação no município de Mossoró-RN. *XVII Congresso Brasileiro de Agrometeorologia* 11: 1-10.

Souza, L.F.S., Oliveira, A.M.G. 2021. Recomendações de calagem e adubação para abacaxi, acerola, banana, citros, mamão, mandioca, manga e maracujá. Embrapa, Brasília, Brasil. 306 p.

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