

DOI: <http://dx.doi.org/10.1590/1807-1929/agriambi.v25n5p325-331>

## Strategies of fertilizer application for ornamental pineapple plants grown in pots under anti-aphid screen<sup>1</sup>

### Estratégias de adubação para plantas envasadas de abacaxizeiro ornamental cultivadas em telado antiafídeo

Márcio D. S. Santos<sup>2</sup>, Ana C. P. P. de Carvalho<sup>3\*</sup>, Guilherme V. do Bomfim<sup>2</sup>,  
Benito M. de Azevedo<sup>2</sup>, Carlos N. V. Fernandes<sup>4</sup> & Hayver O. Téllez<sup>2</sup>

<sup>1</sup> Research developed at Federal University of Ceará, Fortaleza, CE, Brazil

<sup>2</sup> Universidade Federal do Ceará, Fortaleza, CE, Brazil

<sup>3</sup> Embrapa Agroindústria Tropical, Fortaleza, CE, Brazil

<sup>4</sup> Instituto Federal de Educação, Ciência e Tecnologia do Ceará, Iguatu, CE, Brazil

#### HIGHLIGHTS:

*Application of mineral fertilizer for ornamental pineapple crops can be done using slow-release or conventional fertilizers.*

*Fertilizer application in ornamental pineapple crops can be done through incorporation of the fertilizer into the substrate or through fertigation.*

*The lack of fertilizer application harms the esthetic quality of ornamental pineapple leaves.*

**ABSTRACT:** Production of ornamental pineapple plants in pots is a recent mode of growing pineapple that demands information on application of soil mineral fertilizers to compose the production system. Thus, the objective of this study was to evaluate the effects of five strategies of application of soil mineral fertilizer on the vegetative and reproductive growths of potted ornamental pineapple plants. The experiment was conducted under an anti-aphid screen, from June 17, 2015 to May 21, 2016, in Fortaleza, Ceará state, Brazil. A completely randomized design with six treatments and four replicates was used, consisted of four plants per plot. The treatments consisted of application of a slow-release fertilizer; conventional soil fertilizer application; fertigation at every 30, 60, and 90 days; and no soil fertilizer application (control). The plants were grown in 1 L pots and irrigated using a drip system every two days. The variables evaluated were: number of leaves; 'D' leaf length and width; shoot apex diameter; plant height; flowering rate; length and diameter of peduncle, syncarp, and crown; crown to syncarp ratio; and percentage of marketable plants. Despite the different plant growth, all strategies of soil fertilizer application used can be recommended for ornamental pineapple plants, since they do not hinder the esthetic quality and dimensions required for marketing these plants in pots. Pineapple production without application of soil fertilizers should be avoided, since it reduces the percentage of marketable plants.

**Key words:** *Ananas comosus* var. *erectifolius*, ornamental plants, fertigation

**RESUMO:** A produção de abacaxizeiro ornamental em vaso é uma modalidade de cultivo recente que demanda por informações sobre adubação mineral para compor o sistema de produção. Assim, objetivou-se com este estudo avaliar os efeitos de cinco estratégias de adubação mineral sobre o crescimento vegetativo e reprodutivo de plantas envasadas de abacaxizeiro ornamental. O experimento foi realizado em telado antiafídeo (17/06/2015 a 21/05/2016), em Fortaleza, Ceará, Brasil, seguindo o delineamento inteiramente casualizado, com seis tratamentos, quatro repetições e quatro plantas por parcela. Os tratamentos consistiram em: adubação com fertilizante de liberação lenta; adubação convencional; fertirrigação a cada 30, 60 e 90 dias; e ausência de adubação (testemunha). As plantas foram cultivadas em vasos de 1 L e irrigadas por gotejamento a cada dois dias. Foram analisadas as variáveis: número de folhas; comprimento e largura da folha 'D'; diâmetro da roseta; altura da planta; taxa de floração; comprimento e diâmetro do pedúnculo, sincarpo e coroa; relação coroa/sincarpo; e percentagem de plantas comerciáveis. Apesar do crescimento diferenciado das plantas, todas as estratégias de adubação podem ser recomendadas para o abacaxizeiro ornamental, pois não comprometem a estética e as dimensões exigidas para a comercialização em vaso. A produção da cultura sem adubação deve ser evitada, pois reduz a percentagem de plantas comerciáveis.

**Palavras-chave:** *Ananas comosus* var. *erectifolius*, plantas ornamentais, fertigação

• Ref. 229312 – Received 27 Sept, 2019

\* Corresponding author - E-mail: [cristina.carvalho@embrapa.br](mailto:cristina.carvalho@embrapa.br)

• Accepted 03 Feb, 2021 • Published 05 Mar, 2021

Edited by: Hans Raj Gheyi

This is an open-access article distributed under the Creative Commons Attribution 4.0 International License.



## INTRODUCTION

Ornamental pineapple is a rustic exotic plant with multiple colors and long post-harvest life (Pereira et al., 2018) that can be marketed in the sectors of cut flower, foliage, landscaping, gardening, and pot plant (Souza et al., 2012; 2014). *Ananas comosus* var. *erectifolius* is the most economically important variety of ornamental pineapple plants (Alves et al., 2014), which is appreciated as a cut flower and has been stood out as a pot plant (Pereira et al., 2018).

Considering that the growing of crops in pots was recently-adopted by producers, few information is found on the management of this crop system. The available studies refer mainly to genetic (Taniguchi et al., 2015; Lima et al., 2017), nutrition (Viégas et al., 2014; Barbosa et al., 2015), and physiology (Reis et al., 2007; Mendes et al., 2011) of plants.

Information on the application of mineral soil fertilizers mainly refers to the use of slow-release fertilizers (Hawerth et al., 2014). Studies on different fertilizers are important for the choice of type and form of application, which depends on several factors, such as cost, availability, technology of application, and irrigation (Malhotra, 2016).

Currently, the lack of specific recommendations for growing of ornamental pineapple plants (*A. comosus* var. *erectifolius*) has stimulated empirical soil fertilizer applications for this crop. This practice combined with excessive sprinkler irrigations has increased leaching and decreased the quality of these plants for marketing. Techniques that consider reductions in nutrient losses by leaching, such as drip irrigation (Carr, 2012; Wolff et al., 2017; Lv et al., 2019), split application of soil fertilizers (Kumar et al., 2016; Brezolin et al., 2017), and use of slow-release fertilizers (Ha et al., 2018; Li et al., 2019) can be alternatives to improve the nutritional management of ornamental pineapple plants.

Therefore, considering the importance of this crop and the lack of specific information on soil fertilizer applications, the objective of this study was to evaluate the effects of strategies of soil fertilizer application on the commercial production of ornamental pineapple plants (*A. comosus* var. *erectifolius*) grown in pots under drip irrigation.

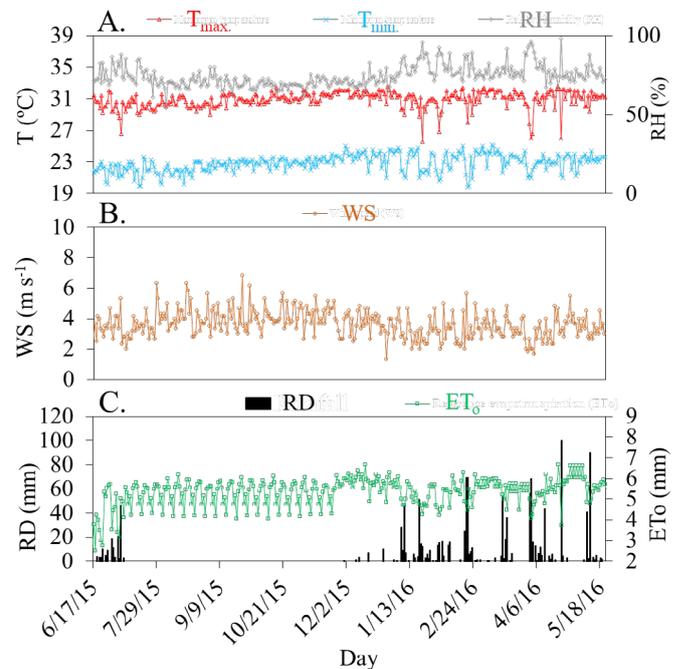
## MATERIAL AND METHODS

The experiment was conducted from June 17, 2015 to May 21, 2016, with pineapple plants grown under an anti-aphid screen (50 mesh), at the Federal University of Ceará, Fortaleza, Ceará state, Brazil (3° 44' 45" S, 38° 34' 55" W, and altitude of 19.5 m).

The region presents Aw' climate, according to the Köppen classification, characterized as tropical rainy of Savanna. Winter is the driest period, and the highest rainfall depths are found in the summer and autumn.

Daily data of temperature, air relative humidity, wind speed, rainfall depth, and reference evapotranspiration during the experiment (Figure 1) were recorded using a digital meteorological station installed under the screen cover.

The maximum, minimum, and average of weather variables were, respectively: 33.0, 21.6, and 30.4 °C (maximum temperature); 31.4, 19.8, and 22.9 °C (minimum temperature);



**Figure 1.** Maximum ( $T_{max}$ ) and minimum ( $T_{min}$ ) temperatures, relative air humidity (RH) (A), wind speed (WS) (B), rainfall depths (RD), and reference evapotranspiration ( $ET_o$ ) (C) during the growth of ornamental pineapple plants under an anti-aphid screen

97.5, 62.0, and 75.6% (air relative humidity); and 6.8, 0.8, and 3.5  $m s^{-1}$  (wind speed). The rainfall depths totaled 1,237.7 mm, distributed from June to July, 2015 and from January to May, 2016. The reference evapotranspiration totaled 1,836.2 mm, with maximum, minimum, and average of 6.7, 3.5, and 5.4 mm, respectively.

The biological material consisted of micro-propagated seedlings of ornamental pineapple plants, acclimatized during two months (April 15 to June 16, 2015) under a 70% shade screen. The seedlings were then transplanted (June 17, 2015) to black plant pots containing a commercial organic substrate and were irrigated using a surface drip system.

The commercial pots had a conical trunk shape and an approximate volume of 1.0 L (13.9 cm width and 11.6 cm height), with 10.2 cm wide bottom containing 16 holes. The pots were distributed on a cemented surface under the screen, with spacing of 15 × 15 cm.

The substrate used (HS Florestal, Holambra Substratos, Brazil) was composed of composted pinus bark, plant peat, and vermiculite, presenting a water retention capacity at 10 cm of 51.4%; dry density of 290.2  $kg m^{-3}$ ; 147.5  $g kg^{-1}$  of organic C; 4.2  $g kg^{-1}$  of total N; C:N of 35.2; 93.7  $mg L^{-1}$  of P (Mehlich); 435  $mg L^{-1}$  of K (Mehlich); 53.1  $mg L^{-1}$  of Ca; 238  $mg L^{-1}$  Mg; 475.3  $mmol_c kg^{-1}$  of cation exchange capacity; pH (in water) of 5.0; and electrical conductivity of the saturated extract of 0.9  $dS m^{-1}$ .

A surface drip irrigation system was used, which was composed of a water reservoir, a motor pump, PVC main lines ( $\phi = 20$  mm), derivation lines and lateral lines of low-density polyethylene ( $\phi = 16$  mm), a gate valve, a glycerin pressure gauge, a disc filter, and pressure compensating drippers of 3.2  $L h^{-1}$ , arranged at the plant roots through microtubes.

The water used for the irrigation presented low salinity and sodicity; Ca, Mg, Na, K, Cl, and  $\text{HCO}_3$  contents of 1.0, 1.7, 4.3, 0.2, 3.8, and 3.6  $\text{mmol}_c \text{L}^{-1}$ , respectively; electrical conductivity of 0.73  $\text{dS m}^{-1}$ ; sodium adsorption ratio of 3.81; and pH of 7.9.

The irrigations of the ornamental pineapple plants were carried out every two days, considering the difference between the crop evapotranspiration ( $\text{ET}_c$ ) of eatable pineapples and the effective rainfall depths ( $\text{RD}_e$ ). The  $\text{ET}_c$  was calculated by the product between the reference evapotranspiration of Penman-Monteith (Allen et al., 2006) and the crop coefficient ( $K_c$ ) for each phenological stage of the crop (Almeida, 1995): stage I (1-60 days); stage II (61-210 days); stage III (211-270 days); and stage IV (271-360 days). The  $K_c$  used for the irrigation was interpolated from 0.6 to 1.2 for stage II (150 days); 1.2 for stage III (90 days); and from 1.2 to 0.6 for stage IV (102 days). The  $\text{RD}_e$  was considered all rainfall depths lower than 9.8 mm, which is the maximum water depths in pots with area of 0.0154  $\text{m}^2$ , substrate presenting weight of 0.29 kg, and water retention capacity of 51.4%. Under this management, each plant received 30.2 L (1,962.7 mm) of water during the experiment, from the effective rainfall and irrigation.

The experiment was conducted in a completely randomized experimental design with six treatments, four replicates, and four plants per plot. The treatments consisted of five strategies of application of soil fertilizer and a control: application of soil fertilizer using a slow-release fertilizer; conventional soil fertilizer application; fertigation every 30, 60, and 90 days; and no application of soil fertilizer.

The application of slow-release fertilizer to the soil was carried out using a commercial fertilizer (Osmocote® Plus, Everris, Dublin, USA). Considering that it has a duration of approximately three months, the total recommended rate for growth of ornamental pineapple plants in pots of 13.2 g (Hawerroth et al., 2014) was split into three applications of 4.4 g, after the transplanting. The fertilizer was applied by incorporating it manually into the surroundings of the plant roots.

This soil fertilizer was considered a reference for the quantification of the fertilizer doses applied in the other treatments. Thus, the amounts of macro and micronutrients, based on the recommended dose of the slow-release fertilizer, were maintained in the other treatments (Table 1).

The macronutrient sources for the other treatments were: white potassium chloride, ammonium sulfate, urea,

**Table 1.** Quantities of macro and micronutrients in 13.2 g of the commercial slow-release fertilizer used (Osmocote® Plus, Everris, Dublin, USA)

Macronutrient	N	P	K	Mg	S	
Purity (%)	15	9	12	1.30	5.90	
Quantity (g)	1.98	1.188	1.584	0.172	0.779	
Micronutrients	Bo	Cu	Fe	Mn	Mo	Zn
Purity (%)	0.02	0.05	0.46	0.06	0.02	0.05
Quantity (mg)	3	7	61	8	3	7

**Table 2.** Mineral fertilizers used for the conventional application and fertigation

Fertilizer	Ammonium monophosphate		Ammonium sulfate		Urea	Potassium chloride	Magnesium sulfate	
Nutrient	N	P	N	S	N	K	Mg	S
Purity (%)	9	48	21	22	45	58	9	13
Quantity (g)	0.223	2.475	0.46	2.192	2.882	2.731	1.907	0.248

magnesium sulfate, and ammonium monophosphate (Table 2). The sources of micronutrients were their pure forms, in the same quantities of the commercial slow-release fertilizer used.

The conventional soil fertilizer application was carried out using the fertilizers described in Table 2, split into two applications, similar to the soil fertilizer application for eatable pineapple plants: 1/3 at the transplanting and 2/3 at one month after the transplanting. The fertilizer was applied by incorporating it manually into the surroundings of the plant roots.

The application of soil fertilizers by fertigation was carried out using the fertilizers described in Table 2, at 30, 60, and 90 days after the transplanting, according to each treatment. The fertilizers were dissolved and applied directly to the substrate, using a solution volume proportional to the irrigated water volume.

The control consisted of ornamental pineapple plants grown in the commercial substrate, without application of fertilizer.

The cultural practices were done manually, which consisted of cleaning of the screen, removal of dry leaves and tillers, and floral induction. The floral induction was carried out at nine months after the transplanting (March 16, 2016), using 30 mL of a ethephon-based solution. The solution was prepared using 1 L of water, 0.45 mL of Ethrel® (Bayer, Leverkusen, Germany) representing 0.324 g of ethephon, 0.35 g of calcium hydroxide, and 20 g of urea, and was applied manually to the region of the apical shoot by using a plastic container. Most plants presented formation of floral buds and fruits at 35 days (April 20, 2016) and 65 days (May 20, 2016) after the floral induction, respectively. The main stages of the experiment are shown in Figure 2.

After formation of infructescence (May 21, 2016), the following variables were evaluated: number of leaves; 'D' leaf length and width (cm); shoot apex diameter (cm); plant



**Figure 2.** Transplanting (A), growth leaf (B), beginning of flowering (C), and formation of infructescence (D) of ornamental pineapple plants grown in pots under an anti-aphid screen

height (cm); flowering rate (%); length and diameter of peduncle, syncarp, and crown (cm); crown to syncarp ratio; and percentage of marketable plants (%).

All plants of the plot were measured for number of leaves, 'D' leaf length and width, shoot apex diameter, plant height, flowering rate, and percentage of marketable plants. The other variables were measured using two floral stems per plot.

The number of leaves was obtained by counting all leaves of the plant. The 'D' leaf length was measured from its insertion in the stem to the leaf apex. The 'D' leaf width was measured from one margin to the other of the leaf, in the widest region. The shoot apex diameter was measured between the apexes of two leaves on opposite sides. Plant height was measured from the stem base region to the apex of the highest leaf. These measures were carried out using a tape measure.

The flowering rate was evaluated by dividing the number of plants with infructescence by the total number of plants. The peduncle length was measured from its insertion in the leaves to the syncarp base. The peduncle diameter was measured at its mid height. The syncarp and crown lengths were measured by the distance between their poles. The syncarp and crown diameters were measured at their central region. The crown to syncarp ratio was evaluated by dividing their lengths. These measures were carried out using a digital caliper.

The percentage of marketable plants was evaluated by the ratio between the number of commercial plants and the total number of plants. Commercial plants were considered those that presented no esthetic quality problems in the leaves and floral stems (deformation, wither, discoloration, chlorosis, necrosis, and spots) and were classified for use in pots: plant height < 65.0 cm; shoot apex diameter < 80.0 cm; 'D' leaf length < 60.0 cm; syncarp length < 5.0 cm; syncarp diameter < 3.0 cm; peduncle length < 30.0 cm; crown length < 5.0 cm; and crown to syncarp ratio of up to 1.5 (Souza et al., 2007; 2012).

The data were subjected to analysis of variance and the means were compared by the Scott-Knott test ( $p \leq 0.05$ ).

## RESULTS AND DISCUSSION

The variables of vegetative growth of the ornamental pineapple plants evaluated were significantly affected by the treatments, except for the number of leaves (Table 3).

**Table 3.** Analysis of variance and mean test for variables of vegetative growth of ornamental pineapple plants grown in pots under an anti-aphid screen

Source of variation	F calculated ( $p \leq 0.05$ )				
	NL	DLL	DLW	SAD	PH
Treatment	2.2 <sup>ns</sup>	8.6*	9.3*	4.2*	9.8*
Coefficient of variation (%)	8.7	11	8.9	7.7	8.8
Treatments	Scott-Knott test (mean $\pm$ confidence interval) ( $p \leq 0.05$ )				
	(unit)	(cm)	(cm)	(cm)	(cm)
SRF	43.1 $\pm$ 2.4 a	47.1 $\pm$ 1.8 a	2.6 $\pm$ 0.2 a	75.6 $\pm$ 3.3 a	61.4 $\pm$ 3.4 a
Fert-30	41.6 $\pm$ 1.3 a	46.1 $\pm$ 2.7 a	2.8 $\pm$ 0.1 a	66.8 $\pm$ 1.0 b	58.7 $\pm$ 1.7 a
Fert-60	43.7 $\pm$ 2.3 a	42.9 $\pm$ 2.0 a	2.8 $\pm$ 0.1 a	68.6 $\pm$ 1.4 b	51.7 $\pm$ 2.8 b
Fert-90	42.2 $\pm$ 2.0 a	33.6 $\pm$ 2.5 b	2.6 $\pm$ 0.1 a	64.2 $\pm$ 2.5 b	52.4 $\pm$ 1.7 b
CFA	36.5 $\pm$ 0.7 a	33.1 $\pm$ 1.3 b	2.1 $\pm$ 0.2 b	62.4 $\pm$ 2.1 b	43.5 $\pm$ 1.0 c
Control	40.1 $\pm$ 0.9 a	35.3 $\pm$ 2.2 b	2.1 $\pm$ 0.1 b	60.9 $\pm$ 2.9 b	46.0 $\pm$ 3.2 c

\*, <sup>ns</sup> - Significant and not significant at  $p \leq 0.05$  by the F test; Means followed by the same letter in the columns are not different by the Scott-Knott test at  $p \leq 0.05$ ; SRF - Slow-release fertilizer (Osmocote<sup>®</sup> Plus, Everris, Dublin, USA); Ferti-30, Ferti-60, and Ferti-90 - Fertigation every 30, 60, and 90 days, respectively; CFA - Conventional fertilizer application; Control - No application of soil fertilizer. NL - Number of leaves; DLL - 'D' leaf length; DLW - 'D' leaf width; SAD - Shoot apex diameter; PH - Plant height

The number of leaves was not affected by the treatments, and presented mean of 41 units.

The highest 'D' leaf lengths were found in plants under application of slow-release fertilizer to the substrate and under fertigation at every 30 and 60 days, and the lowest were found in plants subjected to fertigation at every 90 days, application of conventional soil fertilizer, and in those of the control treatment. The mean of the highest 'D' leaf lengths (45.4 cm) was 33.5% higher than that of the lowest lengths (34 cm).

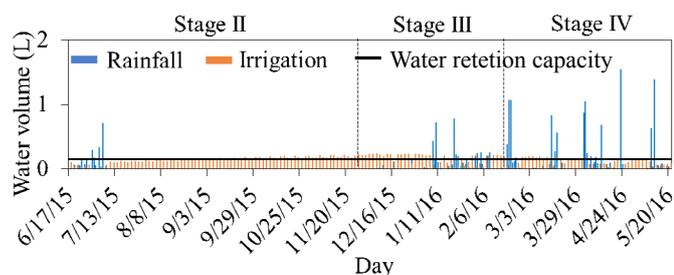
The highest 'D' leaf widths were found in plants under application of slow-release fertilizer and in those under all fertigation regimes. The lowest 'D' leaf widths were found in plants under conventional soil fertilizer application and in those of the control treatment. The mean of the highest widths (2.7 cm) was 28.6% higher than that of the lowest widths (2.1 cm).

The highest shoot apex diameter (75.6 cm) was found in plants under application of slow-release fertilizer. This value was 17% higher than the mean of the lowest diameters (64.6 cm), which were found in all treatments with fertigation regimes, in the treatment with conventional fertilizer application, and in the control.

The highest plant heights were found in plants under application of slow-release fertilizer and in those under fertigation at every 30 days. Intermediate plant heights were found in plants under fertigation at every 60 and 90 days; and the lowest values were found in plants under conventional fertilizer application and in those of the control treatment. The mean of the highest plant heights (60 cm) was 15.4 and 34.2% higher than that of the intermediate (52 cm) and lowest (44.7 cm) plant heights, respectively. The mean of the intermediate heights was 16.3% higher than that of the lowest heights.

According to the results, the decrease in vegetative growth was more pronounced in plants of the control and in those of the treatments with fewer number of fertilizer applications by using water-soluble fertilizers (conventional fertilizer application, and fertigation every 60 and 90 days). These treatments were more subjected to nutrients losses by leaching due to drainages of the irrigation water and, mainly, of water from the high-intensity rainfalls (Figure 3).

The irrigation probably leached less nutrients than the rainfalls, since the water volume applied during the experiment was close to the pots' capacity. The high-intensity rainfalls

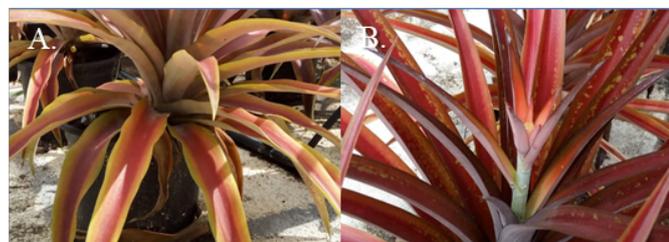


**Figure 3.** Rainfall and irrigation volumes during the phenological stages of ornamental pineapple plants grown in pots under an anti-aphid screen

(18 events) presented a water volume higher than the pots' capacity, which may have intensified the nutrient loss by excessive drainage. Water volumes above the retention capacity increase leaching of mobile nutrients from water-soluble fertilizers, such as N (Jia et al., 2014) and K (Mendes et al., 2016). Thus, their use can be justified only when used in small quantities in the irrigation water to avoid excess salts in the root zone (Kisekka et al., 2019).

Nutrient loss by leaching can cause several nutritional deficiency symptoms in crops. In ornamental pineapple plants (*Ananas comosus* var. *erectifolius*), deficiencies of P, Ca, and S reduce the number and size of leaves and the plant height. Moreover, deficiencies of N and Mg change the color of leaves, which may present a pale green or yellowish shades in the whole length of the leaf edge (Viégas et al., 2014).

The overall size of the plants decreased in treatments with fewer number of applications of soil fertilizer. However, leaf yellowing (chlorosis) occurred only in some plants grown with no application of fertilizer (Figure 4).



**Figure 4.** Ornamental pineapple plants grown in pots under an anti-aphid screen, showing presence (without fertilizer application) (A) and absence (with fertilizer application) (B) of leaf chlorosis

**Table 4.** Analysis of variance and mean test for variables of reproductive growth of ornamental pineapple plants grown in pots under an anti-aphid screen

Source of variation	F calculated ( $p \leq 0.05$ )								
	FR	PD	PL	CD	CL	SD	SL	C:S	MP
Treatment	0.2 <sup>ns</sup>	3.7*	0.4 <sup>ns</sup>	1.1 <sup>ns</sup>	0.5 <sup>ns</sup>	1.4 <sup>ns</sup>	0.2 <sup>ns</sup>	0.3 <sup>ns</sup>	6.1*
Coefficient of variation (%)	13.8	13.1	21.1	26.8	8.2	6	13.1	13.1	16.7
Treatments	Scott-Knott test (mean $\pm$ confidence interval) ( $p \leq 0.05$ )								
	(%)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(adm.)	(%)
SRF	93.7 $\pm$ 6.1 a	1.1 $\pm$ 0.09 a	24.4 $\pm$ 4.8 a	4.7 $\pm$ 0.5 a	4.5 $\pm$ 0.2 a	2.9 $\pm$ 0.10 a	4.2 $\pm$ 0.3 a	1.2 $\pm$ 0.05 a	93.7 $\pm$ 6.1 a
Fert-30	93.7 $\pm$ 6.1 a	1.0 $\pm$ 0.18 a	28.1 $\pm$ 1.9 a	5.5 $\pm$ 0.1 a	4.6 $\pm$ 0.1 a	3.0 $\pm$ 0.02 a	3.9 $\pm$ 0.2 a	1.2 $\pm$ 0.02 a	93.7 $\pm$ 6.1 a
Fert-60	93.7 $\pm$ 6.1 a	1.1 $\pm$ 0.16 a	25.9 $\pm$ 3.9 a	4.7 $\pm$ 0.7 a	4.7 $\pm$ 0.2 a	2.9 $\pm$ 0.07 a	4.2 $\pm$ 0.1 a	1.1 $\pm$ 0.09 a	93.7 $\pm$ 6.1 a
Fert-90	93.7 $\pm$ 6.1 a	0.9 $\pm$ 0.05 b	23.7 $\pm$ 1.6 a	3.5 $\pm$ 0.5 a	4.7 $\pm$ 0.3 a	3.0 $\pm$ 0.03 a	4.1 $\pm$ 0.1 a	1.1 $\pm$ 0.09 a	93.7 $\pm$ 6.1 a
CFA	87.5 $\pm$ 7.1 a	0.8 $\pm$ 0.07 b	26.6 $\pm$ 3.2 a	5.2 $\pm$ 1.0 a	4.9 $\pm$ 0.1 a	2.7 $\pm$ 0.10 a	3.9 $\pm$ 0.4 a	1.2 $\pm$ 0.06 a	81.2 $\pm$ 6.1 a
Control	93.7 $\pm$ 6.1 a	0.8 $\pm$ 0.04 b	24.8 $\pm$ 1.8 a	4.6 $\pm$ 0.4 a	4.8 $\pm$ 0.1 a	2.8 $\pm$ 0.09 a	3.9 $\pm$ 0.3 a	1.2 $\pm$ 0.10 a	50.0 $\pm$ 10.0 b

\*, <sup>ns</sup> - Significant and not significant at  $p \leq 0.05$  by the F test; Means followed by the same letter in the columns are not different by the Scott-Knott test at  $p \leq 0.05$ ; SRF - Slow-release fertilizer (Osmocote Plus, Everris, Dublin, USA); Fert-30, Fert-60, and Fert-90 - Fertigation every 30, 60, and 90 days, respectively; CFA - Conventional fertilizer application; Control - No application of soil fertilizer. FR - Flowering rate; PD - Peduncle diameter; PL - Peduncle length; CD - Crown diameter; CL - Crown length; SD - Syncarp diameter; SL - Syncarp length; C:S - Crown to syncarp ratio; MP - Marketable plants

The nutritional deficiency was more pronounced in plants grown without application of fertilizers due to leaching of nutrients from the substrate (Figure 3). Nutrient losses in treatments with application of soil fertilizers were probably higher only at the beginning of the plant developmental stage II and after the second half of stage III, even in the treatments with fewer number of fertilizer applications. Thus, the plants were probably less affected by nutritional deficiency between these periods (approximately seven months without rainfall).

Despite the difference between the treatments, all plants grown in treatments with fertilizer applications presented no problems in leaf esthetic quality, such as deformation, wither, discoloration, chlorosis, necrosis, and spots. Thus, they fitted into the category for growth in pots, since they exhibited 'D' leaf lengths, shoot apex diameters, and plant heights lower than 60.0, 80.0, and 65.0 cm, respectively (Souza et al., 2012).

Only peduncle diameter and percentage of marketable plants were affected by the treatments (Table 4).

The flowering rate ranged from 93.7 to 87.5%, with mean of 92.7%. Flowering rates above 90% are common in eatable pineapple plants subjected to floral induction by using ethephon-based solution (Cunha, 2005). The lack of flowering in some plants was probably because of effects of biotic (cuticular layers, trichomes, etc.) and abiotic (temperature, moisture, etc.) factors on the efficiency of the ethephon (Cunha, 2005).

The sensitivity of pineapple plants to artificial floral induction depends on the maturity of the plants, which need to have reached adequate size and age to respond to application of ethylene (Cunha, 2005; Poel et al., 2009). Considering that the age of evaluated plants was the same, the size of most plants was adequate, despite the variation between treatments. Establishing a minimum limit for plant size to ensure the response of ornamental pineapple plants to floral inducers is difficult due to the lack of information about floral induction of such plants based on plant size, mainly for the variety evaluated in the present study.

The higher peduncle diameters were found in plants of the treatment with application of slow-release fertilizer and treatments with fertigation at every 30 and 60 days, presenting mean of 1.1 cm. The lowest peduncle diameters were found in plants under fertigation at every 90 days, conventional fertilizer application, and in those of the control, presenting mean of

0.8 cm. The mean of the highest peduncle diameters was 37.7% higher than that of the lowest diameters.

The other reproductive growth variables were not affected by the treatments. The means for peduncle length, crown diameter, crown length, syncarp diameter, syncarp length, and crown to syncarp ratio were 25.5, 4.6, 4.7, 2.9, 4.1 and 1.2, respectively.

The dimensions of reproductive growth variables met the requirements of the category for use in pots, in all treatments. The syncarp length and diameter were, respectively, lower than 5.0 and 3.0 cm, peduncle and crown lengths were, respectively, lower than 30.0 and 5.0 cm, and crown to syncarp ratio was up to 1.5 (Souza et al., 2007; 2012). In addition, floral stems exhibited no morphological anomalies (shape, color, spot, mutation, etc.) that could hinder their commercial value.

High percentages of marketable plants were found for all strategies of application of soil fertilizers. The means ranged from 81.2 to 93.7%, with mean of 91.2%. The lowest percentage of marketable plants (50%) was found in plants under absence of soil fertilizer application; in this treatment, the low percentage of marketable plants was due to the leaf esthetic quality, which was hindered by occurrence of chlorosis.

Considering the results found, all strategies of application of soil fertilizers tested in the present study can be used for growing ornamental pineapple plants in pots. The choice of the application strategy to be used will depend on several factors, such as local availability and price of the soil fertilizer, availability and cost of labor, and presence of fertigation equipment.

## CONCLUSIONS

1. The strategy of application of soil fertilizer used affects the 'D' leaf length and width, shoot apex diameter, plant height, and peduncle diameter of ornamental pineapple plants, but does not hinder the esthetic quality and dimensions required for marketing these plants in pots.

2. Ornamental pineapple plants (*Ananas comosus* var. *erectifolius*) can be grown using 13.2 g per pots of the slow-release fertilizer tested; based on the same quantities of macro and micronutrients contained in that slow-release fertilizer, using soil mineral fertilizers by conventional application or by fertigation at every 30, 60, or 90 days.

3. The production of ornamental pineapple plants without application of soil mineral fertilizer should be avoided, since it reduces the percentage of marketable plants.

## ACKNOWLEDGEMENTS

The authors thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the financial support; the Federal University of Ceará for providing the experimental area and infrastructure; and the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) for providing the agricultural inputs and scientific support.

## LITERATURE CITED

Allen, R. G.; Pereira, L. S.; Raes, D.; Smith, M. Evapotranspiración del cultivo: guías para la determinación de los requerimientos de agua de los cultivos. Roma: FAO, 2006. 300p.

- Almeida, O. A. de. Irrigação em abacaxi. Cruz das Almas: EMBRAPA, 1995. 33p.
- Alves, K. A.; Londe, L. N.; Melo, E. F.; Rodrigues, G. B. Multiplication of ornamental pineapple in different concentrations of BAP and periods evaluation of development in vitro. *Bioscience Journal*, v.30, p.188-198, 2014.
- Barbosa, T. M. B.; Santos, J. Z. L.; Tucci, C. A. F.; Silva, S. V. da; Cardoso, A. A. de S.; Pereira, B. F. F. Phosphorus sources: Effects on growth and phosphorus fractions of Curauá (*Ananas erectifolius* L. B. Smith). *Communications in Soil Science and Plant Analysis*, v.46, p.1200-1211, 2015. <https://doi.org/10.1080/00103624.2015.1033531>
- Brezolin, A. P.; Silva, J. A. G. da; Roos-Frantz, F.; Binelo, M. O.; Krüger, C. A. M. B.; Arenhardt, E. G.; Marolli, A.; Mantai, R. D.; Scremin, O. B.; Dornelles, E. F. Wheat yield obtained from nitrogen dose and fractionation. *African Journal of Agricultural Research*, v.2, p.566-576, 2017.
- Carr, M. K. V. The water relations and irrigation requirements of pineapple (*Ananas comosus* var. *comosus*): A review. *Experimental Agriculture*, v.48, p.488-501, 2012. <https://doi.org/10.1017/S0014479712000385>
- Cunha, G. A. P. da. Applied aspects of pineapple flowering. *Bragantia*, v.64, p.499-516, 2005. <https://doi.org/10.1590/S0006-87052005000400001>
- Ha, B. Y.; Kim, H. R.; Kim, D. H.; Woo, J. W.; Jo, Y. J.; Kwon, S. I. Growth effects of the application of new controlled-release fertilizers on *Phalaenopsis* spp. *Applied Biological Chemistry*, v.61, p.625-633, 2018. <https://doi.org/10.1007/s13765-018-0401-5>
- Hawerth, F. J.; Mauta, D. de S.; Cândido, M. dos S.; Taniguchi, C. A. K.; Hawerth, M. C.; Serrano, L. A. L. Adubo de liberação lenta na produção de abacaxizeiro ornamental em vaso. Fortaleza: Embrapa Agroindústria Tropical, 2014. 19p.
- Jia, X.; Shao, L.; Liu, P.; Zhao, B.; Gu, L.; Dong, S.; Zhang, J.; Zhao, B. Effect of different nitrogen and irrigation treatments on yield and nitrate leaching of summer maize (*Zea mays* L.) under lysimeter conditions. *Agricultural Water Management*, v.137, p.92-103, 2014. <https://doi.org/10.1016/j.agwat.2014.02.010>
- Kisekka, I.; Kandelous, M. M.; Sanden, B.; Hopmans, J. W. Uncertainties in leaching assessment in micro-irrigated fields using water balance approach. *Agricultural Water Management*, v.213, p.107-115, 2019. <https://doi.org/10.1016/j.agwat.2018.10.012>
- Kumar, M.; Rajput, T. B. S.; Kumar, R.; Patel, N. Water and nitrate dynamics in baby corn (*Zea mays* L.) under different fertigation frequencies and operating pressures in semi-arid region of India. *Agricultural Water Management*, v.163, p.263-274, 2016. <https://doi.org/10.1016/j.agwat.2015.10.002>
- Li, X.; Yan, Z.; Khalid, M.; Sun, Y.; Shi, Y.; Tang, D. Controlled-release compound fertilizers improve the growth and flowering of potted *Freesia hybrida*. *Biocatalysis and Agricultural Biotechnology*, v.17, p.480-485, 2019. <https://doi.org/10.1016/j.bcab.2019.01.004>
- Lima, O. S.; Souza, E. H. de; Dias, L. E. da C.; Souza, C. P. F.; Souza, F. V. D. Characterization and selection of ornamental pineapple hybrids with emphasis on sinuous stems and black fruits. *Pesquisa Agropecuária Tropical*, v.47, p.237-245, 2017. <http://dx.doi.org/10.1590/1983-40632016v4746163>
- Lv, H.; Lin, S.; Wang, Y.; Lian, X.; Zhao, Y.; Li, Y.; Du, J.; Wang, Z.; Wang, J.; Butterbach-Bahl, K. Drip fertigation significantly reduces nitrogen leaching in solar greenhouse vegetable production system. *Environmental Pollution*, v.245, p.694-701, 2019. <https://doi.org/10.1016/j.envpol.2018.11.042>

- Malhotra, S. K. Water soluble fertilizers in horticultural crops - An appraisal. *Indian Journal of Agricultural Sciences*, v.86, p.1245-56, 2016.
- Mendes, B. S. da S.; Willadino, L.; Cunha, P. C. da; Oliveira Filho, R. A. de; Câmara, T. R. Mecanismos fisiológicos e bioquímicos do abacaxi ornamental sob estresse salino. *Revista Caatinga*, v.24, p.71-77, 2011.
- Mendes, W. da C.; Alves Júnior, J.; Cunha, P. C. R. da; Silva, A. R. da; Evangelista, A. W. P.; Casaroli, D. Potassium leaching in different soils as a function of irrigation depths. *Revista Brasileira de Engenharia Agrícola e Ambiental*, v.20, p.972-977, 2016. <https://doi.org/10.1590/1807-1929/agriambi.v20n11p972-977>
- Pereira, G. N. D.; Souza, E. H. de; Souza, J. da S.; Souza, F. V. D. Public perception and acceptance of ornamental pineapple hybrids. *Horticultura Ornamental*, v.24, p.116-124, 2018. <http://dx.doi.org/10.14295/oh.v24i2.1154>
- Poel, B. V. de; Ceusters, J.; Proft, M. P. de. Determination of pineapple (*Ananas comosus*, MD-2 hybrid cultivar) plant maturity, the efficiency of flowering induction agents and the use of activated carbon. *Scientia Horticulturae*, v.120, p.58-63, 2009. <https://doi.org/10.1016/j.scienta.2008.09.014>
- Reis, I. N. R. de S.; Santos Filho, B. G. dos; Castro, C. V. B.; Lameira, C. N.; Rossato, V. Trocas gasosas e alocação de biomassa em plantas jovens de Curauá (*Ananas erectifolius* L. B. Smith) submetidas ao alagamento. *Revista Brasileira de Biociências*, v.5, p.507-509, 2007.
- Souza, E. H. de; Costa, M. A. P. de C.; Santos-Serejo, J. A.; Souza, F. V. D. Selection and use recommendation in hybrids of ornamental pineapple. *Revista Ciência Agronômica*, v.45, p.409-416, 2014. <https://doi.org/10.1590/S1806-66902014000200024>
- Souza, E. H. de; Souza, F. V. D.; Costa, M. A. P. de C.; Costa Júnior, D. S.; Santos-Serejo, J. A. dos; Amorim, E. P.; Ledo, C. A. da S. Genetic variation of the *Ananas genus* with ornamental potential. *Genetic Resources and Crop Evolution*, v.59, p.1357-1376, 2012. <https://doi.org/10.1007/s10722-011-9763-9>
- Souza, F. V. D.; Cabral, J. R. S.; Souza, E. H. de; Santos, O. S. N.; Santos-Serejo, J. A. dos; Ferreira, F. R. Caracterização morfológica de abacaxizeiros ornamentais. *Magistra*, v.19, p.319-325, 2007.
- Taniguchi, C. A. K.; Castro, A. C. R. de; Silva, T. F. da; Café, F. B. da S. Development of pineapple as an ornamental potted plant. *Acta Horticulturae*, v.1087, p.379-384, 2015. <https://doi.org/10.17660/ActaHortic.2015.1087.50>
- Viégas, I. J. M.; Silva, R. N. P.; Silva, D. A. S.; Oliveira Neto, C. F.; Conceição, H. E. O.; Mascarenhas, G. S.; Okumura, R. S.; Monfort, L. E. F.; Silva, R. T. L. Mineral composition and visual symptoms of nutrients deficiencies in Curauá plants (*Ananas comosus* var. *erectifolius*). *Australian Journal of Crop Science*, v.8, p.747-753, 2014.
- Wolff, M. W.; Hopmans, J. W.; Stockert, C. M.; Burger, M.; Sanden, B. L.; Smart, D. R. Effects of drip fertigation frequency and N-source on soil N<sub>2</sub>O production in almonds. *Agriculture, Ecosystems & Environment*, v.238, p.67-77, 2017. <https://doi.org/10.1016/j.agee.2016.08.001>