



Revista Brasileira de Ciências Agrárias

ISSN: 1981-1160

Pró-Reitoria de Pesquisa e Pós-Graduação - Universidade
Federal Rural de Pernambuco

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Revista Brasileira de Ciências Agrárias, vol. 13, no. 1, 2018, pp. 1-8
Pró-Reitoria de Pesquisa e Pós-Graduação - Universidade Federal Rural de Pernambuco

DOI: <https://doi.org/10.5039/agraria.v13i1a5499>

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Quality of 'Imperial' pineapple infructescence in function of nitrogen and potassium fertilization

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ABSTRACT: The quality aspects of pineapple infructescences are influenced by nutritional management. Thus, the objective was to evaluate the physical-chemical characteristics of the infructescences of cv. Imperial, submitted to fertilization with nitrogen (N) and potassium (K). The experimental design was a randomized complete block design with three replicates and the treatments were arranged in a factorial scheme according to the *Plan Plueba* III matrix, which consisted of a combination of five doses of N: 15; 90; 150; 210 and 285 kg ha⁻¹ and five doses of K: 21.6; 129.6; 216.0; 302.4 and 410.4 kg ha⁻¹. The measured characteristics of the infructescence were fresh mass; length; diameter; firmness; yield of pulp and crown; coloring of the shell and pulp; soluble solids (SS); titratable acidity (TA); SS/AT ratio and ascorbic acid. The elevation of the K₂O doses to 410.4 kg ha⁻¹ increased the infructescence mass with crown, length and diameter of the infructescence and the soluble solids content, being harvested in the plants that received this fertilization, infructescence with the average values of 632.34 g, 9.0 cm, 84.80 mm and 16.42%, respectively. Plants that received N doses of 285 kg ha⁻¹ favored pulp yield, a* and b* coloring index of the bark and the SS/AT ratio, giving mean values of 44.50%, 9.64, 33.06 and 30.10, respectively. Doses of 285 kg ha⁻¹ of N and 410.4 kg ha⁻¹ of K₂O promote improvements in the physical-chemical characteristics of infructescences of 'Imperial' pineapple.

Key words: *Ananas comosus* L. var. *comosus*; mineral fertilization; post-harvest

Qualidade de infrutescências de abacaxizeiro 'Imperial', em função da adubação nitrogenada e potássica

RESUMO: Os aspectos de qualidade das infrutescências de abacaxizeiro são influenciados pelo manejo nutricional. Assim, o trabalho foi realizado com o objetivo de avaliar as características físico-químicas das infrutescências de abacaxizeiro cv. Imperial, submetidos à adubação com nitrogênio (N) e potássio (K). O delineamento experimental foi casualizado em blocos, com três repetições e os tratamentos foram dispostos em esquema fatorial conforme a matriz *Plan Plueba* III, que consistiram na combinação de cinco doses de N: 15; 90; 150; 210 e 285 kg ha⁻¹ e cinco doses de K: 21,6; 129,6; 216,0; 302,4 e 410,4 kg ha⁻¹. As características mensuradas nas infrutescências foram massa fresca; comprimento; diâmetro; firmeza; rendimento da polpa e da coroa; coloração da casca e da polpa; sólidos solúveis (SS); acidez titulável (AT); relação SS/AT e ácido ascórbico. A elevação das doses de K₂O para 410,4 kg ha⁻¹ aumentou a massa da infrutescência com coroa, comprimento e diâmetro da infrutescência e o teor de sólidos solúveis, colhendo-se nas plantas que receberam esta adubação, infrutescência com os tamanhos médios de 632,34 g, 9,0 cm, 84,80 mm e 16,42%, respectivamente. As plantas que receberam doses de N de 285 kg ha⁻¹ favoreceram o rendimento da polpa, o índice de coloração a* e b* da casca e a relação SS/AT proporcionando valores médios de 44,50%, 9,64, 33,06 e 30,10, respectivamente. As doses de 285 kg ha⁻¹ de N e 410,4 kg ha⁻¹ de K₂O promoveram melhorias nas características físico-químicas de infrutescências do abacaxizeiro 'Imperial'.

Palavras-chave: *Ananas comosus* L. var. *comosus*; adubação mineral; pós-colheita

Introduction

Brazilian pineapple cultivation has predominantly the Pérola and Smooth Cayenne cultivars. The Pérola cultivar is more widespread in the North and Northeast regions and the Smooth Cayenne cultivar in the Southeast and Midwest regions. Both cultivars are susceptible to fusariosis, caused by the fungus *Fusarium subglutinans*, which is a highly destructive disease that can cause estimated losses of 30 to 40% of infructescences. In this sense, new cultivars resistant to fusariosis were introduced to replace the two most widespread cultivars in the country, such as the 'Imperial' (Cabral & Matos, 2005; Ventura et al., 2009; Caetano et al., 2015).

The introduction of new cultivars of fusarium-resistant pineapples, such as cv. Imperial, can be promising, as it will allow the diversification of the production system. This cultivar was obtained from the crossing of 'Perolera' with 'Smooth Cayenne', by Embrapa Mandioca and Fruticultura, resistant to fusariosis and internal darkening of the infructescence, which allows the reduction of the use of fungicide, with a reduction in the costs of production (Cabral & Matos, 2005). The plants are medium size, without spines at the edges, infructescence with high sugar content, moderate titratable acidity and moderate ascorbic acid content (Cabral & Matos, 2005; Caetano et al., 2015).

Although 'Imperial' is promising for the pineapple producing regions, research on this cultivar is scarce. Due to the commercially farmed cultivar, the nutritional demand has not been adequately studied and the fertilizers being used are based on the general recommendation for pineapple cultivation. There is no nutritional reference for cultivation in most of the North and Northeast regions, hindering to expand.

The nitrogen and potassium are among the nutrients most required by pineapple. Nitrogen (N) is part of amino acids, amides, proteins, nucleic acid and coenzymes (Ramos et al., 2010). Potassium plays a role in plant metabolism, acting as an activator of several enzymes during photosynthesis, respiration, the opening of stomata and maintenance of cellular turgidity (Marschner, 2012). In this way, the inadequate supply of a particular nutrient usually results in nutritional disorders. Ramos et al. (2010) showed that N deficiency in cv. Imperial resulted in infructescences with high acidity, without aroma and flavor.

Due to the low natural fertility of the soils of the Northeast region and the high nutritional requirement of the pineapple, plant nutrition is determinant in increasing productivity. The nutritional status of pineapple depends on soil physical and chemical characteristics, water availability, root system development and physical and biological factors influencing soil nutrient extraction, affecting the growth, production, and quality of the infructescences (Malezieux & Bartholomew, 2003).

Considering the importance of fertilization in mineral nutrition for pineapple and that the new cultivars resistant to fusariosis do not have reference to nutritional demands, the fertilizers that are being used assume that the demands are

the same as the traditional cultivars in the Region. Therefore, the work was carried out with the objective of evaluating the physical-chemical characteristics of the infructescences of cv. Imperial, submitted to fertilization with doses of N and K.

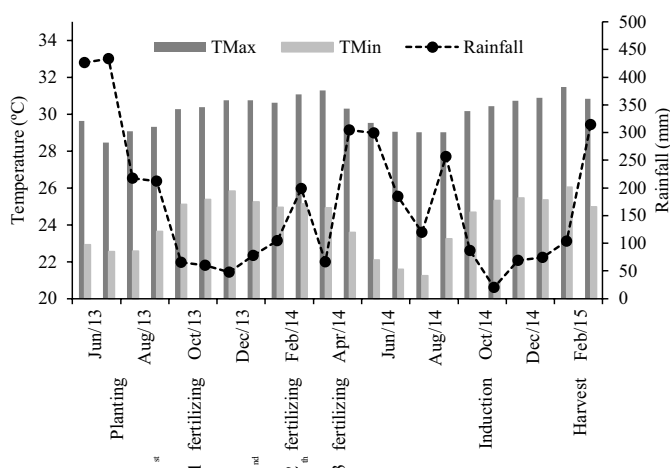
Materials and Methods

The experiment was carried out at the Jaguarema farm located in the municipality of Alhandra, in the Zona da Mata, the state of Paraíba, defined by the geographic coordinates of 7° 21.9' 43"S and 34° 56.1' 93"W and altitude of 49 m. The predominant climate in the region is 'As', hot and humid, with autumn-winter rains, an annual average temperature ranging from 22 to 26 °C and annual mean precipitation of 1,677 and 1,787 mm in 2013 and 2014, respectively (AESA, 2016), verified in Figure 1.

The soil of the experimental area is classified as Quartzarenic Neosol. Initially, the soil was collected in the 0-20 cm depth layer for chemical analysis, and 30 simple samples were collected to form a composite sample. Subsequently, the soil was submitted for analysis in the Soil Laboratory of the Federal University of Paraíba and presented the following chemical characteristics: pH em água (1:2.5) – 5.28; P – 21.42 mg dm⁻³; K⁺ – 22.67 mg dm⁻³; Na⁺ – 0.03; H⁺ + Al³⁺ – 3.38; Al³⁺ – 0.25; Ca²⁺ – 0.40; Mg²⁺ – 0.35; SB – 0.84; CTC – 4.22 in cmol_c dm⁻³, respectively; V – 19.91%; m – 22.94% e m.o-10.70 g kg⁻¹. The granulometric analysis presented 905, 48 and 47 g kg⁻¹ of sand, silt and clay, respectively, located in the sand textural class (Embrapa, 2013).

Imperial pineapple seedlings were grown in vitro. They were acclimatized for one year in a hotbed of the Fruit Sector of the Federal University of Paraíba and selected for sanitary aspects and size (30 ± 5 cm).

After the soil tillage operations with of two cross gradations, without soil correction, the seedlings were planted under no-tillage conditions in the single rows system, spacing 0.80 x 0.30 m.



Source: AESA (2016).

Figure 1. Minimum temperature, maximum and precipitation in Alhandra, PB, Brazil, during the experimental period, evidencing the main plant nutritional management times.

Phosphate fertilization was applied in a single dose in the soil near the plant base at 65 days after planting (DAP) using single superphosphate (18% P_2O_5), N (urea 45% N) and chloride of potassium (60% K_2O) 65, 195 and 255 DAP were applied. The plants received leaf sprays with micronutrients (B, Zn, Cu and Fe) at 135, 195, 255 and 315 DAP using borax (1,9 kg ha^{-1}), zinc sulphate (8 kg ha^{-1}), copper sulphate (8 kg ha^{-1}) and iron sulphate (16 kg ha^{-1}), according to the recommendation of Oliveira et al. (2002).

The experiment was organized in the factorial scheme according to the Plan Plueba III matrix (Table 1), distributed in randomized blocks, with 10 treatments and three replicates.

The highest dose of the nitrogen (N) and potassium (K) nutrients recommended in the technical bulletins of the states of Northeast for the pineapple was verified to establish the doses to be studied. On top of this, 20% of the highest dose of recommendation was added, and the mean nutrient dose was calculated. This was then applied to the matrix, obtaining the doses of N and K used in the study. In this way, five doses of N: 15 were used; 90; 150; 210 and 285 kg ha^{-1} , having as source urea and five doses of K: 21.6; 129.6; 216.0; 302.4 and 410.4 kg ha^{-1} having as source KCl.

For weed control, manual weeding was performed every two months, until the sixteenth month after planting and control of cochineal (*Dysmicoccus brevipes*), with the application of the insecticide Evidence[®], 30 g 100 L⁻¹ of Water.

The floral induction was carried out at 14 months after planting, since seedlings from in vitro culture were used, by applying 50 mL plant⁻¹ of the Ethrel[®] solution (2-chloroethyl phosphonic acid), adding 2% of urea, in the central rosette.

After four months of floral induction, from each useful plot, 10 infructescences were collected randomly, when they had reached physiological maturity, presenting more than 70% of the peel completely yellow. The infructescences were taken to the Laboratory of Fruticulture, Center of Agrarian Sciences, Federal University of Paraíba, where they were evaluated for the physicochemical characteristics.

The infructescences were evaluated for the characteristics of fresh mass of infructescence with crown; length of the infructescence and diameter, with the aid of a digital caliper; firmness determined individually at two distinct points in the

median region of the infructescence, with Magness Taylor Pressure Tester (Drill Press Stand, Canada); yield of the crown, bark, stem and pulp, by weighing the crown infructescence and subsequently of each separate component. The yield of the crown results from the crown mass times a hundred, divided by the mass of the crown infructescence; and coloring of the shell and pulp, using a Minolta portable digital colorimeter, expressed in the parameters: L*; a* and b*.

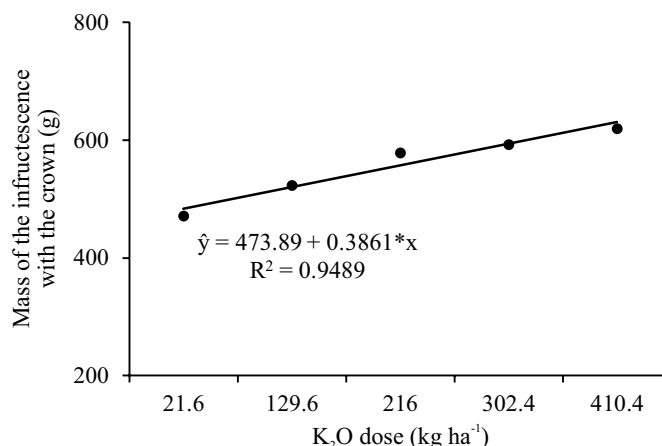
For the chemical analyses, samples of the ten infructescences per plot were taken, and the analyses were performed in three replicates. Soluble solids (%) were determined using a digital refractometer (Kruss-optronic, Hamburg, Germany), according to AOAC (2005); Titratable acidity (% citric acid), determined by titration of the juice with 0.1M NaOH solution (IAL, 2005); calculated the SS/AT ratio; and ascorbic acid (mg 100 g⁻¹ pulp), determined by titration with 0.002% 2,6-dichlorophenol-indophenol solution (AOAC, 2005).

The data were submitted to analysis of variance and polynomial regression for the quantitative factors. The criteria for choosing the regression models were the biological meaning, testing up to quadratic level. The significance of up to 5% probability and coefficient of determination (R^2) above 60%, using SAS University software was considered (Cody, 2015).

Results and Discussion

For the mass of the infructescence with the crown of the pineapple cv. Imperial, linear growth and a 23.74% increase were observed with increasing doses of K_2O (Figure 2).

The results show that even with the increase in the infructescence mass with the increasing application of K_2O , they did not reach the minimum standard of commercialization, evidencing a greater demand of the nutrient. Considering the reference pattern of the traditional cultivars, the minimum mass of the pineapple for commercialization should be 900 g, when the infructescences are very small (≤ 700 g) or very large ($\geq 2,300$ g), they present low commercial value for fresh consumption



* Significant at 5% probability by F test.

Figure 2. Mass of the infructescence with the crown of 'Imperial' pineapple in relation to the doses of potassium.

Table 1. Pan Puebla III matrix, with the description of the treatments of the urea and potassium chloride doses, applied in the cultivation of 'Imperial' pineapple.

Treatment	Level		Dose (kg ha^{-1})	
	N	K	N	K
1	-0.4	-0.4	90.0	129.6
2	-0.4	0.4	90.0	302.4
3	0.4	-0.4	210.0	129.6
4	0.4	0.4	210.0	302.4
5	0	0	150.0	216.0
6	-0.9	-0.4	15.0	129.6
7	0.9	0.4	285.0	302.4
8	-0.4	-0.9	90.0	21.6
9	0.4	0.9	210.0	410.4
10	-0.9	-0.9	15.0	21.6

(MAPA, 2002; Vilela et al., 2015). It is necessary to emphasize that the average mass of infructescences of plants coming from in vitro culture, in the first cycle, is smaller since they tend to present fewer reserves and slower growth. Subsequent plantings with balanced fertilization and previous residues of pineapple can increase area productivity (Liu et al., 2013).

The low mass of the infructescence can also be justified by the fact that cultivars with resistance to fusariosis are usually smaller than those traditionally cultivated. In addition, the precipitations during the conduction of the experiment were irregular (Figure 1). However, the daily precipitation values are within the minimum required for the crop. Commercial pineapple cultivation requires water demand ranging from 1.3 to 5.0 mm day⁻¹ depending on the stage of development (Reinhardt et al., 2002).

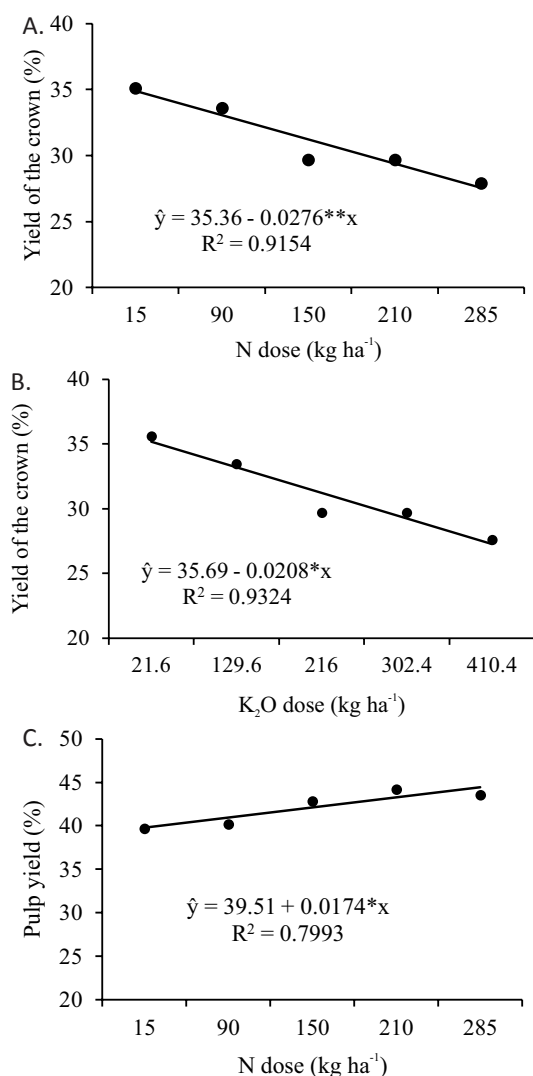
For the yield of the crown, there is an isolated effect of the application of nitrogen and potassium doses. The increase of the N and K₂O doses resulted in a linear reduction of the yield of the crown (Figure 3A and B), that is, reduction of 27.10 and

29.80%, respectively. In contrast, elevation of N doses linearly increased the yield values of the infructescence pulp of 'Imperial' pineapple, with an increase of 10.63% (Figure 3C).

The increase in N and K₂O doses promoted a decrease in crown yield. Reduction of the crown is a desired factor when there is an increase in infructescence yield. According to Cabral & Matos (2005), the crown mass of cv. Imperial should be approximately 120 g and have a length of 17.8 cm. In this study, a mass of 130 to 213 g was found, and 14 to 25 cm of crown length. However, for infructescences destined to export, due to the standardization of packaging, the ideal one is crown with 5-13 cm length.

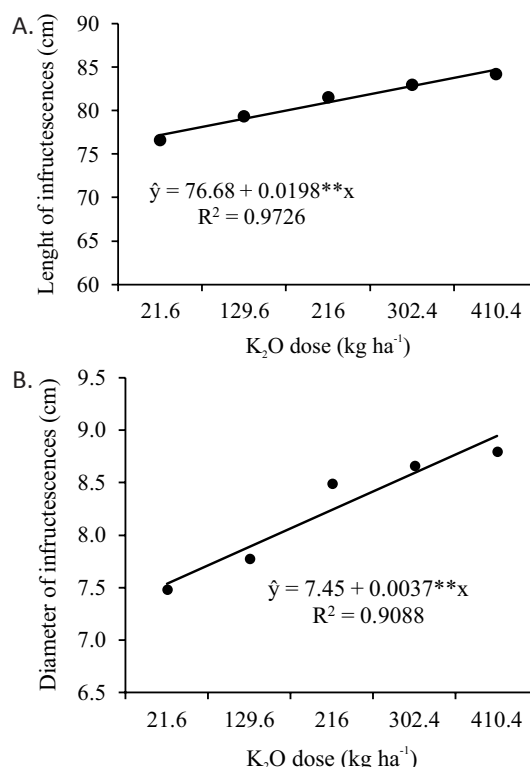
The length and diameter of the infructescences of the pineapple cv. Imperial levels were elevated with K₂O doses (Figure 4). In both variables, growth was linear with increasing doses of K₂O, with an increase of 16.33% in relation to the length of the infructescences (Figure 4A) and of 9.10% in the infructescence (Figure 4B).

Characterizing cv. Imperial, Cabral & Matos (2005) showed infructescence with 18.50 cm in length and 135.0 mm in median diameter. The lower results in this study are related to the fact that they are seedlings from in vitro cultivation, in the first production, that usually results in smaller infructescences. The incorporation of the cultural remains and evaluation in subsequent cultivation, as well as the elevation of the nutrient doses, can increase these values. Therefore, work with this cultivar using higher doses of N and K, and seedlings from subsequent production are of paramount importance. In this way, the maximum plant response will be verified, since



** and * Significant at 1% and 5% of probability by the F test, respectively.

Figure 3. The yield of the crown of infructescences of 'Imperial' pineapple in relation to nitrogen (A) and potassium (B) and pulp yield in relation to nitrogen (C).



** and * Significant at 1% and 5% of probability by the F test, respectively.

Figure 4. Length (A) and diameter (B) of infructescences of 'Imperial' pineapple in relation to potassium doses.

high concentrations of N produce higher but lower quality infructescences.

The adequate amount of N and K increases the weight, the size of the infructescences and the thickness of the peel. However, the excess of N in pineapple can reduce the ascorbic acid content, the consistency and the acidity of the infructescences, besides increasing the translucency of the pulp (Malezieux & Bartholomew, 2003). In this sense, for Guarçoni & Ventura (2011) the market requirement will define the amount of nitrogen to be applied.

According to Kant et al. (2011), when nitrogen is available in the soil, there is an inorganic N uptake, synthesis, and storage of amino acids used in the synthesis of proteins and enzymes involved in biochemical pathways. This process governs the growth and development of the plant and, when nitrogen assimilation and remobilization are critical, compromise the supply of amino acids to the reproductive organs, resulting in lower growth.

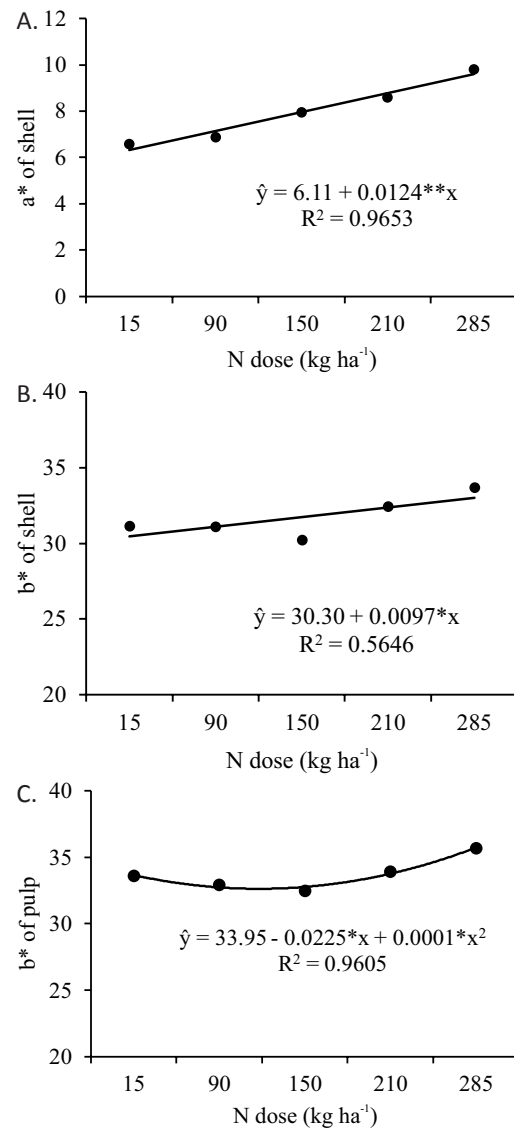
Figure 5 shows the values of the indices a^* and b^* as a function of nitrogen fertilization. These indices indicate the level of maturation of the infructescences; when the values are low it means that the color of the bark of the infructescence is green and when the indexes increase, it shows the change in the pigmentation of the bark due to the degradation of chlorophyll and synthesis of carotenoids (Berilli et al., 2014).

In the a^* and b^* index for the coloring of the bark, there was a linear increase with the elevation of the nitrogen doses, characterizing greater pigmentation of the bark, with increments of 34.65% and 7.92%, respectively (Figure 5A and B). For the b^* index of the pulp color, there was an adjustment of the quadratic regression, showing a decrease in the color of the pulp up to the dose of 112.50 kg ha⁻¹ of N which showed less coloration, presenting a b^* index of 32.68 (Figure 5C).

The color of the bark is related to maturation, climatic conditions during the growing season and fertilization. Very N masks maturation, as there is no color breakage, and very K promotes the greening of the bark, but not in the pulp. The results show that the increasing doses of N favored the gradual increase of the a^* and b^* indexes of the bark, due to the degradation of the chlorophyll. Therefore, the nitrogen levels applied were not excessive, since the infructescences did not have the coloration of the masked bark.

At the time of harvest, the infructescence presented more than 70% of the fruit completely yellow. Besides the bark, the pulp at the time of harvest was yellowish in color according to the culture standard. The pulp coloration is one of the determinants for export, since the foreign market prefers yellow flesh infructescences (Viana et al., 2013), indicating the potential that the 'Imperial' presents for export.

The soluble solids content of the infructescences was influenced by nitrogen and potassium fertilization. With the application of N, there was a quadratic response, with a minimum SS content in the infructescences estimated at 14.76%, with the application of 84.37 kg ha⁻¹ of N (Figure 6A). Regarding the potassium fertilization, there is an increasing



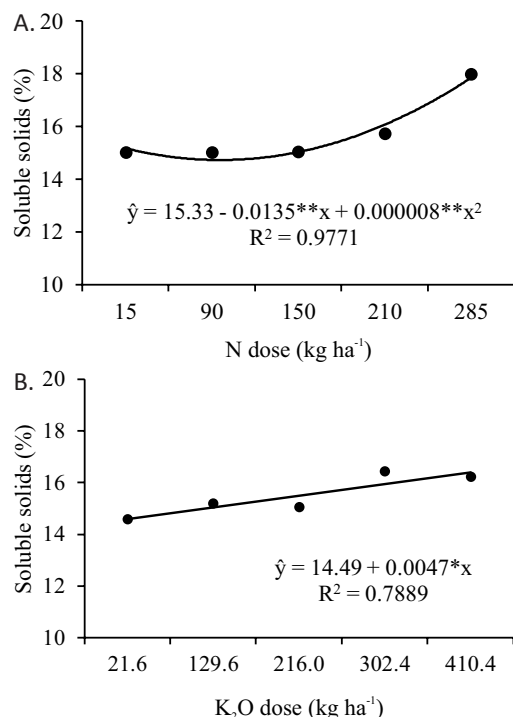
** and * Significant at 1% and 5% probability by the F test, respectively.

Figure 5. Indices a^* (A) and b^* (B) of the color of the shell and index b^* of the color of the pulp (C) of infructescence of 'Imperial' pineapple in relation to the doses of nitrogen.

linear effect of SS, presenting an increase of 11.14% with an elevation of K₂O doses (Figure 6B).

Soluble solids (SS) indicate the number of solids, mainly sugars dissolved in the juice or fruit pulp. In the pineapple, the minimum SS content for marketing of infructescences for the whole national territory corresponds to 12% (MAPA, 2002). In this study, the doses of N and K₂O promoted infructescences with levels higher than the minimum required, being a positive attribute both for in rural infructescence consumption and for the juice industry.

Studies have shown that high N applications affect the quality aspects of pineapple. Omotoso & Akinrinde (2013) reported a decrease in soluble solids content and titratable acidity of 'Smooth Cayenne' with the application of high doses of N and related to the dilution of the cell content caused by the increase in infructescence mass. Oliveira et al. (2015) reported the application of 550 kg ha⁻¹ of N titratable acidity



** and * Significant at 1% and 5% probability by the F test, respectively.

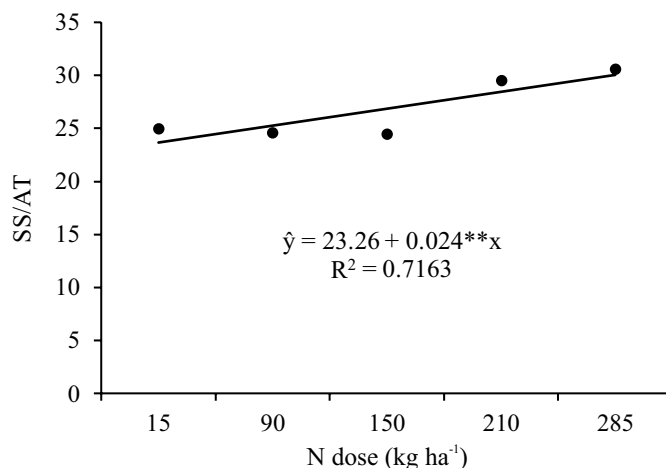
Figure 6. Soluble solids in infructescences of 'Imperial' pineapple in relation to nitrogen (A) and potassium (B).

reduction and soluble solids in cv. Imperial. However, a dose of 600 kg ha⁻¹ of K₂O promoted better results in the solids, with 19.4%. The behavior of reduction of solids with an increase of N doses was observed in this study, until the dose of 84.37 kg ha⁻¹ of N, probably because of concentrations below that required by cv. Imperial. However, the elevation behavior of this characteristic with the elevation of K₂O doses was similar.

The potassium doses provided in cv. Vitória increased in titratable acidity (0.38%) and soluble solids (17.62%) linearly. However, the application of N had opposite effect (Caetano et al., 2013). The activity of citratesintase and aconitase promotes changes in the acidity of the pineapple. There is a direct relationship between the titratable acidity and the changes in the amount of potassium, possibly to balance the vacuolar load (Saradhulhat & Paull, 2007).

The relationship between SS/AT was influenced by increasing doses of N, registering increases of 21.53% with the highest dose of N (Figure 7).

The SS/AT relationship is related to palatability, important for the acceptance of the infructescence by the consumer. Abílio et al. (2009) evaluating the chemical parameters of the cultivars Pérola and Smooth Cayenne, traditionally planted in the State of Paraíba, Emepa-01, Imperial, and MD-2, verified that the pulp of cv. Imperial had the SS/AT ratio values of 42.56, much higher than those found in other cultivars. Oliveira et al. (2015) evaluating doses of N and K₂O in cv. Imperial, found a higher value of 57.7 of this relation in the dose of 550 kg ha⁻¹ of N. This result was higher than this study, although the values reached are within the marketing standard of the infructescences.



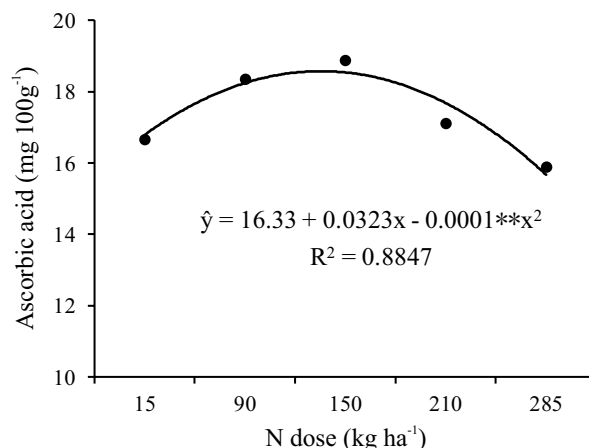
** Significant at 1% probability by F test.

Figure 7. The soluble solid ratio of titratable acidity in infructescences of 'Imperial' pineapple in relation to nitrogen doses.

Nitrogen fertilization may have an indirect impact on the acidity of the infructescence, since the increase of the vegetative growth can cause shading, consequently decrease the temperature and reduce the transpiration, or it can divert the assimilates to the vegetative growth in detriment to the development of the infructescence (Etienne et al., 2013).

The ascorbic acid content in the infructescences was influenced by nitrogen fertilization. The maximum dose of N was estimated at 161.50 kg ha⁻¹, for the ascorbic acid maximum, which was 18.94 mg 100 g⁻¹ (Figure 8).

The ascorbic acid content is used as the quality index of pineapple and its content varies according to the growing conditions as demonstrated in the present study. Lee & Kader (2000) also verified the influence of N on ascorbic acid levels. The greater light intensity during the growing season of pineapple provides a higher content of ascorbic acid, high concentrations of nitrogen fertilizers can decrease the ascorbic acid content because it increases the growth of the plants. Therefore, it can reduce the light intensity and accumulation of ascorbic acid in shaded parts. However, at



** Significant at 1% probability by F test.

Figure 8. Ascorbic acid in infructescence of 'Imperial' pineapple in relation to the nitrogen doses.

low concentrations of N, accumulation of AA occurs due to the lower biosynthesis of proteins, and photoassimilates are directed towards the synthesis of compounds of secondary metabolism (Seung & Kader, 2000; Marschner, 2012).

In the 'Smooth Cayenne' pineapple, the ascorbic acid content was reduced in plants with N and K deficiency (Martins et al., 2009), while Dantas et al. (2015) reported that nitrogen fertilization above 10 g plant⁻¹ urea and 152 g plant⁻¹ chicken manure, reduced the antioxidant activity of cv. Vitória, probably by the diminution of bioactive compounds like flavonoids and ascorbic acid.

The results demonstrate that cv. Imperial can be an alternative cultivation, promoting the diversification of cultivars, because the resistance to the main disease of the pineapple, that is the Fusariose, can reduce its production costs. As verified in the present study, this cultivar presents quality characteristics attractive to the consumer, able to contribute to the generation of income and in the improvement of the quality of life of the familiar producers.

Conclusions

Elevation of K₂O to 410.4 kg ha⁻¹ yielded increased crown infructescence mass, length and diameter of the infructescence, and soluble solids content.

The infructescence from plants that received nitrogen doses of 285 kg ha⁻¹ presented higher pulp yield, bark color index and SS/AT ratio.

The doses of 285 kg ha⁻¹ of N and 410.4 kg ha⁻¹ of K₂O promoted improvements in the physical-chemical characteristics of the infructescences of 'Imperial' pineapple.

Acknowledgment

To the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for granting the research grant to the first author.

To Mr. Genilson Cabral da Silva, for the assignment of the test area and for all the support in its development.

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