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Soils and plant nutrition

Potassium fertilization in pineapple fruit quality

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Abstract - Potassium is a mineral nutrient that affects the growth and quality of pineapple fruits. This study aimed to evaluate the quality of 'Vitória' pineapple fruits submitted to application of potassium doses. The experiment was carried out from May 2017 to November 2018, in the municipality of São Francisco do Itabapoana (RJ), Brazil. The design was randomized blocks, with four replicates. Treatments were five K_2O doses: 0; 6; 12; 18 and 24 g plant^{-1}, applied as KCl, split into two applications after flower induction. Fruit and crown fresh masses, fruit and crown diameters, fruit and crown lengths, titratable acidity, soluble solids, vitamin C, juice pH and soluble solids/titratable acidity ratio were evaluated. Potassium fertilization promoted greater fruit length, diameter and mass. Titratable acidity, soluble solids and vitamin C values increased linearly as a function of potassium doses. Potassium fertilization improves the quality of 'Vitória' pineapple fruits under field conditions.

Index terms: *Ananas comosus* (L) Merr., pineapple, mineral nutrition, potassium, cultivar Vitória.

Adubação potássica na qualidade de frutos de abacaxizeiro

Resumo - O potássio é um nutriente que afeta o crescimento e a qualidade dos frutos do abacaxizeiro. O estudo objetivou avaliar a qualidade de frutos em abacaxizeiro 'Vitória' submetido a aplicação de doses de potássio. O experimento foi realizado de maio de 2017 a novembro de 2018, em São Francisco do Itabapoana (RJ), Brasil. O delineamento foi em blocos ao acaso, com quatro repetições. Os tratamentos foram cinco doses de K_2O: 0; 6; 12; 18 e 24 g planta^{-1}, aplicadas na forma de KCl, parceladas em duas aplicações, após a indução floral. As massas frescas do fruto e da coroa, diâmetros do fruto e do cilindro central, comprimentos do fruto e da coroa, acidez titulável, sólidos solúveis, vitamina C, pH do suco e relação sólidos solúveis/acidez titulável foram avaliadas. A adubação potássica promoveu maiores comprimento, diâmetro e massa de fruto. Os valores de acidez titulável, sólidos solúveis e vitamina C aumentaram linearmente em função das doses de potássio. A adubação potássica promove a melhoria da qualidade dos frutos de abacaxizeiro 'Vitória' em condições de campo.

Termos para indexação: *Ananas comosus* (L) Merr., abacaxi, nutrição mineral, potássio, cultivar Vitória.

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Introduction

Brazil is the third world's largest pineapple producer (FAO, 2019). Despite the importance of balanced fertilization for this crop, there is little information about the effects of potassium fertilization doses on yield and quality of 'Vitória' pineapple fruits, which is a recent pineapple cultivar resistant to fusariosis (VENTURA et al., 2009).

The use of fertilizers in pineapple cultivation occurs because soils in tropical regions may have low levels of available potassium (K) and, therefore, it is necessary to complement this nutrient with fertilizers to provide sustainable yields due to the high demand for this nutrient. K is an essential nutrient and also the most abundant cation in plants, but K is not a constituent of any organic molecule or plant structure. K is involved in several biochemical and physiological processes vital for seed germination and emergence, stomatal regulation, phloem transport, cation-anion balance, protein synthesis, photosynthesis, energy transfer, osmoregulation, nutrient balance, growth, yield and resistance to plant stress (CAKMAK, 2005; MARSCHNER, 2012). K is also responsible for the performance of several enzymatic functions, because enzymes require K as a cofactor for activation, and stands out as a cation with the greatest influence on the quality attributes that determine the successful marketing of several fruits (LESTER et al., 2010; WANG et al. 2013).

Among the factors that affect plant production, adequate mineral nutrition with K was directly associated with increased yield, with increases in titratable acidity and soluble solids as a function of increased potassium fertilization. In addition, K can influence other characteristics such as juice yield, pH, pulp color, internal browning, vitamin C, fruit diameter and skin firmness; improvement in fruit color and increase in shelf life (SOARES et al., 2005; RAMOS et al., 2010; CAETANO et al., 2013; RIOS et al., 2018; CUNHA et al., 2019).

Considering the importance of mineral nutrition for the quality of pineapple fruits and the existing gap regarding the nutritional demands of new fusariosis-resistant cultivars, especially under field conditions, further studies are needed for a better understanding of the relationship between mineral nutrition and fruit quality. The aim of this study was to evaluate the quality of 'Vitória' pineapple fruits submitted to application of K doses.

Material and methods

The experiment was carried out in the rural area of the municipality of São Francisco de Itabapoana (RJ), on a private property (21°28'S and 41°7'W, 4 m above sea level). The soil is classified as Alic Yellow Argisol, with sandy texture and gently undulating relief. A composite soil sample was collected in the 0-20 cm layer, prepared and analyzed. The soil had the following characteristics: pH of 4.2 in water; P (Mehlich-1 Extractor) 9 mg dm^{-3}; K 62.4 mg dm^{-3}; Na 0.06 cmol dm^{-3}; $H^+ + Al^+$ 3.56 cmol dm^{-3}; Al^{+3} 0.63 cmol dm^{-3}; Ca^{2+} 0.18 cmol dm^{-3}; Mg^{+2} 0.06 cmol dm^{-3}; SB 0.46 cmol dm^{-3}; CEC 4.02 cmol dm^{-3}; V 11%; m 58% and organic matter 7.07 g dm^{-3}. Acidity correction was performed with the application of 1.95 t ha^{-1} of dolomitic lime on the surface 60 days before planting to raise pH to 5.8. Temperature and rainfall data were collected by the meteorological station of the National Institute of Meteorology (INMET) and compiled in the experimental period (Figure 1).

'Vitória' pineapple seedlings used in planting had approximately 35 cm in length and 215 g of fresh mass, provided by Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural of Espírito Santo (Incaper), in partnership with a producer in the southern region of the state of Espírito Santo.

The design used was randomized blocks, with four replicates and five K_2O doses (0, 6, 12, 18 and 24 g $plant^{-1}$); the potassium source used was potassium chloride (KCl); application was scattered, split twice, after flower induction. The experimental plot consisted of six simple rows. Each row consisted of eight plants spaced 0.3 m between plants and 0.9 m between rows. In total, the plot consisted of 48 plants, with 24 useful plants, of which five fruits were evaluated.

The nitrogen source (N) used was urea, the nitrogen fertilizer was applied in three equal applications, two applications were carried out before flower induction and the last application was carried out after flowering, totaling 20 g of N (740 kg ha^{-1} of urea). Phosphate fertilization was applied in the form of simple superphosphate, at dose of 15 g P_2O_5 (555 kg ha^{-1}). The application was carried out on the soil surface, at the time of planting (OLIVEIRA et al., 2009). Flower induction was performed 13 months (412 days) after planting, by applying 50 mL $plant^{-1}$ of the Ethrel® solution to the leaf rosette.

Before flower induction, pineapple 'D' leaves were collected to evaluate macronutrient content, length, fresh and dry mass. To determine the mineral nutrient content, leaves were cleaned and dried in a forced air circulation oven at 65°C. After drying, leaves were ground in a Willey type micromill, sieved at 20 mesh and homogenized. Whole leaves were used to quantify nutritional contents (SIEBENEICHLER et al., 2002).

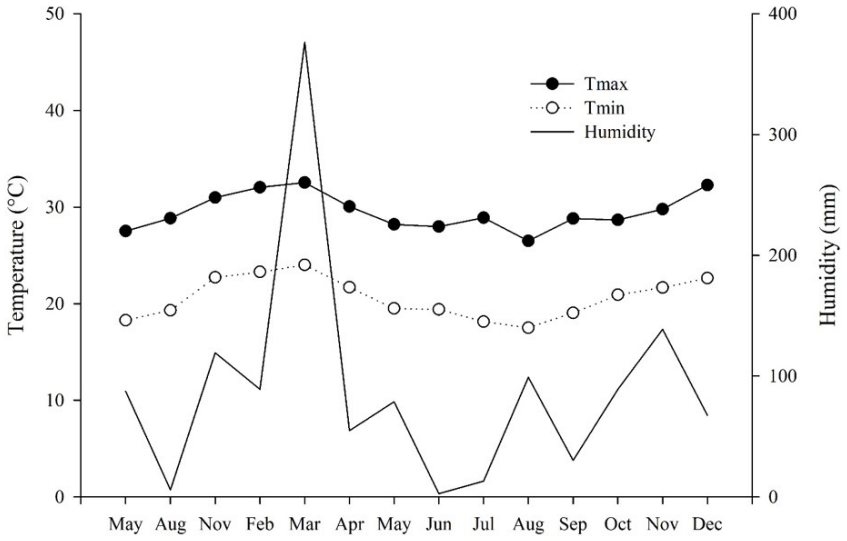

Figure 1. Average of daily temperature (°C) and rainfall values (mm) from May 2017 to December 2018. Campos dos Goytacazes, 2021. Source: INMET/ http://www.inmet.gov.br/

For the determination of N contents, samples were submitted to sulfuric digestion, in which nitrogen was determined by the method of Nessler (Jackson, 1965). The leaf phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) contents were analyzed using ICP-OES, after digestion with HNO_3 and H_2O_2 (PETERS, 2005). ICP conditions evaluated were: plasma gas 8.0 L min^{-1}, auxiliary gas 0.70 L min^{-1} and transport gas 0.55 L min^{-1} quantified in plasma (ICPE-9000) of Shimadzu® brand.

Fruits were harvested seventeen months after planting, in November 2018, when they reached stage five of maturation (OGAWA et al., 2017). Soon after harvesting, data on whole fruit mass, uncrowned fruit mass, crown mass, fruit length, crown length and fruit and central cylinder diameters were obtained. To obtain mass data, digital scale was used. For length data, measuring tape was used and for diameter data, digital caliper was used.

Juice was extracted from the fruit pulp without adding water in a "mixer" type mini-processor. In the juice, the following variables were determined: titratable acidity through titration with 0.1 N sodium hydroxide, expressed as % citric acid (g 100 mL^{-1} of juice); soluble solids (ºBrix), determined by digital refractometer, SS/TA ratio; juice pH, determined with digital pH meter; vitamin C, determined by titrating juice with 2,6-dichlorophenolindophenol and sodium salt solution, and expressed in mg of ascorbic acid 100 mL^{-1} of juice (AOAC, 2016).

Data were submitted to analysis of variance, and then regression analysis at 5% probability was applied.

Results and discussion

'D' leaves at the time of flower induction had 52.6 cm in length, 21.1 g of fresh mass and 3.4 g of dry mass. The nutritional contents found were 16.3 g kg^{-1} for N, 2.79 g kg^{-1} for P, 25.8 g kg^{-1} for K, 4.15 g kg^{-1} for Ca, 4.02 g kg^{-1} for Mg and 1.22 g kg^{-1} for S.

K fertilization linearly increased the whole fruit mass, uncrowned fruit mass, fruit diameter, central cylinder diameter, soluble solids (SS), vitamin C and titratable acidity (TA) and linearly reduced the SS/TA ratio of juice from 'Vitoria' pineapple fruits (Figures 2 and 3). Statistical analysis showed no significant effect for characteristics crown length and mass and juice pH.

At the time of potassium fertilization, the soil nutrient content was 33 mg dm^{-3} of K, considered low (FREIRE, 2013) for 'Pérola', 'Jupi' and 'Smooth Cayenne' cultivars. For these cultivars, with this K soil content, it is recommended to apply 12 g $plant^{-1}$ of K_2O. However, for 'Vitória' cultivar, there is no K recommendation at the moment.

The increase in K_2O fertilization provided an increase of 91.5% in whole fruit mass (Figure 2), when compared to fruits grown without potassium fertilization. This is due to the vital role of K in enzymatic activities for energy utilization and carbohydrate translocation, providing mass gain in pineapple fruits (WANG et al., 2018).

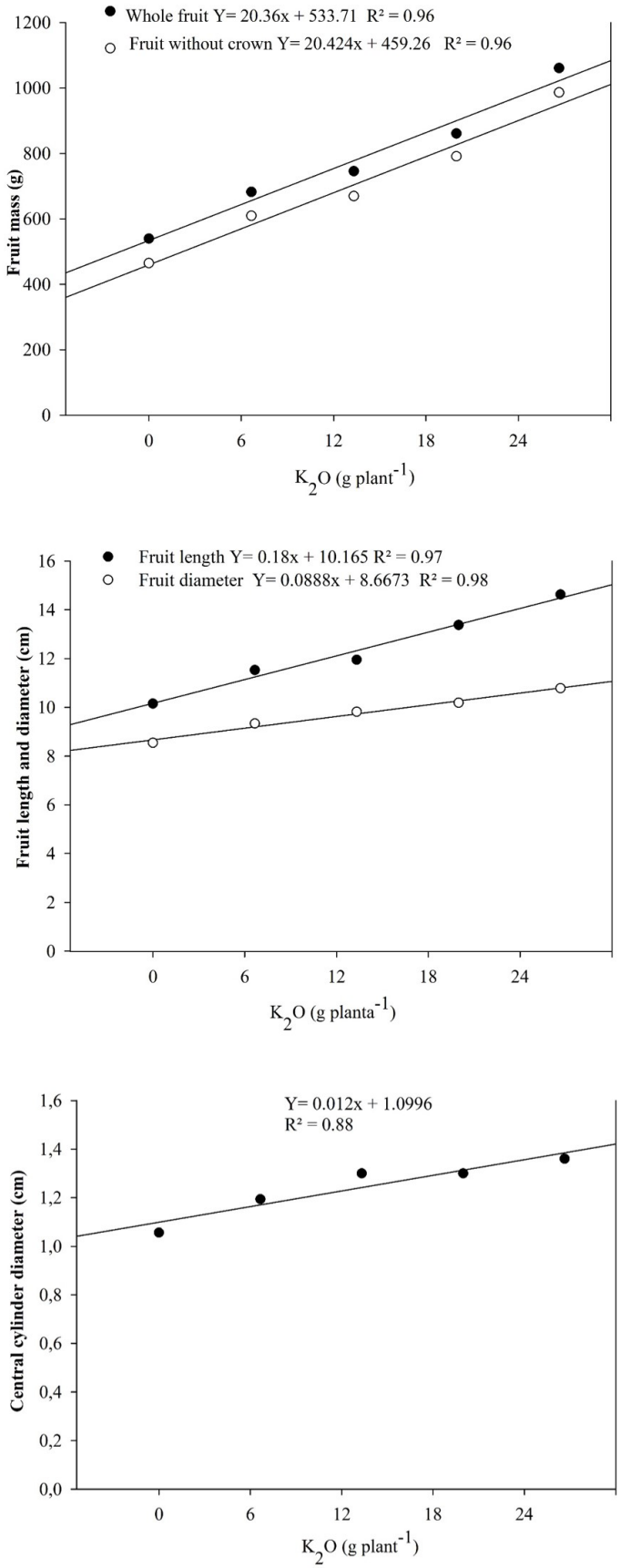

Figure 2. Whole fruit and uncrowned fruit masses, fruit length and diameter and central cylinder diameter of 'Vitória' pineapple fruits as a function of applied K_2O doses.

Fusariosis-resistant cultivars, when cultivated in the field, as 'Vitória' pineapple, tend to have lower whole fruit mass values than those traditionally cultivated. Considering the reference standard of traditional cultivars, the minimum mass for pineapple marketing should be 900-1200 g fruit^{-1}. All the fruits harvested of the present study were classified in this category (BRASIL, 2002). Similar results were obtained by Caetano et al. (2013); Cardoso et al. (2013) and Silva et al. (2012), who found whole fruit masses of 1.247, 1.057 and 911.1 g, respectively, for the same cultivar, but in different conditions.

Variables fruit length and diameter grew linearly as a function of K_2O doses, with maximum of 14.5 cm for fruit length and 10.7 cm for fruit diameter at K_2O dose of 24 g plant^{-1} (Figure 2). The increase in these variables is due to a positive response of plants to increased potassium levels in the soil, resulting in larger fruits, as K plays an important role in the metabolic reactions of various physiological processes (WANG et al., 2018). Spironello et al. (2004) and Ramos et al. (2009), studied 'Smooth Cayenne' and 'Imperial' pineapple cultivars and observed the effect of K application on the increase in fruit length and diameter.

The central cylinder diameter was adjusted to the increasing linear regression model, reaching maximum value of 1.39 cm at K_2O dose of 24 g plant^{-1} (Figure 2). Ventura et al. (2009) compared the central cylinder diameter of 'Vitória', 'Pérola' and 'Smooth Cayenne' cultivars and observed values of 1.2, 2.3 and 2.7 cm, respectively, verifying that fruits with smaller central cylinder diameter values tend to have greater pulp gains, which allows for better use of the fruit pulp. According to Berilli et al. (2014), fruits with smaller central cylinder diameter are preferred by consumers, thus characterizing the 'Vitória' cultivar as superior compared to the others in this variable.

The increase in potassium fertilization did not affect the pH of fruits, maintaining values of 3.41 in all evaluated fruits. Cunha et al. (2019) observed pH values of 3.6 and 3.8 for the same cultivar, without and with potassium fertilization, demonstrating that potassium fertilization has little influence on this parameter. Other authors obtained values close to those of the present study (Silva et al., 2012; Berilli et al., 2014; Silva et al., 2015; Barker et al., 2018).

K is the main nutrient that influences the quality attributes of pineapple fruits. It was observed that SS and TA increased linearly with the increase in potassium doses applied to the soil (Figure 3). The SS value obtained at K_2O dose of 24 g plant^{-1} was 14.7 °Brix, a result close to value found by Ventura et al. (2009), which was 15.8 ºBrix for this cultivar and above minimum requirement for the marketing of pineapple fruits in Brazil, which is 12 °Brix (BRASIL, 2002).

TA showed increasing linear response to all K doses (6,12,18 and 24 g of K_2O plant^{-1}). The maximum TA value observed was 1.26%. Values above 1% were observed by Barker et al. (2018) and Cunha et al. (2019). Ventura et al. (2009) observed TA values of 0.69 and 0.8%, respectively, for the same cultivar. The TA and sweetness (SS) are two of the main factors that determine the quality of pineapple fruits for consumption (SARADHULDHAT and PAULL, 2007).

TA formation involves the synthesis of organic acids, which can be stored in the vacuole in large amounts, increasing fruit acidity in response to the supply of potassium fertilization (BOTREL et al., 2004; SPIRONELLO et al., 2004; ETIENNE et al., 2004; ETIENNE et al., 2004; al., 2013). The response to K_2O fertilization in the increase of SS and TA of 'Vitória' fruits shows the important role that the nutrient plays on the quality characteristics of pineapple fruits. The TA content in the pineapple pulp is essential for the good acceptance in the consumer market, as low pulp acidity results in tasteless fruits with reduced aroma (GUARÇONI and VENTURA, 2011; CAETANO et al., 2013).

The SS/TA ratio provides flavor to the fruit, and in this study, reduction was observed with increasing K_2O doses used, and the decrease can be attributed to the increase in TA (Figure 3). The SS/TA ratio reduced 35% in treatment with K_2O dose of 24 g plant^{-1}, compared to treatment without potassium fertilization, showing SS/TA ratio values acceptable to the fresh fruit consumer market

Vitamin C contents increased linearly with the increase in potassium fertilization (Figure 3). When the highest K dose was applied, the vitamin C level (11.45 mg) was 210% higher than value observed for fruits of plants not fertilized with K (3.69 mg). The results obtained at the highest K dose provided vitamin C contents 62.9% higher than values verified by Berilli et al. (2014), for the same cultivar. Spironello et al. (2004) studied the effects of NPK fertilization on the production and quality of pineapple fruits and verified that the increment of K doses increased the vitamin C levels in the pineapple juice. Vitamin C is present in several fruits and vegetables, and its presence is best known in citrus fruits, bringing benefits to human health, such as antioxidant capacity and reduction of free radicals (VILLAGRÁN et al., 2019).

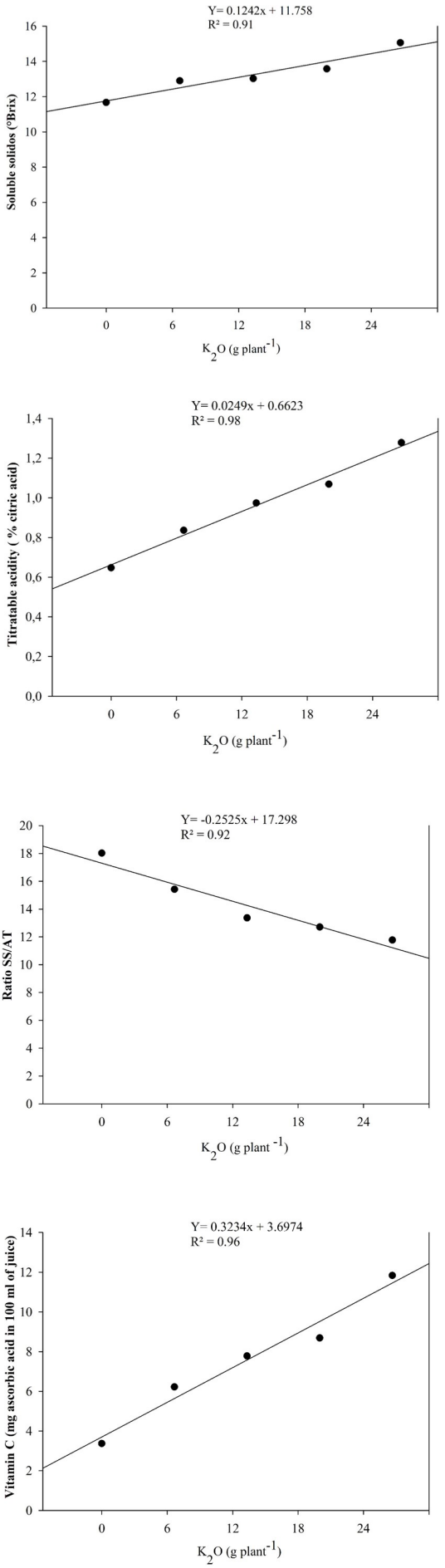

Figure 3. Soluble solids, titratable acidity, SS/TA ratio and Vitamin C content of 'Vitória' pineapple fruits as a function of applied K_2O doses.

Conclusions

The potassium fertilization resulted in the production of heavier fruits, with greater whole fruit mass, increased soluble solids content, titratable acidity and vitamin C compared to fruits with no potassium fertilization. Vitória cultivar responded positively to potassium fertilization at the maximum K_2O dose of 24 g plant^{-1} and density of 37000 plants ha^{-1}.

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