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Fertilization with nitrogen and potassium in banana cultivars 'Grand Naine', 'FHIA 17' and 'Nanicão IAC 2001' cultivated in Ribeira Valley, São Paulo State, Brazil

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ABSTRACT. The 'Grand Naine' banana cultivar is grown around the world, but it is susceptible to black Sigatoka fungus. The 'FHIA 17' and 'Nanicão IAC 2001' cultivars have the potential to replace susceptible cultivars, but there is little information about their nitrogen and potassium nutritional requirements. This study aimed to identify the best fertilizer recommendation with N and K for banana cultivars 'FHIA 17', 'Nanicão IAC 2001', and 'Grand Naine'. The applied fertilizer levels with N and K_2O in two production cycles were as follows: NK0, without fertilization; NK1, 175 N and 285 kg K_2O ha^{-1} year^{-1}; NK2, 350 N and 570 kg K_2O ha^{-1} year^{-1}; and NK 3, 525 N and 855 kg K_2O ha^{-1} year^{-1}. It was concluded that the N and K fertilization levels influenced most of the phenological and production parameters of 'Grand Naine' and 'Nanicão IAC 2001'. 'Nanicão IAC 2001' and 'Grand Naine' achieved maximum yield with an application of 525 kg N ha^{-1} year^{-1} and 855 kg K_2O ha^{-1} year^{-1}. The 'FHIA 17' cultivar showed a low response to nitrogen and potassium fertilization. Regardless of cultivars, to achieve maximum productivity (44.2 and 43.3 ton ha^{-1} year^{-1}), an application at 150% and 124% of the fertilizer recommendation is required in the 1st and 2nd production cycles, respectively.

Keywords: nutrition, genetic improvement, *Musa* spp.

Adubação nitrogenada e potássica nas bananeiras 'Grande Naine', 'FHIA 17' e 'Nanicão IAC 2001' cultivadas no Vale do Ribeira, Estado de São Paulo, Brasil

RESUMO. A cultivar Grande Naine é largamente cultivada no mundo, porém é suscetível à Sigatoka-negra. As cultivares FHIA 17 e Nanicão IAC 2001 possuem potencial para substituí-la, porém, pouco se conhece sobre suas necessidades nutricionais de nitrogênio e potássio. Objetivou-se identificar os melhores níveis de recomendação de adubação contendo N e K para as bananeiras FHIA 17, Nanicão IAC 2001 e Grande Naine. Os níveis de adubação com N e K_2O aplicados em dois ciclos de produção foram: NK0: sem adubação; NK1: 175 e 285 kg ha^{-1} ano^{-1}; NK2: 350 e 570 kg ha^{-1} ano^{-1}; NK3: 525 e 855 kg Tha^{-1} ano^{-1}, respectivamente. Conclui-se que os níveis de adubação de N e K influenciam a maioria das características fenológicas e produtivas das cvs. Grande Naine e Nanicão IAC 2001. As cultivares Nanicão IAC 2001 e Grande Naine necessitam para atingir a máxima produtividade a aplicação de 150% da recomendação de adubação (525 kg de N e 855 kg de K_2O ha^{-1} ano^{-1}). A cultivar FHIA 17 apresenta baixa resposta à adubação nitrogenada e potássica. Independente das cultivares, o 1º e 2º ciclos de produção necessitam da aplicação de 150 e 124% da recomendação de adubação, respectivamente, para atingir a máxima produtividade (44,2 e 43,3 ton ha^{-1} ano^{-1}).

Palavras-chave: nutrição, melhoramento genético, *Musa* spp.

Introduction

The Ribeira Valley is the main banana-producing region of São Paulo State with an area of 34,500 hectares and production of approximately 952,700 tons (Nomura et al., 2013b). The region has favourable climatic conditions for banana growth during most of the year and is characterized by cultivation on small farms (10-20 ha) focusing on the production of banana type Nanica.

Banana type Nanica includes the Cavendish and Gros Michel subgroups and forms the basis of the domestic and world market (Soto-Ballestero, 2008). The commercially exploited cultivars in São Paulo are 'Grand Naine', 'Williams', and 'Nanicão', but all of them have at least one undesirable trait for commercial exploitation, such as plant height, productivity, tolerance to pests and diseases, or drought or cold resistance (Nomura, Damatto Jr., Fuzitani, Amorim, & Silva, 2013a).

The Honduran Agricultural Research Foundation (FHIA) breeding programme has developed several banana cultivars, such as 'FHIA 17' (AAAA), a hybrid of the Gros Michel cultivar that stands out among the banana type Nanica. Another cultivar that stands out among the banana type Nanica is the 'Nanicão IAC 2001' (AAA - Cavendish), which was selected by the Agronomic Institute (APTA/IAC). Both cultivars have a great potential for introduction into the Brazilian production system, especially in São Paulo, because they have fruit features similar to those of the 'Grand Naine' cultivar and because they are tolerant to black Sigatoka fungus (*Mycosphaerella fijiensis* Morelet) and Panamá disease (*Fusarium oxysporum* f. sp. *cubense*).

The final step of breeding is to evaluate plants in different regions to determine its soil and climate adaptability, as well as its resistance to pests and diseases (Roque, Amorim, Ferreira, Ledo, & Amorim, 2014; Mendonça, Duarte, Costa, Matos, & Seleguini, 2013; Nomura et al., 2013a; 2013b; Oliveira, Lessa, Silva, & Oliveira, 2008). Fruit postharvest characteristics are also an important parameter for evaluating the final quality of produced fruits (Godoy et al., 2016; Reis, Viana, Jesus, Santos, & Oliveira, 2016; Castricini, Santos, Deliza, Coelho, & Rodrigues, 2015). Few studies have looked at new banana cultivars and their nutritional requirements in different soil and climatic conditions; this is necessary because the nutritional requirements of these materials are not always the same as traditionally cultivated bananas.

Banana plants require large amounts of nutrients to maintain high yields over time in commercial crops. These nutrients may be supplied by the soil (areas with natural high fertility) or by fertilization in amounts and proportions that are at least equivalent to the nutrients extracted by harvest (Soto-Ballestero, 2008). Most of the soils cultivated with banana in the Ribeira Valley region have low fertility, and the lack of fertilizer during the plant production cycle is one factor responsible for low banana yield (Moreira, 1999). Local banana fertilizer recommendations do not specify the cultivar, so there is no recommendation for the different types or banana subgroups. According Teixeira, Nomura, Damatto Jr., and Fuzitani (2014), nitrogen fertilization recommendations range from 120 to 500 kg ha^{-1} in accordance with expected productivity, and potassium varies from 90 to 730 kg ha^{-1} in accordance with the potassium content in the soil.

Potassium (K) and nitrogen (N) are the most extracted macronutrients by banana plants, as they are directly related to plant growth, yield and banana fruit quality (Moreira, 1999). Potassium is the macronutrient extracted in greater amounts by banana plants (62% of the total macronutrient and 41% of the plant nutrients), which directly affects photosynthesis, the translocation of photosynthates, and the water balance in plants and fruits (Kumar & Kumar, 2008; Moreira, 1999). Nitrogen acts directly on vegetative growth, emissions and the development of shoot plants and increases the amount of dry matter in plants (Moreira, 1999).

This research aimed to identify the best fertilizer recommendation levels containing N and K and their effects on the phenological and productive characteristics of banana cultivars 'FHIA 17', 'Nanicão IAC 2001', and 'Grand Naine' grown in the soil and climatic conditions of the Ribeira Valley region, São Paulo State, Brazil.

Material and methods

This research was carried out at the experimental farm of Agência Paulista de Tecnologia dos Agronegócios (APTA) Regional Vale do Ribeira, in Pariquera-Açu County (Brazil), which has the following geographical coordinates: 24º36'31" South and 47º53'48" West, altitude of 25 m. The climate is tropical rainy with no dry season (Af), according to the Köppen classification. Data from a series of 10 years (2004-2014), recorded at APTA Regional Vale do Ribeira, shows that the average annual maximum and minimum temperatures were 26.8°C and 17.7°C, respectively, and that the average annual rainfall was 1,524.5 mm.

Soil samples were collected at the depth of 0-20 cm to determine the chemical properties of the samples and for lime and fertilizer recommendations for adequate banana production. The soil had the following characteristics: pH ($CaCl_2$) = 4.2; O.M. = 26.7 g dm^{-3}; P (resin) = 4.0 mg dm^{-3}; K = 0.6 mmol dm^{-3}; Ca = 12.7 mmol dm^{-3}; Mg = 4.7 mmol dm^{-3}; H + Al = 80.7 mmol dm^{-3}; SB = 18.0 mmol dm^{-3}; CTC = 98.7 mmol dm^{-3}; V = 19%; B = 0.24 mg dm^{-3}; Cu = 0.1 mg dm^{-3}; Fe = 111.7 mg dm^{-3}; Mn = 1.8 mg dm^{-3}; and Zn = 0.2 mg dm^{-3}. Dolomitic limestone was applied over the total area with the aim of elevating base saturation to 60% and increasing the magnesium content above 9.0 mmol dm^{-3}, as recommended by Teixeira et al. (2014). The phosphorus requirement was met with an application of 600 kg ha^{-1} of simple superphosphate to the total area.

'FHIA 17', 'IAC Nanicão 2001', and 'Grand Naine' banana production was evaluated for two production cycles (2013-2014). The 'Grand Naine' cultivar is considered the standard cultivar because it is widely used in commercial plantations in Brazil.

The standard fertilization with N and K (100%) was calculated in accordance to the soil chemical analysis in order to reach an expected yield of 40 to 50 ton ha^{-1} (as recommended by Teixeira et al., 2014). Fertilizer doses with N and K were as follows: NK0 = no fertilizer was applied; NK1 = an application of 50% of the standard recommendation of N and K (175 kg ha^{-1} of N and 285 kg K_2O ha^{-1} $year^{-1}$); NK2 = an application of 100% of the standard recommendation of N and K (350 kg ha^{-1} of N and 570 kg K_2O ha^{-1} $year^{-1}$); and NK3 = an application of 150% of standard recommendation of N and K (525 kg N ha^{-1} and 855 kg K_2O ha^{-1} $year^{-1}$). The N sources were urea and ammonium sulphate with interspersed applications, and the K source was potassium chloride. Fertilization in the 1st and 2nd production cycles were divided into five applications at the following percentages: 10, 25, 30, 20, and 15% of the total dose at each level of fertilization. The first fertilization application was applied 45 days after planting (in the 1st cycle) and 60 days after the harvest of the 1st bunch (in the 2nd cycle). The other fertilizer applications were applied in intervals of 60 days after the first application, preferably in the most favourable months for the development of banana (from August to May of each year).

Seedlings were produced by micropropagation, acclimatized in the nursery, and planted in the field when they had 5 to 6 leaves and were approximately 30 cm tall. Plant field spacing was determined based on cultivar average high: 2.0 m *x* 3.0 m (1,667 plants per hectare) for 'FHIA 17' (AAAA - subgroup Gros Michel) and 2.0 m *x* 2.5 m (2,000 plants per hectare) for 'Grand Naine' and 'Nanicão IAC 2001' (AAA - Cavendish). Crop management was based on Moreira (1999) recommendations.

Preventive fungicide applications were applied to the 'Grand Naine' cultivar because it is susceptible to black Sigatoka fungus. Fungicide applications were applied at intervals determined by plant monitoring, such as recommended by Fouré and Ganry (2008) and modified by Moraes, Modenese-Gorla, Fukuda, and Silva (2011). For the 'FHIA 17' and 'Nanicão IAC 2001' cultivars, fungicide applications were not performed because of their tolerance to black Sigatoka.

The plant development parameters evaluated were as follows: height of the pseudostem (measured from the ground level to the insertion of the last leaf), pseudostem diameter (measured at 30 cm above ground level), the number of active leaves at blooming and harvest time (only leaves that had more than half green area were counted), total cycle, and the daughter-plant height (measured at the mother-plant harvest time).

Bunches were harvested when the fruits of the 2nd hand had diameters between 34-36 mm, and the following was evaluated: the fresh mass of marketable bunches (kg); yield (estimated from the fresh mass of marketable bunches, planting density and the total cycle (ton ha^{-1} $year^{-1}$)); the total number of fruits in a bunch; 2nd hand fruit fresh mass (g); and 2nd hand fruit length (measured on the convex face of the fruit (cm)).

The experimental design was a randomized block design, and treatments were organized in a 3 x 4 factorial scheme (cultivars x fertilization doses) with culture cycle as sub plots (2 production cycles). Individual treatments were replicated three times and contained four plants. The data were submitted to variance and F-test analyses using the statistical programme SISVAR (Ferreira, 2011). When the results were significant for the quantitative variable (fertilization), regression equations were adjusted, and when the results were significant only for the qualitative variables (cultivars and cycle), the averages were compared using Tukey's test at a 5% probability.

Results and discussion

Plant development

The leaf number at blooming, daughter-plant height, and the diameter and height of the pseudostem were influenced by cultivar and fertilizer dose. A triple interaction was not observed among cultivar, cycle and fertilizer dose.

The number of active leaves at blooming is an important parameter for banana bunch development because it reflects the potential yield, as these leaves are directly related to the plant photosynthetic rate (Soto-Ballestero, 2008) and promote starch accumulation in fruits. For the leaf number at blooming, it can be observed in Figure 1A that only the 'Grand Naine' cultivar regression equation was adjusted. Plant had more leaves with the application of 123% of the fertilizer recommendation. However, this fertilization level did not provide the highest fresh mass of marketable bunches and yield (Figure 2C and D). These results could be explained by the greater loss of leaves due to black Sigatoka fungus on plants fertilized with the highest levels. According to Moreira (1999), banana plants with excess N can show a high incidence of black Sigatoka. Nevertheless, this reduction in the number of leaves did not compromise yield. The leaf number in the other two cultivars did not present changes in response to fertilizer levels, and all of them had a sufficient number of leaves to reach suitable fruit development. According to Soto-Ballestero (2008),

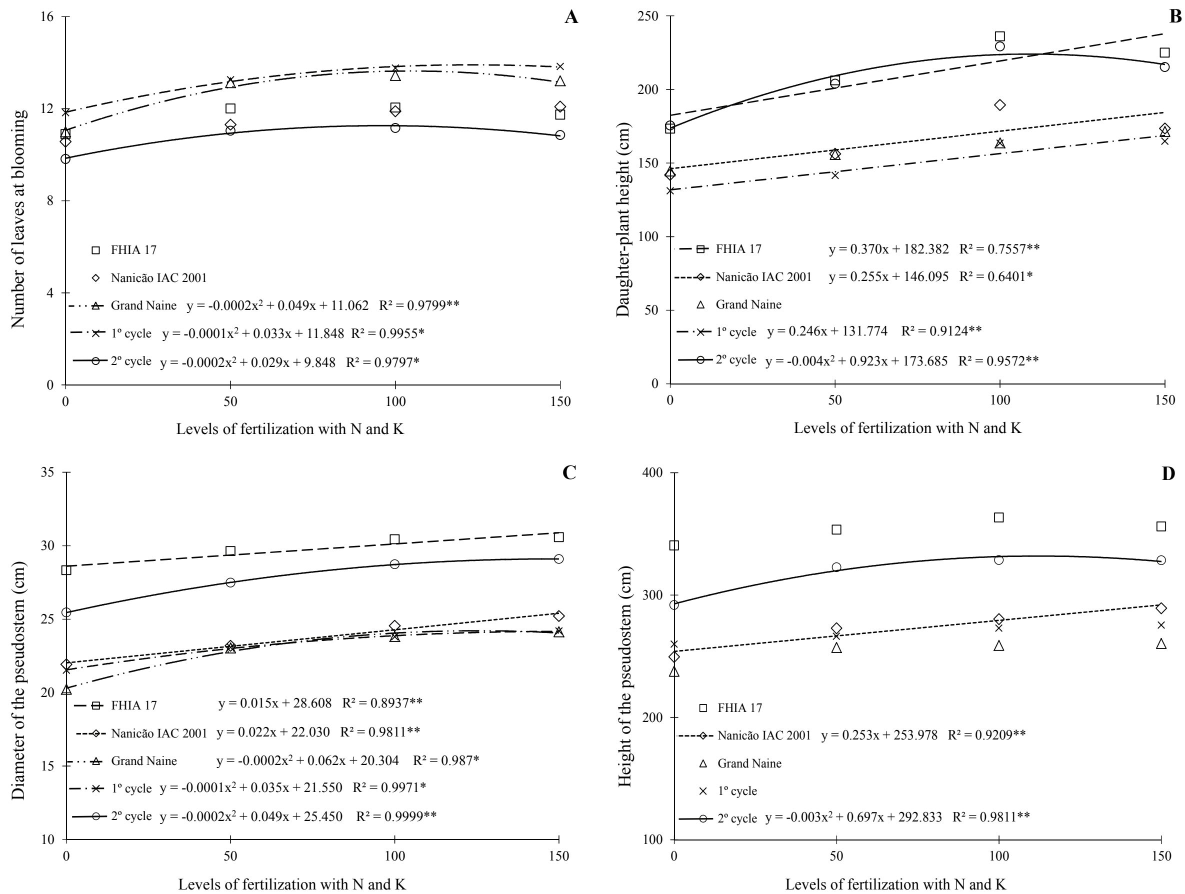

Figure 1. The development of banana cultivars 'Grand Naine', 'FHIA 17', and 'Nanicão IAC 2001' under different levels of fertilization with N and K (50%: 175 N + 285 K_2O; 100%: 350 N + 570 K_2O; and 150%: 525 N + 855 K_2O kg ha^{-1} $year^{-1}$) in two cycles. Pariquera-Açú, São Paulo State, Brazil, 2016. $^{**}p \leq 0.01$ and $^{*}p \leq 0.05$. R^2 = coefficient of determination.

banana plants of the Cavendish subgroup should have at least eight active leaves during bunch development. The maintenance of a larger number of leaves in the 'FHIA 17' and 'Nanicão IAC 2001' may be due to their resistance or tolerance to foliar diseases, especially black Sigatoka (Nomura et al., 2013b).

The active number of leaves at plant blooming presented an interaction between the production cycles and fertilizer levels in both production cycles, reaching a maximal response with the applications of 165% and 73% of the fertilizer recommendation in the 1st and 2nd cycles, respectively (Figure 1A).

The active leaf number at harvest time was different among cycles and among cultivars in the second cycle (Table 1). The cultivars maintained sufficient quantities of leaves in both cycles for suitable fruit. Teixeira, Ruggiero, and Natale (2001) recommended that the number of active leaves should be equal to the hands in the bunch. Rodrigues, Dias, and Pacheco (2009) recommended the maintenance of 10 to 12 leaves in the 'Prata-Anã' banana plant to achieve maximum yield and help maintain healthy banana plantations.

The 'Grand Naine' cultivar showed more leaves at harvest and were healthier due to the preventive applications of fungicides to control black Sigatoka. 'FHIA 17' and 'Nanicão IAC 2001', even with fewer leaves in the 2nd cycle (Table 1), had healthy and functional growth and yield without chemical disease control, proving their tolerance to black Sigatoka.

The fewer leaves at plant blooming until bunch harvest is mainly due to the translocation of assimilates to fruit filling, which becomes the preferred drain in the plant due to the natural senescence of leaves and because of the incidence *versus* tolerance to the black Sigatoka fungus (Silva, Pires, Pestana, Alves, & Silveira, 2006). Another factor that affects the durability of banana leaves after inflorescence emergence relates to the nutritional deficiency of N and K and is mainly due to the translocation of N and K from the older leaves to the fruits (Teixeira et al., 2001).

Table 1. The number of leaves at harvest, plant total cycle and fruit length of banana cultivars 'Grand Naine', 'FHIA 17' and 'Nanicão IAC 2001' under different levels of fertilization with N and K (50%: 175 N + 285 K_2O; 100%: 350 N + 570 K_2O; and 150%: 525 N + 855 K_2O kg ha^{-1} $year^{-1}$), Pariquera-Açú, São Paulo State, Brazil, 2016.

Number of leaves at harvest			
Cultivars	Cycles 1st	Cycles 2nd	Means
FHIA 17	8.2 A	4.9 b B	6.6 ab
Nanicão IAC 2001	7.9 A	3.7 c B	5.8 b
Grand Naine	8.0	7.1 a	7.6 a
Means	8.0 A	5.2 B	
V.C. 1 (%)	26.5		
V.C. 2 (%)	17.9		
Plant total cycle (days)			
Cultivars	Cycles 1st	Cycles 2nd	Means
FHIA 17	462.8 b	459.3 b	461.0 b
Nanicão IAC 2001	412.8 a B	359.2 a A	394.5 a
Grand Naine	406.7 a	382.3 a	386.0 a
Means	427.4 B	400.3 A	
V.C. 1 (%)	6.5		
V.C. 2 (%)	8.9		
Fruit length (cm)			
Cultivars	Cycles 1st	Cycles 2nd	Means
FHIA 17	18.7	23.4	21.0
Nanicão IAC 2001	23.3 A	18.7 B	21.0
Grand Naine	22.4	21.4	21.9
Means	23.0 A	19.6 B	
V.C. 1 (%)	13.6		
V.C. 2 (%)	13.0		

Means followed by different letters, lowercase among cultivars and uppercase between fertilization levels and production cycle, differ by Tukey's test ($p < 0.05$). V.C. = variation coefficient.

For the plant total cycle, a difference was observed between the qualitative variables (cultivars and cycles), as shown in Table 1. 'FHIA 17' had the longest total cycle among the evaluated cultivars, corroborating with Nomura et al. (2013a). The 'Grand Naine' and 'Nanicão IAC 2001' cultivars had shorter total cycles compared to 'FHIA 17'. In commercial banana production, reducing the period of fruit maintenance in the field is recommended to decrease pest and disease risk and to reduce pesticide use (Rodrigues, Souto, & Silva, 2006; Santos, Carneiro, Silveira Neto, Paniago Jr., & Peixoto, 2006).

The thinning of daughter-plants in banana production is aimed at continuing production over the years, and therefore, maintaining and developing daughter-plants in anticipation of the next production cycle ensures a rapid economic return on the invested capital. In evaluating daughter-plant height, it was observed that there was interaction between cultivars and fertilizer levels for this feature. 'FHIA 17' and 'Nanicão IAC 2001' reached maximum estimated values at the highest applied dose of N and K, regardless of the production cycle (Figure 1B). Despite that 'FHIA 17' displayed a larger daughter-plant at harvest, it did not promote the precocity in the 2nd cycle, which was possibly influenced by other factors such as genetics and climate.

There was interaction between cycles and fertilizer levels for banana daughter-plant height. In the 1st cycle, daughter-plants reached maximum height with the application of 150% of banana fertilizer recommendation, while in the 2nd cycle, daughter-plants reached the largest height with the application of 115% of the recommendation (Figure 1B). The low amount of fertilizers required in the 2nd cycle was because plants were well established in the field, the mother-plant translocated nutrients to the daughter-plant, and was due to the decomposition and nutrient release of the 1st cycle crop residues (Moreira & Fageria, 2009). Moreover, the successive applications of fertilizer increased soil K in the experimental field, as reported by Teixeira, Natale, Bettiol Neto, and Martins (2007), who found that successive applications of K in banana favoured the accumulation of this nutrient, most notably in the surface layer and in the areas closest to the plants.

The 'FHIA 17' and 'Nanicão IAC 2001' cultivars showed an increase in the pseudostem diameter due to the addition of N and K, obtaining the highest diameters with the application at the maximum dose (150%), whereas 'Grand Naine' reached an estimated maximum diameter by applying 155% of the recommendation (Figure 1C). The pseudostem is constituted by wrapped leaf sheaths, making it rigid, as the emergence of new leaves occurs (Soto-Ballestero, 2008). The proper nutrient supply furthers leaf development, and consequently, the pseudostem increases its height and diameter. Pseudostems stores large amounts of nutrients, especially N and K (67.9 and 233.1 kg ha^{-1}, respectively), which is used for fruit filling (Soto-Ballestero, 2008).

An interaction was observed between the production cycles and fertilizer levels for the pseudostem diameter. In the 1st cycle, the maximum value was estimated with an application of 175% of the fertilizer recommendation and in the 2nd cycle with the application of 123% of the recommendation (Figure 1C). The lower requirement of nutrients in the 2nd cycle is probably due to nutrient recycling from crop residue, especially that from the pseudostem, leaves and rhizomes of the banana plants. Hoffmann, Oliveira, Souza, Gheyi, and Souza Jr. (2010) found that the return of nutrients to the soil was between 497 to 305 kg ha^{-1} for K and 91 and 121 kg ha^{-1} for N for the 'Grand Naine' and 'Gros Michel' cultivars, respectively.

An interaction was found between cultivars and N and K fertilization levels in pseudostem height for 'Nanicão IAC 2001', reaching the minimum estimated height without fertilization (Figure 1D). For 'FHIA 17' and 'Grand Naine', plant height was similar among the N and K doses. This probably is due to previous nutrients stored in the soil, which was sufficient for proper plant development. There is also the possibility of nutrients being provided by crop residue mineralization, which mainly provides N and K.

Regardless of the cultivars, plant height in the 2nd cycle was simultaneously affected by fertilizer levels and by cycles. The highest pseudostem was obtained with the application of 116% of the fertilizer recommendation (Figure 1D). Farmers prefer shorter plants because there is no need to use anchors to support the plants and because it would be possible to increase planting density (Amorim, Santos-Serejo, Amorim, Ferreira, & Silva, 2013). According to the results obtained in this experiment, plants were smaller when they did not receive any fertilizer, but with this treatment, the production and yield were very low (Figure 2C and D). Despite the increase of pseudostem height by the fertilization levels, all cultivars were kept smaller than the band of 250 to 350 cm, which is preferable to the farmers (Santos et al., 2006). It was observed in the field that cv. 'FHIA 17' had a high number of fallen plants due to their susceptibility to banana weevil [*Cosmopolites sordidus* (Germ.)] and nematodes.

Banana plant height and pseudostem diameter are important parameters in crop management because they are related to plant vigour and they affect bunch harvesting and breaking/tipping adult plants, consequently causing fewer losses in yield (Farias, Donato, Pereira, & Silva, 2010). Generally, these overturned plants are caused by the direct action of strong winds and are related to large-sized plants with small pseudostem diameters (Teixeira et al., 2001). This is generally observed in cultivars of the Cavendish and Gros Michel subgroups (Moreira, 1999), which require anchors to support them to avoid yield and fruit quality loss.

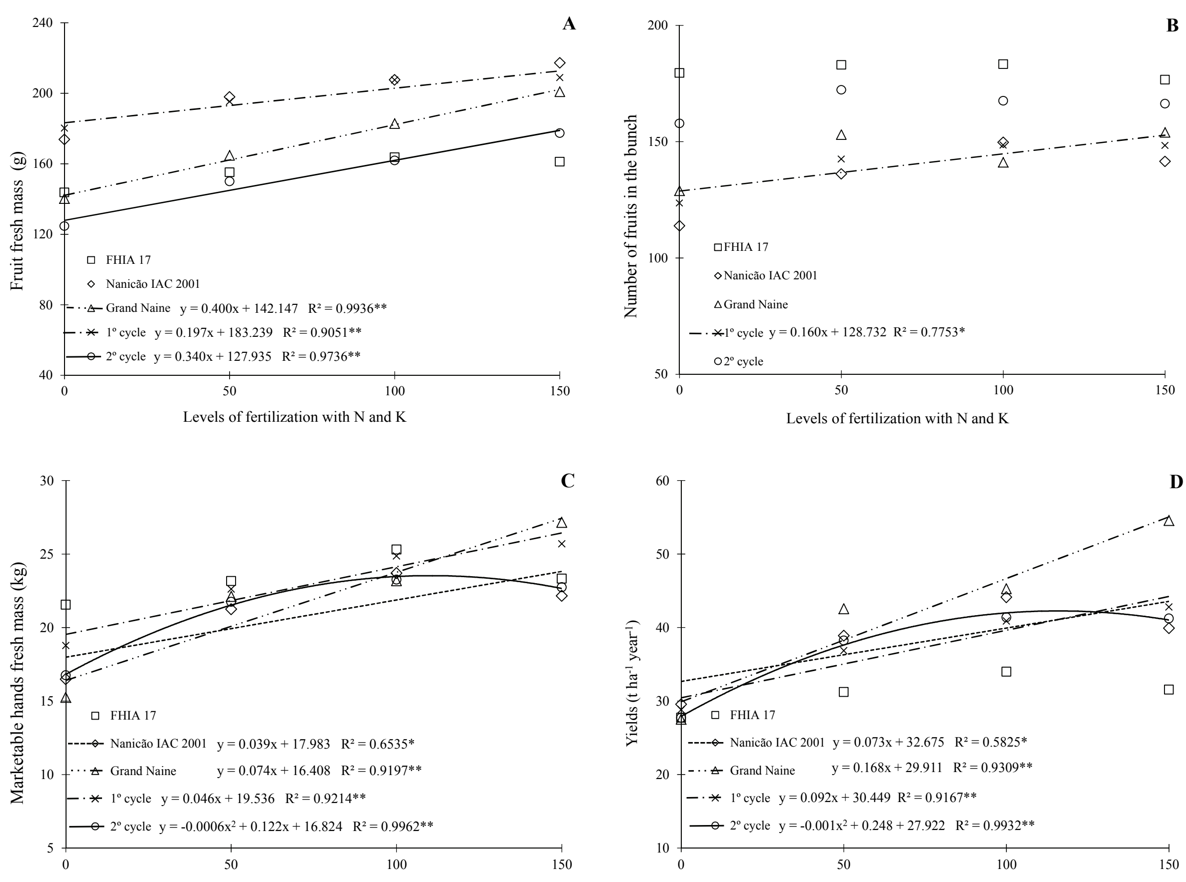

Figure 2. The production parameters means for banana cultivars 'Grand Naine', 'FHIA 17' and 'Nanicão IAC 2001' under different levels of fertilization with N and K (50%: 175 N + 285 K_2O; 100%: 350 N + 570 K_2O; and 150%: 525 N + 855 K_2O kg ha^{-1} year^{-1}) in two production cycles. Pariquera-Açú, São Paulo State, Brazil, 2016. **p ≤ 0.01 and *p ≤ 0.05. R^2 = determination coefficient.

Production

Fertilizer levels did not affect fruit length. Regardless of the production cycles, the ‘FHIA 17’, ‘Nanicão IAC 2001’ and ‘Grand Naine’ cultivars had fruit length averages, respectively, of 21.0 cm, 21.0 cm and 21.9 cm (Table 1). The fruit length of the Nanica type cultivars in this study were similar to the range (20.9 to 25.0 cm) found by Borges, Silva, Oliveira, and Roberto (2011), Donato et al. (2006), Mendonça et al. (2013), Njuguna et al. (2008), Nomura et al. (2013b), and Ramos, Leonel, Mischan, and Damatto Jr. (2009). The final size of banana fruit depends on several factors, such as temperature, the number of leaves and leaf area during bunch development, soil fertility, water availability, and maturity stage at harvest (Robinson & Gálan-Saúco, 2011). These authors found that banana shape and size are cultivar features, thus the reason why there was a low response to fertilization levels for this parameter in this study.

N and K levels increased fruit fresh mass in ‘FHIA 17’ and in both production cycles due to the significant interaction between cultivars and production cycles with fertilization levels. The highest fruit fresh mass was achieved at the highest level of fertilizer recommendation (150%) (Figure 2A). Fruit mass is an important trait for selecting cultivars and consumer preference, but fruit mass should not be considered an isolated trait because other components can reflect fruit quality, such as length and fruit diameter (Garruti et al., 2012).

The fruit number per bunch was not affected by cultivar and fertilizer levels (Figure 2B), but in the 2nd cycle, all cultivars had higher fruit numbers with an average of 181 fruits for ‘FHIA 17’, 144 fruits for ‘Grand Naine’, and 135 fruits for ‘Nanicão IAC 2001’. The genomic group of each cultivar is a very important factor that controls production potential such as the number of fruit, hands in the bunch, and bunch mass. The cultivars that belong to the genomic group AAA (Cavendish and Gros Michel) and its hybrids (‘FHIA 17’) generally have a higher potential for fruit production, ranging from 10 to 30 fruits per hand and 5 to 16 hands per bunch, depending on the season and growing conditions (Robinson & Gálan-Saúco, 2011).

The total number of fruits in the 1st production cycle was affected by the fertilizer levels, where the estimated maximum response was achieved at the highest applied dose (150%) (Figure 1B). Regardless of fertilizer levels, there was a higher number of fruit in the 2nd cycle, with the average of 166 fruits per bunch. According to Robinson and Gálan-Saúco (2011) and Soto-Ballestero (2008), the number of hands and fruits in the bunch is mainly influenced by genetics, growing cycle, temperature, plant vigour, and by plant management at the floral differentiation stage. In this study, banana plants in the 2nd cycle had better nutritional conditions, as there was a connection between the rhizome of the mother-plant and daughter-plan, acting as an "umbilical cord", where sap and hormones could be exchanged (Moreira, 1999). It is recommended that the harvested plants remain in the field for at least one month to transfer nutrients from the mother-plant to the daughter-plant (Soto-Ballestero, 2008).

The increase of fertilizer for ‘Nanicão IAC 2001’ and ‘Grand Naine’ increased the marketable hands fresh mass, with the highest mass obtained by applying 150% of the fertilizer recommendation (Figure 2C). There was also a significant interaction between production cycles and fertilizer levels for marketable hands fresh mass, with maximum estimated values when 150% and 102% of the fertilizer recommendation was applied at the 1st and 2nd cycle, respectively (Figure 2C). The marketable hands mass for ‘FHIA 17’ and ‘Nanicão IAC 2001’ was reduced in the 2nd cycle due to a severe incidence of black Sigatoka in this cycle. The ‘Grand Naine’ did not had problems with the black Sigatoka fungus because it had been treated with preventive fungicides; therefore, ‘Grand Naine’ marketable hands produced higher fresh mass in the 2nd cycle. Furthermore, this cultivar in the 1st cycle had high productive potential, as also noted by Bolfarini, Javara, Leonel, and Leonel (2014), who observed bunches at 31.18 kg, grown in Botucatu (São Paulo State).

Regardless of production cycles, the fertilization levels resulted in increasing yields for ‘Nanicão IAC 2001’ and ‘Grand Naine’ (Figure 2D). The maximum estimated yields were achieved with the highest dose (150%), promoting an increase of 33.5 and 84.2% compared to the treatment without fertilization. These results corroborate the results of Soto-Ballestero (2008), who reported that Cavendish bananas are much more responsive to potassium fertilizer than the cultivars of the subgroup Gros Michel (‘FHIA 17’). There were differences for yield among the cultivars, with banana cultivars ‘Grand Naine’ (42.5 ton ha^{-1} year^{-1}) and ‘Nanicão IAC 2001’ (38.1 ton ha^{-1} year^{-1}) having superior yield compared to ‘FHIA 17’ (31.1 ton ha^{-1} year^{-1}), regardless of the fertilizer levels and production cycles.

Despite that ‘FHIA 17’ presented marketable hands fresh mass very close to the other cultivars (Figure 2C), a low yield due to the lower planting density (1,667 plants ha^{-1}) and the highest total cycle (Table 1) was observed. Donato et al. (2006) found that cultivars from Cavendish and Gros Michel subgroups are potentially more productive than the Prata subgroup. These authors found a yield of 78.1 ton ha^{-1} year^{-1} for cv. 'Grand Naine' grown in Guanambi (BA), which is much higher than that found in this study. This increase is mainly because the region (Guanambi) has favourable climatic conditions for banana cultivation, the absence of the black Sigatoka fungus and appropriate water supplies by irrigation.

Variance analysis determined a significant effect in the interaction of cycles and fertilization levels on yield for both production cycles. In the 1st cycle, yield reached an estimated 37.3 ton ha^{-1} year^{-1} with the maximum applied dose (150%), while in the 2nd cycle, yield reached 37.1 ton ha^{-1} year^{-1} applying 124% of the fertilizer recommendation (Figure 2D). These values are above the international average yield (14.2 ton ha^{-1}) (Soto-Ballestero, 2008).

Conclusion

Given the experimental conditions of this study, the following was concluded: 'Nanicão IAC 2001' and 'Grand Naine' require an application of 150% of the fertilizer recommendation (525 kg N ha^{-1} year^{-1} and 855 kg K_2O ha^{-1} year^{-1}) to achieve maximum yield (43.6 and 55.1 ton ha^{-1} year^{-1}, respectively); the 'FHIA 17' banana showed a low response to nitrogen and potassium fertilization; and regardless of cultivar, to achieve maximum productivity (44.2 and 43.3 ton ha^{-1} year^{-1}, respectively), an application of 150 and 124% of the fertilizer recommendation in the 1st and 2nd production cycles is required, respectively.

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