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Nitrogen and potassium fertilization on 'Caipira' and 'BRS Princesa' bananas in the Ribeira Valley

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ABSTRACT
'BRS Princesa' (AAAB) and 'Caipira' (AAA) banana cultivars have similar sensorial features in comparison to the 'Maçã' banana. They are resistant to Panama disease, which allows them to grow in the Ribeira Valley, the largest banana plantation area in the São Paulo State. However, there is no information on how to fertilize crop under these edaphoclimatic conditions. This study aimed to evaluate the development and production of 'Caipira' and 'BRS Princesa' bananas, by applying four fertilization doses of N and K_2O (no fertilization; 175 and 285 kg ha^{-1} year^{-1}; 350 and 570 kg ha^{-1} year^{-1}; 525 and 855 kg ha^{-1} year^{-1}). The most adequate fertilizer recommendation for 'Caipira' and 'BRS Princesa' cultivars was 150% of the standard recommendation for banana (525 kg ha^{-1} year^{-1} of N and 855 kg ha^{-1} year^{-1} of K_2O) in both production cycles, promoting adequate growth and production, since most of the evaluated characteristics showed linear responses with the increase in the fertilization doses. 'Caipira' and 'BRS Princesa' require higher amounts of N and K than that recommended for the banana crop in the São Paulo State, in order to express their productive potential.

Palavras-chave:
Musa spp.
banana
nutrição

Adubação nitrogenada e potássica nas bananeiras 'Caipira' e 'BRS Princesa' no Vale do Ribeira

RESUMO
As cultivares de bananeira BRS Princesa (AAAB) e Caipira (AAA) possuem características sensoriais semelhantes à banana 'Maçã' visto que apresentam resistência ao Mal-do-Panamá, o que favorece seu plantio no Vale do Ribeira, a principal região produtora de bananas do Estado de São Paulo; entretanto não existem informações sobre como proceder à adubação nesta condição edafoclimática. Objetivou-se, nesta pesquisa, avaliar o crescimento e a produção das cultivares BRS Princesa e Caipira em quatro doses de adubação de N e K (sem adubação; 175 e 285 kg ha^{-1} ano^{-1}; 350 e 570 kg ha^{-1} ano^{-1}; 525 e 855 kg ha^{-1} ano^{-}1). A recomendação de adubação mais adequada para as cultivares Caipira e BRS Princesa foi de 150% da recomendação padrão para a bananeira (525 kg ha^{-1} ano^{-1} de N e 855 kg ha^{-1} ano^{-1} de K_2O) em ambos os ciclos, promovendo crescimento e produção adequados de vez que a maioria das características avaliadas apresentou respostas lineares com o aumento das doses de adubação. As cultivares Caipira e BRS Princesa necessitam de maior quantidade de nitrogênio e potássio do que o recomendado para a cultura da bananeira no Estado de São Paulo a fim de expressar seu potencial produtivo.

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Introduction

The Ribeira Valley has favorable edaphoclimatic conditions for the cultivation of most commercial banana cultivars ('Maçã', 'Prata-Anã', 'Nanicão', 'Grande Naine' and 'Terra'); however, 'Maçã' banana is little cultivated in the region due to its high susceptibility to Panama disease (*Fusarium oxysporum* f. sp. *cubense*).

One of the main difficulties in the acceptance of 'Maçã' banana hybrids has been the maintenance of its characteristic flavor, which is very original among all edible bananas; thus, the Embrapa Cassava and Tropical Fruits developed and introduced in Brazil various genotypes to substitute the 'Maçã' banana, selecting 'BRS Princesa' (YB42-07) and the cultivar 'Caipira' ('Yangambi km 05' - AAA), native to Western Africa, both with resistance to the main phytosanitary problems of the crop, such as Panama disease, Yellow Sigatoka (*Mycosphaerella musicola*) and Black Sigatoka (*M. fijiensis*) (Nomura et al., 2013b).

Bananas are highly efficient at producing phytomass in a short period of time (Melo et al., 2010) and thus require expressive amounts of nutrients, especially nitrogen (N) and potassium (K). These two nutrients are the most demanded by bananas, affecting plant development, besides influencing the number of hands per bunch and of fruits per hand, and root development (Kumar & Kumar, 2008). Melo et al. (2010) concluded that the greatest gain in shoot dry phytomass production (8,054.88 g plant^{-1}) was obtained in the combination of high doses of N and K (700 kg ha^{-1} year^{-1} of N and 1,200 kg ha^{-1} year^{-1} of K_2O); however, little is known about the effects of nutrition on the growth and production of cultivars resistant to the diseases and under the edaphoclimatic conditions of the Ribeira Valley. In addition, the recommendations of the Bulletin 200 (Teixeira et al., 2014), which do not specify the subgroup or cultivar for the use of the recommendation table, have been used in the commercial banana plantations of the Ribeira Valley. Therefore, this study aimed to evaluate the growth and production of 'Caipira' and 'BRS Princesa' bananas cultivated under different doses of N and K.

Material and Methods

The experiment was carried out at the Experimental Farm of the São Paulo Agency for Agribusiness Technology (APTA), Regional Center of the Ribeira Valley, located in the municipality of Pariquera-Açu-SP, Brazil (24º 36' 31" S; 47º 53' 48" W; 25 m), whose climate is classified as rainy tropical, without a dry season (Af). Data recorded at the unit (2004 to 2014) show annual means of maximum temperature of 26.8 ºC, minimum of 17.7 ºC and rainfall of 1,524.5 mm.

The evaluated cultivars were 'Caipira' (Yangambi km 05, AAA) and 'BRS Princesa' (YB42-07, AAAB). Standard fertilizations with N and K (100%) were calculated based on the result of the soil chemical analysis, for an expected yield of 30 to 40 Mg ha^{-1}, meeting the recommendation of Teixeira et al. (2014). In the treatment NK0, N and K fertilizations were not applied; in NK1, 50% of the standard recommendation of N and K was applied (175 kg ha^{-1} year^{-1} of N and 285 kg ha^{-1} year^{-1} of K_2O); in NK2, 100% of the standard recommendation of N and K was applied (350 kg ha^{-1} year^{-1} of N and 570 kg ha^{-1} year^{-1} of K_2O) and, in NK3, 150% of the standard recommendation of N and K was applied (525 kg ha^{-1} year^{-1} of N and 855 kg ha^{-1} year^{-1} of K_2O). The N sources were urea and ammonium sulfate, with alternate applications, while the K source was potassium chloride; both were in agreement with the intervals of application recommended by Teixeira et al. (2014).

The seedlings, propagated and acclimatized, were planted when they showed 5 to 6 leaves and 30 cm of height at spacing of 2.0 x 3.0 m (1,667 plants ha^{-1}) on January 26, 2012. Crop management and conduction were performed according to the recommendations of Moreira (1999).

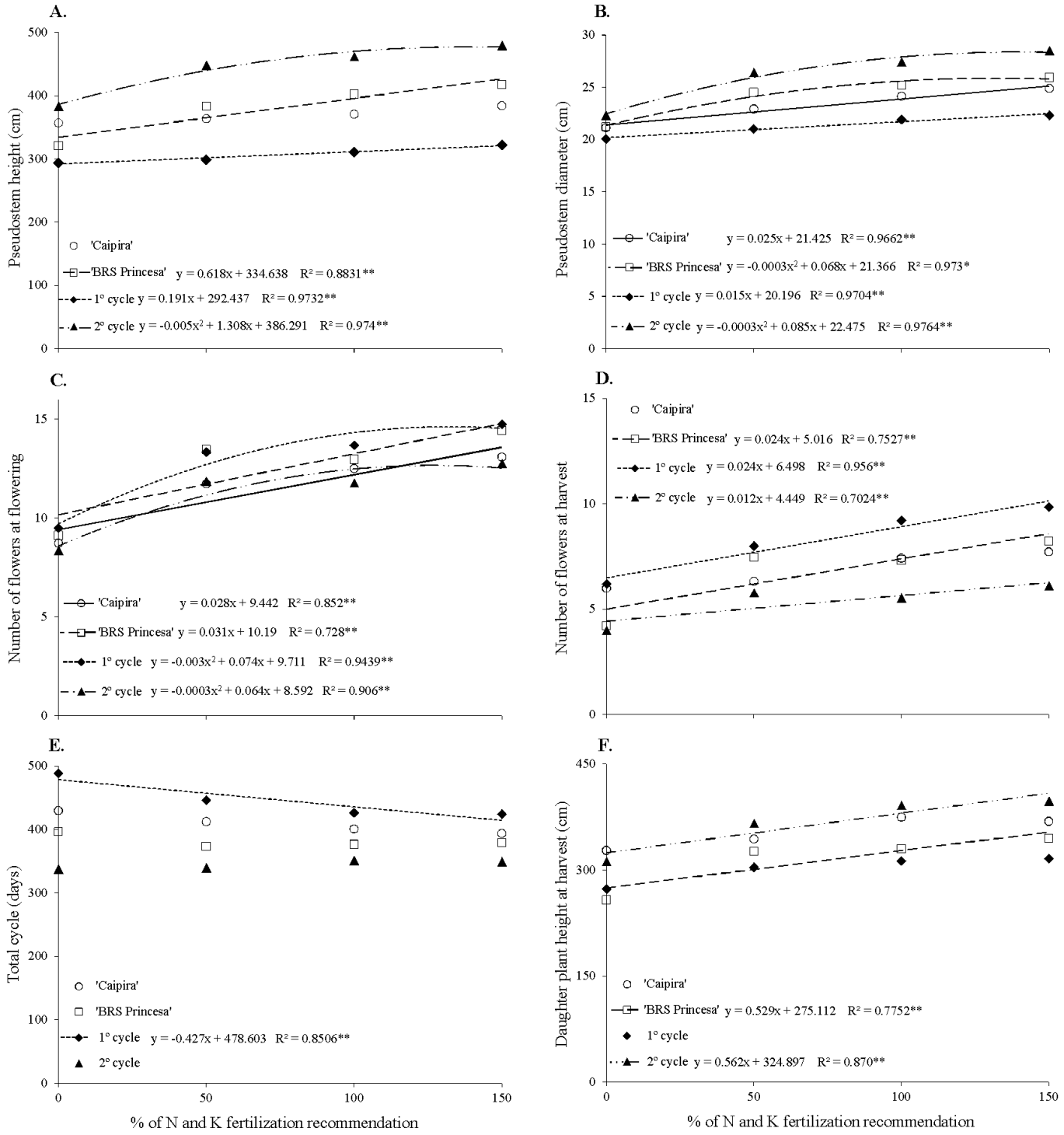
The soil showed the following characteristics (0-20 cm): pH ($CaCl_2$) = 4.2; OM = 26.7 g dm^{-3}; P (resin) = 4.0 mg dm^{-3}; K = 0.6 mmol$_c$ dm^{-3}; Ca = 12.7 mmol$_c$ dm^{-3}; Mg = 4.7 mmol$_c$ dm^{-3}; H + Al = 80.7 mmol$_c$ dm^{-3}; SB = 17.6 mmol$_c$ dm^{-3}; CEC = 98.1 mmol$_c$ dm^{-3}; V = 18.7%; 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 in the entire area, increasing base saturation to 60% and magnesium content to above 9.0 mmol$_c$ dm^{-3}, as recommended by Teixeira et al. (2014). In addition, 600 kg ha^{-1} of single superphosphate was applied in order to meet phosphorus requirements.

The following characteristics were evaluated: pseudostem height and diameter (cm); number of active flowers at flowering and at the harvest of the bunches; total cycle (1st cycle: number of days from planting to the harvest of the 1st bunch; 2nd cycle: number of days from the harvest of the bunch in the 1st cycle to the harvest of the bunch in the 2nd cycle); height of the daughter plant, measured at the harvest of the mother plant (cm). At the harvest of the bunches, when the fruits of the 2º hand showed diameter between 32 and 34 mm, the following variables were analyzed: fresh weight of marketable hands (kg); yield (Mg ha^{-1} year^{-1}); number of fruits per bunch; fresh weight of the 2nd hand (kg); fresh weight per fruit of the 2nd hand (g) and length of fruits of the 2nd hand (cm). The bunches of the 1st cycle were harvested from January 9 to July 31, 2013, and those from the 2º cycle from December 19, 2013, to September 4, 2014.

The experimental design was randomized blocks in a 2 x 4 factorial scheme (cultivars x fertilization doses) and split plots in time (cycles). Plants were evaluated during two production cycles based on three replicates of four plants. The data were subjected to analysis of variance by F test and fitted, when significant, in order to obtain the regression equations.

Results and Discussion

Most of the evaluated characteristics showed that both cultivars respond to N and K fertilizations (Figures 1 and 2), in both vegetative growth and flowering. This response was linear for most characteristics, indicating the possibility of applying higher doses of N and K. Pseudostem height (Figure 1A), pseudostem diameter (Figure 1B), number of active flowers at flowering (Figure 1 C) and at the harvest of the bunches (Figure 1D) and daughter plant height (Figure 1F) of both cultivars showed linear and quadratic responses as the doses of N and K increased. The positive effect of these



**p ≤ 0.01; *p ≤ 0.05; R^2 – Coefficient of determination

Figure 1. Means of growth characteristics of 'Caipira' and 'BRS Princesa' bananas under doses of N and K (0: without fertilization; 50%: 175 N + 285 K_2O; 100%: 350 N + 570 K_2O and 150%: 525 N + 855 K_2O, in kg ha^{-1} $year^{-1}$)

elements on the vegetative growth of banana plants has been reported by other authors, including Ratke et al. (2012) and Silva et al. (2012).

Given the lack of literature referring to the cultivation of 'Maçã' banana in the Ribeira Valley region and its high susceptibility to Panama disease, this study used, for comparison purposes, the existing literature for 'Maçã' banana evaluated in other regions of the country, regardless of the adopted treatments and cultural managements. Thus, the cultivars 'Maçã', 'Caipira' and 'BRS Princesa' cultivated in Botucatu, SP, Andirá, PR, and Goiânia, GO (Ramos et al., 2009; Borges et al., 2011; Mendonça et al., 2013, respectively) showed lower values of pseudostem height in the 1º production cycle, in comparison to the cultivars evaluated in the present study (Figures 1A and 1B). This superiority of banana height in the Ribeira Valley may be related to the favorable climatic conditions (temperature and rainfall), as observed by Nomura et al. (2013a), who also observed very high values of pseudostem height (>4.5 m) in the cultivars 'Caipira' and 'BRS Princesa' produced in the Ribeira Valley.

According to Santos et al. (2006), the ideal height range of marketable banana plants is between 2.0 and 3.5 m, which

facilitates the cultural tracts and the harvest of bunches. Pseudostem heights in both cultivars remained above the ideal range in the 2º cycle, even in the absence of fertilizer application (Figure 1B). Along with the difficulty of harvest, higher plants also show higher susceptibility to toppling, which may lead to the reduction in fruit quality. This effect can be minimized by the greater pseudostem diameter (Borges et al., 2011; Ramos et al., 2009), a fact observed in 'BRS Princesa' banana, which, despite its great height, notably in the 2º cycle, did not suffer break or toppling; on the other hand, for 'Caipira', whose pseudostem diameter was smaller than that of 'BRS Princesa' (Figure 1B), there were losses of plants by toppling and break.

The number of leaves at flowering and harvest (Figures 1C and 1D) is an important characteristic to be considered in the evaluations of resistance or tolerance to leaf diseases, especially Black Sigatoka, a disease that decreases the photosynthetically active area and, consequently, reduces the production (Nomura et al., 2013a). Furthermore, the maintenance of the leaves during the period of fruit filling is important for an adequate bunch development, since there is no production of leaves after flowering (Rodrigues et al., 2006). Rodrigues et al. (2009) evaluated the effect of defoliation levels on the cv. 'Prata-Anã' cultivated in Jaíba-MG and concluded that the maintenance of 10 to 12 leaves per plant at flowering led to higher production.

The resistance of the cultivars to Black Sigatoka, maintained during the entire cycle without the application of fungicides in the plantation, became explicit by the number of leaves at flowering and harvest (Figures 1C and 1D), which was sufficient for the adequate filling of the fruits (Figures 2A, 2B, 2C and 2D). In the present study, a higher number of leaves was maintained in the treatments with 100% and 150% of the recommendation of fertilization (Figure 1D). Teixeira et al. (2001) reported that leaf senescence in banana plants, between the period of inflorescence production and harvest of bunches, is accelerated under conditions of nutritional deficiency of N and K.

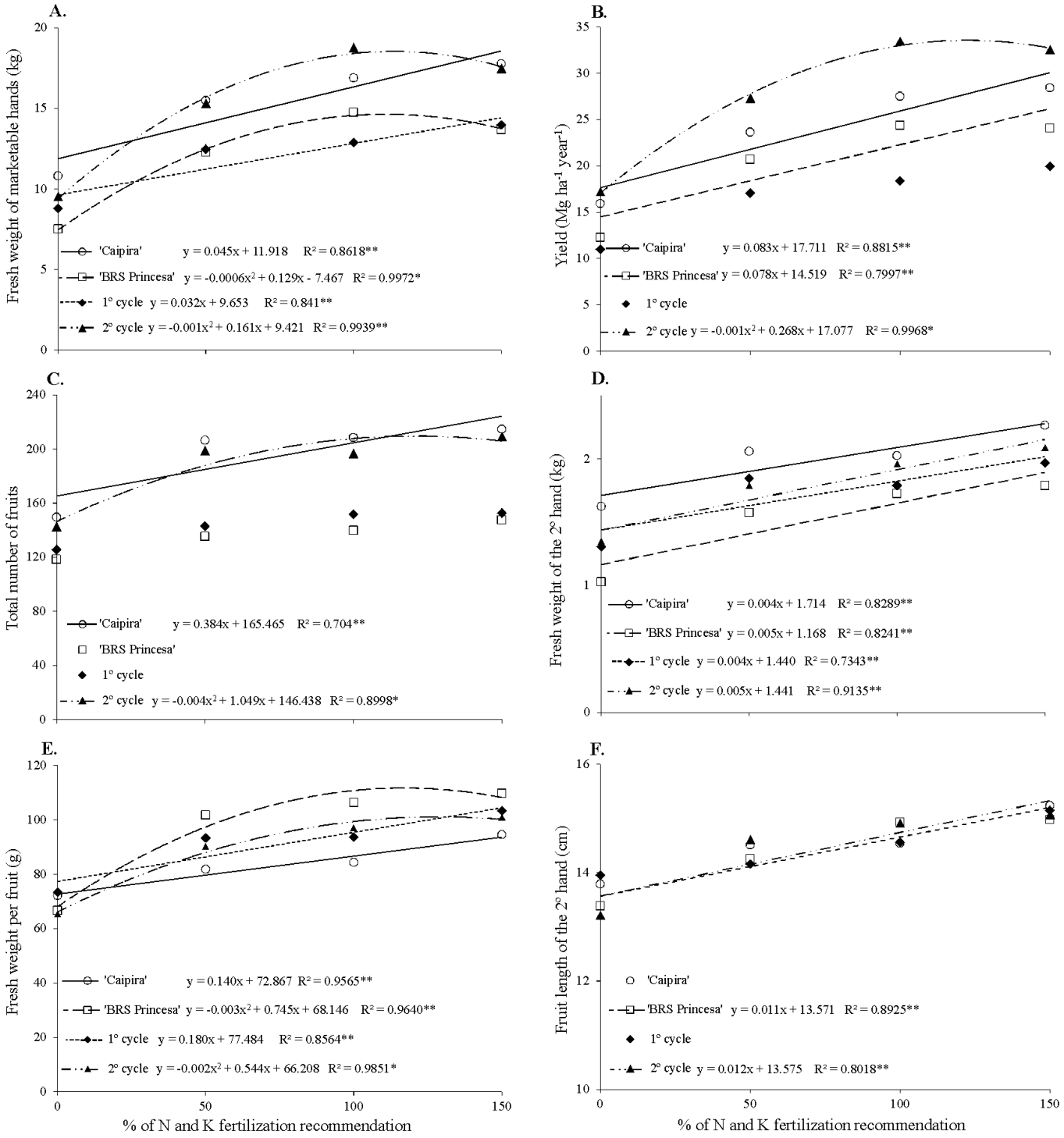
The total cycle of each season, as expected, decreased when larger amounts of fertilizer were applied (Figure 1E), clearly demonstrating the occurrence of nutritional deficiency at the lowest fertilizer doses, thus corroborating the positive effects of N and K on the growth and development of banana trees (Moreira, 1999). Precocity is advantageous from the economic point of view, since the shorter the period until harvest, the higher is the number of production cycles, which increases yield and the profitability of the farmer. In addition, with a shorter period of permanence of plants at the field, there is a reduction in the time of exposure of fruits to damage-causing agents and, consequently, lower use of pesticides (Rodrigues et al., 2006). Another factor that may favor the reduction of crop cycle is the greater height of the daughter plant, for promoting anticipation of flowering and fruiting in the following cycle and, as a result, faster economic return. In the cv. 'BRS Princesa' and in the 2º cycle, the greatest heights of the daughter plant were obtained in the treatments with 100% and 150% of the recommendation of fertilization (Figure 1F).

In characteristics related to the production, the response was predominantly linear (Figure 2), indicating that higher doses of N and K promoted increase in the productions. Considering the fresh weight of marketable hands, 'Caipira' responded better to fertilization compared with 'BRS Princesa' and, for both, there was an increment in the fresh weight of marketable hands from the 1º to the 2º cycle (Figure 2A). Although the plants of the 1º cycle showed higher number of active leaves, both at flowering and at fruiting (Figure 1C and 1D), the amount of leaves in the 2º cycle was sufficient for complete development and filling of the fruits. Robinson & Gálan-Saúco (2011) recommend, in some cases, the removal of leaves of banana trees cultivated in protected environments, since there is often greater amount of leaves than the necessary for a good development of the bunch.

The fresh weight of marketable hands of 'Caipira', in both cycles, was similar to that obtained in the study of Nomura et al. (2013b). In comparison to 'Maçã', both cultivars showed higher fresh weight of marketable hands (Ramos et al., 2009; Mendonça et al., 2013), which indicates its competitive potential for the national market. The yield of both cultivars, even in the absence of fertilization, was higher than the mean of the 'Maçã' banana, of 9.9 Mg ha^{-1} (Ramos et al., 2009), confirming the potential of the cultivars 'Caipira' and 'BRS Princesa'. This characteristic followed the tendency of the fresh weight of marketable hands and the total number of fruits in the bunch, i.e., it was higher in 'Caipira' and in the 2º cycle (Figure 2B). The fertilization doses influenced yield in the 2º cycle, reaching maximum value of 35.0 Mg ha $year^{-1}$ with the application of 134% of the recommendation (Figure 2B), regardless of the cultivars. The positive effects of N and K on banana yield have already been reported for 'Prata-Anã' (Santos et al., 2009), with results similar to those in the present study.

The cultivar 'Caipira' fertilized with 150% of the recommendation produced, on average, 223 fruits per cycle (Figure 2C), with perspective of being even more productive through the application of higher doses of N and K. This value was much higher than that obtained for 'Maçã', from 60 (Ramos et al., 2009) to 83 fruits per cycle (Mendonça et al., 2013). The yields obtained by 'Caipira' and 'BRS Princesa' were similar to those already observed for the same cultivars by Nomura et al. (2013b). Regardless of the cultivars, there was only effect of fertilization in the 2º cycle, reaching maximum number of fruits with the application of 131% of the recommendation of fertilization (Figure 2C). The positive effect of N and K on the number of fruits of banana trees has already been observed in 'Prata-Anã' (Santos et al., 2009). Borges & Oliveira (2000) reported that the nutrient uptake rate is higher from the fifth month to the flowering, when there is greater accumulation of dry matter. During this period, there is flower differentiation, in which the number of hands and fruits in the bunch is defined (Soto-Ballestero, 2008), requiring the adequate supply of nutrients well before this stage (Moreira, 1999), especially N and K, in order to reach the maximum genetic potential of each cultivar.

It was observed that the fresh weight of the 2º hand of 'Caipira' and 'BRS Princesa' suffered positive influence of the fertilization doses, whose maximum values ('Caipira': 2.3 kg; 'BRS Princesa': 1.9 kg) were obtained with the use of 150% of the recommendation (Figure 2D). The same was observed



**p ≤ 0.01; *p ≤ 0.05; R^2 – Coefficient of determination

Figure 2. Means of the production characteristics of 'Caipira' and 'BRS Princesa' bananas under doses of N and K (0: without fertilization; 50%: 175 N + 285 K_2O; 100%: 350 N + 570 K_2O and 150%: 525 N + 855 K_2O, in kg ha^{-1} $year^{-1}$)

in the production cycles in which both cultivars obtained maximum weights at the highest dose of N and K applied (Figure 2D).

The fresh weight per fruit in the cv. 'BRS Princesa' reached maximum value of 114.0 g with the application of 124% of the recommendation of fertilization, while the cv. 'Caipira' reached maximum value at the highest dose applied, regardless of the production cycles (Figure 2E). The doses of K and K influenced fruit weight in both production cycles, reaching maximum value in the 1° cycle with the application of 150% and maximum value of 103 g in the 2° cycle with the application of 136% of the recommendation of fertilization (Figure 2E). Maia et al. (2003) and Santos et al. (2009) studied the effects of the doses of N and K on 'Prata-Anã' banana cultivated in Jaíba-MG and Aracaju-SE, respectively, and also observed positive effect on fruit weight with the increment of these nutrients.

The cv. 'BRS Princesa' and the 2° production cycle showed influence of N and K doses on the mean fruit length, which reached maximum value (15.2 and 15.4 cm, respectively) at the highest dose applied (Figure 2F). The fruits of 'Caipira'

banana showed size similar to those produced by Nomura et al. (2013b) and the fruits of 'BRS Princesa' were larger.

Robinson & Gálan-Saúco (2011) confirmed the importance of N and K nutrition in banana trees for growth and fruit filling. In this study, the fresh weight of the 2º hand, fresh weight per fruit and fruit length were heavier and larger with the increase in the doses of N and K, partially due to the performance of important functions in the transport of photoassimilates from leaves to fruits, in the synthesis of starch and in cell expansion (Marschner, 1995).

It is supposed that the effect of fertilization in the 1º cycle on yield, number of fruits and fruit length are due to the residual effect of nutrients and to the mineralization of organic matter from crop residues in the area where the banana plantation was implemented. The demands of N in the development and K in the production are very high in these stages (Moreira, 1999) and, possibly, the amount available in the soil was sufficient for an adequate development and for the production of the plants in the 1º cycle.

Maximum yield was not reached with the application of 100% of the recommendation of N and K, determined by Teixeira et al. (2014), undoubtedly due to the genetic potential, higher nutritional demand of these cultivars and the high rainfall in the Ribeira Valley, which may have promoted leaching of nutrients, especially in the months from December to March, when rainfall was normally higher, coinciding with the fertilizations.

Conclusions

1. The recommendation of more adequate fertilization for the cultivars 'Caipira' and 'BRS Princesa' was of 150% of the standard recommendation for the banana crop (525 kg ha^{-1} $year^{-1}$ of N and 855 kg ha^{-1} $year^{-1}$ of K_2O) in both cycles, promoting growth and production.

2. The cultivars 'Caipira' and 'BRS Princesa' require larger amount of N and K than that recommended for the banana crop in the state of São Paulo, in order to express their productive potential.

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