Controlled-release fertilizer in the first banana crop cycle

Fertilizante de liberação controlada no primeiro ciclo da cultura da bananeira

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ABSTRACT

High doses of fertilizers are used in the fertilization of the first cycle of banana crops. These doses are divided in the cycle to reduce losses and applied manually, requiring a great number of people. The objective of this study was to compare a single application of controlled-release fertilizer (CRF) with the split application of conventional mixed fertilizer (CF) evaluating yield, nutritional status and soil chemical characteristics during the first cycle of a banana crop. The experiment was conducted in Sete Barras, SP, Brazil, with the banana (*Musa acuminata*) subgroup Cavendish cv. Grand Naine, first cycle, during 15 months, in the years 2015/16, using the CRF 14-07-27 and the CF 14-07-28. The experimental design was randomized blocks with four replications and five treatments: 900 and 600 g plant^{-1} of CRF, in a single application, and 1,200 g plant^{-1} of CF split in three, five and seven applications. Fertilization with CRF provided the same yield and kept an adequate nutritional status of banana plants compared to treatments using split application of CF. Fertilization with 600 g plant^{-1} of CRF made the soil less acidic than CF, regardless of split application, and kept the levels of P and K in the soil at appropriate levels for banana crops after four months of application.

Keywords: *Musa* sp, Efficiency, Fertilizing.

RESUMO

Na adubação do primeiro ciclo da cultura da bananeira são utilizadas altas doses de adubos. Estas são divididas no ciclo, para reduzir as perdas e aplicadas de forma manual, demandando muita mão de obra. Objetivou-se com o experimento comparar uma única aplicação de fertilizante de liberação controlada com a aplicação parcelada de fertilizante misto convencional, na produtividade, no estado nutricional e nas características químicas do solo, no primeiro ciclo da cultura da bananeira. O experimento foi conduzido em Sete Barras, SP, com a bananeira (*Musa acuminata*) o subgrupo Cavendish cultivar Grand Naine, durante o primeiro ciclo, de 15 meses, nos anos de 2015/16, utilizando o fertilizante de liberação controlada (FLC) 14-07-27 e o fertilizante misto convencional (FC) 14-07-28. Foi adotado o delineamento de blocos ao acaso, com quatro repetições, e cinco tratamentos: 900 e 600 g planta^{-1} do FLC, em única aplicação; 1200 g planta^{-1} do FC parcelados em três, cinco e sete aplicações. A adubação com FLC proporcionou a mesma produtividade e manteve o estado nutricional adequado da bananeira em comparação com os tratamentos com o parcelamento do FC. A adubação com 600 g planta^{-1} do FLC acidificou menos o solo que o FC, independente do parcelamento, e manteve os teores de P e K no solo, em teores adequados para a cultura da banana, quatro meses após a aplicação.

Palavras-chave: *Musa* sp., Eficiência, Adubação.

INTRODUCTION

In 2016, 126.5 million tonnes of bananas were produced in the world. Brazil is the world's fourth largest producer. In that year, the harvested area in Brazil was approximately 530,000 hectares, with a production of 7.2 million tonnes of fruits (FAO, 2018). Currently, the state of São Paulo is Brazil's largest producer of bananas, with about 1.2 million tonnes a year according to IBGE (2018). The production is concentrated at the Ribeira Valley and at São Paulo's coastal area. This makes the agricultural income in these regions increasingly dependent on banana cultivation.

The banana plant is very demanding regarding nutrients, especially during the first cycle, especially the potassium (K) and nitrogen (N), the nutrients most absorbed by this culture (Teixeira *et al*., 2008). Nitrogen is very important during the vegetative growth stage until the early emission of the bunchs (Silva *et al*., 2003). Potassium is relevant to the production and the quality of fruits. The nutrients are supplied to the banana plant through the soil, organic or mineral fertilizers and residues of the culture. However, such nutrients may be subject to leaching, volatilization and runoff (Prasertsak *et al*., 2001; Carpena *et al*., 2002), with intensities depending primarily on the physical and chemical conditions of the soil and rainfall regimes (Borges, 2004). According to the meteorological data from the Integrated Center for Agrometeorology Information of the State of São Paulo (CIIAGRO, 2016), in the last twenty years the average accumulated annual rainfall in the Registro area was 1,612 mm, more than 76% concentrated in the months during which fertilization is performed (September to March). This creates a favorable situation for the loss of nutrients by leaching, and hinders fertilization. According to data collected by Furlaneto *et al*. (2007), the cost of fertilizers for the culture of banana may represent approximately 21% of the effective operational cost.

To increase the efficiency of N and K fertilization, the split application during the crop cycle is a recommended strategy. In the case of São Paulo, Teixeira *et al*. (1997) recommended the application of fertilizers split into three periods (at the beginning, middle and end of the rainy season) for areas with seasonal droughts, or into six periods for areas without water deficit. In the Ribeira Valley region (SP), the fertilization split into three applications distributed from September to April is the most common practice among banana growers.

An alternative to increase the efficiency of N and K fertilizers use by banana plants and to reduce the losses of such nutrients is the use of slow-release fertilizers, controlled or stabilized. Controlled-release fertilizers are products with chemical or physical mechanisms that promote the gradual release of nutrients when applied to the soil. According to Alva (1992), this may reduce losses by leaching and increase nutrient uptake efficiency. Fan *et al*. (2011) defined controlled-release fertilizers (CRF) as polymer-coated fertilizers whose release occurs in a function of temperature and thickness of coat. Controlled-release fertilizers may reduce the operating cost. They are also beneficial to the environment due to a lower emission of greenhouse gases and a lower contamination of water tables. The use of such fertilizers may be an effective alternative to conventional fertilizers for several vegetable and ornamental crops, as identified for some tree species (Neto *et al*., 2003), orange trees (Girardi *et al*., 2010) and eucalyptus seedlings (Silva *et al*., 2015).

The objective of this study was to compare the effects of a single application of controlled-release fertilizer with the effects of a split application of conventional mixed fertilizer on banana yield, nutritional status of the plant and chemical characteristics of the soil, in the first cycle of the banana crop.

MATERIAL AND METHODS

Site

The experiment was conducted at a rural property in the municipality of Sete Barras, south of São Paulo state, in the Ribeira River Valley, Registro region (24º 37′ 48.4″ S and 47º 89′ 70.8″ O; altitude: average of 26 m).

Weather

The climate is Af (humid tropical), according to the Köppen classification, with a mean annual temperature of 24.6 ºC and a mean annual rainfall of 1,635 mm. Meteorological data during the experimental period are shown in Figure 1.

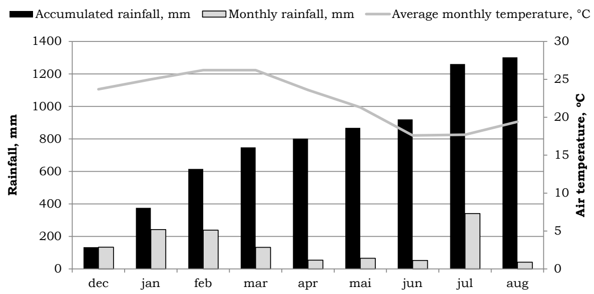

Figure 1 - Monthly rainfall and air temperature of Sete Barras, SP, Brazil, during the experimental period. Source: CIAGRO Online (2015).

<u>Soil</u>

The soil of the experimental area was classified as a Haplic Cambisol and had the following characteristics: pH ($CaCl_2$) = 4.5; 31 g dm^{-3} of OM; 15 mg dm^{-3} of P (resin); 38.2, 2.9, 60, 15 and 116 mmol$_c$ dm^{-3} of potential acidity (H + Al), Al, K, Ca, Mg and (Cation Exchange Capacity) CEC, respectively; 67% of soil base saturation; and 397, 138 and 465 g kg^{-1} of clay, sand and silt, respectively.

Planting

The planting of rhizome seedlings was performed in 2.0 x 2.5 m spacing. At the time, 30 x 30 x 30 cm furrows were fertilized with 400 g of soil conditioner (300 g kg^{-1} of OM – composed of selected peat rich in humic substances), 50 g of simple superphosphate and 30 mL of organic mineral liquid fertilizer (30 g kg^{-1} of C and 10 g kg^{-1} of K_2O). Seedlings of the banana (*Musa acuminata)* subgroup Cavendish cultivar Grande Naine, were treated with carbofuran at a 1:100 ratio, for preventive control of nematodes and banana root weevil (Coleoptera: Curculionidae).

Experimental design and treatments

The experimental design was randomized blocks with five treatments and four replications. The plots consisted of 16 plants. The four central plants were used for evaluations. The treatments consisted of the following fertilizations, which began in November 2015: (1) a single split application using 900 g plant^{-1} of controlled-release fertilizer (CRF) 14-07-27 (75% of the conventional fertilizer dose, according to the recommendations by Teixeira *et al.* (1997) for; (2) a single split application using 600 g plant^{-1} of the CRF 14-07-27 (50% of the conventional fertilizer dose); (3) three split applications (400 g every 66 days) using the conventional mixed fertilizer (CF) 17-07-28; (4) five split applications (240 g every 40 days) using the CF 14-07-28; and (5) seven split applications (170 g, monthly) using the CF 14-07-28. Each plant from the treatments 3, 4 and 5 received a total of 1.2 kg of CF until May. The CRF was Polyblen® 14-07-27 with 30% of conventional fertilizers (composed of urea and potassium chloride, monoammonium phosphate, simple and triple superphosphate) and 70% of controlled-release fertilizer (composed of urea and potassium chloride, both coated with elemental sulfur and polymer). The conventional mixed fertilizer was the 14-07-28 (composed of potassium chloride, ammonium nitrate and MAP- monoammonium phosphate). According to the information from the CRF manufacturer, the release of nutrients occurs within 4 and 5 months depending on soil moisture, and especially soil temperature. The applications of fertilizer were performed manually from November in a circular strip around the plant, 30 cm away from the pseudo-stem.

Features evaluated

At the time of inflorescence emission (March), leaf tissue samples were collected from the third leaf of each useful plant. The central strip of the leaf was cut with a width of 10 cm, eliminating the midrib and the outer halves of this strip. The samples were prepared and analyzed regarding the levels of macro- and micronutrients according to Malavolta *et al.* (1997).

Soil samples were collected (four single samples forming one composite sample per plot) in March (time of inflorescence emission, four months after the beginning of fertilization) and August (after the harvest of bunches, nine months after the beginning of fertilization) at the 0-20 cm layer, where the fertilizers were applied, using an auger probe.

The samples were sent to the laboratory for analysis of pH, organic matter (OM), potential acidity (H+Al), Ca, Mg, K, P, S, B, Zn, Mn, Cu and Fe according to Raij *et al*. (2001).

The harvest of fruits was performed between March and May. After harvesting, the following characteristics were evaluated: number of bunches, bunch mass and fruit weight, number, diameter and length.

Statistical analysis

The results were submitted to analysis of variance and the means were compared by not protected t test (LSD) (Costa, 2003) at 5% probability using the software SISVAR v. 5.2.

RESULTS AND DISCUSSION

Regarding the nutritional status of the plants, the phosphorus (P) concentration in the banana leaf was higher in the CF treatment, split in three applications, compared to the plants fertilized with CRF at the highest dose (Table 1). The K content in the leaf was also higher in the CF treatment, also in three applications, when compared to the CRF treatment at the highest dose.

Table 1 - Concentrations of macro- and micronutrients in the third leaf of a banana plant collected at the time of bunch emission in function of treatments applied (Sete Barras, SP, Brazil)

Treatments	N	P	K	Ca	Mg	S
	g kg^{-1}					
CRF 900 g	23 a	1.8 b	37 ab	16 a	3.3 ab	1.4 a
CRF 600 g	23 a	1.9 ab	35 ab	16 a	3.8 ab	1.4 a
CF 3 x 400 g	24 a	2.0 a	42 a	15 a	2.8 b	1.5 a
CF 5 x 240 g	23 a	1.9 ab	34 b	16 a	3.9 a	1.5 a
CF 7 x 170 g	24 a	1.9 ab	38 ab	15 a	3.3 ab	1.4 a
CV (%)	4.9	5.8	11.5	13.3	19.3	10.5
LSD	1.75	0.16	6.58	3.20	1.0	0.23
Treatments	**B**	**Cu**	**Fe**	**Mn**	**Zn**	
	g kg^{-1}					
CRF 900 g	14 a	8 a	75 a	458 a	19 a	
CRF 600 g	13 a	9 a	69 a	357 b	18 a	
CF 3 x 400 g	14 a	8 a	78 a	421 ab	19 a	
CF 5 x 240 g	13 a	8 a	75 a	453 a	18 a	
CF 7 x 170 g	14 a	9 a	75 a	465 a	19 a	
CV (%)	7.8	7.5	9.5	10.3	6.7	
LSD	1.64	0.97	10.87	68.5	1.91	

Means followed by the same letter do not differ by t test (LSD) at 5% probability level; CRF - controlled-release fertilizer Polyblen® 14-07-27; CF - conventional fertilizer 14-07-28; CV= coefficient of variation

This occurred because leaves were collected in March, shortly after the plants of this treatment (CF split into three applications) had received the last split application of CF (400 g). This is interesting because it reflects a fast response to the change of P and K concentrations in the foliar diagnosis of banana in function of fertilization. It is observed that the plants under this treatment (CF 3 x 400 g) also had a the lowest magnesium (Mg) concentration compared to the treatment using CF split into five applications because of antagonic effect by a higher foliar K concentration. The importance of a balance between these two cations is therefore clear. The decrease in the Mg content in leaf tissues is possibly due to the competitive effect between this nutrient and K, since they are cationic nutrients that strongly compete for the same absorption sites in soil (Mascarenhas *et al*., 2000). The leaf manganese (Mn) concentration was lower in the CRF 600 g treatment.

The use of CRF, with 50% of the CF dose, allowed maintaining the same nutrient contents in the diagnostic leaf as the fertilization with three CF applications (Table 1). For all treatments, only N and sulfur (S) contents were classified as deficient according to Malavolta *et al*. (1997), evidencing that the highest dose used in CF, corresponding to 336 kg ha^{-1} of N was not sufficient to satisfy the N crop needs. According to Teixeira et al. (1997), the dose of N and the N leaf concentration, suggested for the average yield obtained in the experiment, is 500 kg ha^{-1} and 36 g N kg^{-1}, respectively.Therefore, the N dose was below the recommended, as it was not expected to achieve yields above 60 t ha^{-1}. Regarding S, although the controlled-release fertilizer has a coating containing elemental sulfur, it was not able to raise the levels of this nutrient in the leaf compared with the treatments using CF, which contained S in its composition.

At four and nine months after the beginning of fertilization, the split application of the conventional fertilizer (CF) acidified the soil more than the fertilization with 50% of the dose using the controlled-release fertilizer (Table 2). Although controlled-release fertilizers have a coat containing elemental S, which, when oxidized, acidifies the soil, the amount used thereof was lower than the CF. Similarly, Teixeira *et al*. (2007) found that the use of conventional fertilizers resulted in increases in the acidity of the soil mainly due to nitrification.

Table 2 - Average chemical characteristics of the 0-0.2 m soil layer nine months after the beginning of fertilization in function of treatments applied from November (Sete Barras. SP, Brazil)

Treatments	pH	OM	P	K	Ca	Mg
		mg dm^{-3}	------------- mmol$_c$ dm^{-3} -------------			
CRF 900 g	4.6 ab	18 a	35 cd	2.7 c	47 ab	22 a
CRF 600 g	4.8 a	21 a	32 d	1.4 d	51 a	24 a
CF 3 x 400 g	4.4 b	22 a	55 a	5.3 a	41 c	19 c
CF 5 x 240 g	4.4 b	21 a	48 ab	3.9 b	45 bc	19 bc
CF 7 x 170 g	4.4 b	23 a	44 bc	4.4 ab	46 bc	22 ab
CV (%)	2.8	18.4	14.6	20.7	6.9	8.1
LSD	0.19	6.03	9.63	1.13	4.93	2.66
Treatments	**CEC**	**B**	**Cu**	**Fe**	**Mn**	**Zn**
	mmol$_c$ dm^{-3}	------------- mmol$_c$ dm^{-3} -------------				
CRF 900 g	127 b	0.33 a	7.6 a	219 b	68 c	25 a
CRF 600 g	126 b	0.33 a	7.9 a	205 c	69 c	27 a
CF 3 x 400 g	129 ab	0.33 a	7.9 a	235 a	93 a	28 a
CF 5 x 240 g	130 ab	0.34 a	8.0 a	221 b	84 ab	27 a
CF 7 x 170 g	135 a	0.33 a	7.7 a	225 ab	82 b	28 a
CV (%)	3.5	9.6	3.4	3.7	7.5	6.9
LSD	6.93	0.05	0.41	12.6	9.2	2.9

Means followed by the same letter do not differ by t test (LSD) at 5%. CRF - controlled-release fertilizer Polyblen® 14-07-27; CF - conventional fertilizer 14-07-28; CV= coefficient of variation.

Fertilization with CF, split into three applications, provided a content of P, K, iron (Fe) and Mn in the soil higher than the other treatments (Table 2). This result corroborates the effects on P and K contents in the leaf of this treatment, as discussed above (Table 1).

According to Teixeira *et al*. (1997), the P and K concentrations of the soil, in all treatments, may be considered suitable for the cultivation of bananas. The CRF allowed average K contents and high P contents in the soil, even four months after a single application, with the occurrence of a high volume of rain and a high average air temperature (Figure 1). On that date, the CEC was lower in the treatments using CRF due to a lower potential acidity (H+Al). Organic matter, boron (B), copper (Cu) and zinc (Zn) concentrations in the soil were not influenced by the treatments. Fe and Mn levels in the soil were higher in some treatments with CF compared to CRF due to soil acidification caused by CF.

After the harvest of the bunches, nine months after the beginning of fertilization, the treatment with three CF applications provided a higher P content in the soil in relation to the treatment with seven split applications and the treatments using CRF. In this case, it was due to a higher dose of P, as already discussed. The K content in the soil was lower in treatments using CRF, which is justified by the use of lower doses of K (50 and 75% of CF) and also by a time after fertilization longer than the pre-determined to the release of nutrient in the product (4-5 months). However, the lowest dose of CRF did not hinder the K content in the leaf (Table 1), which was considered appropriate according to Malavolta et al. (1997). In the treatments with CF, three split applications provided a higher K content in the soil than five split applications. However, Ca and Mg contents in this treatment also showed that there was a decrease in the adsorption of such cations due to the higher K content in the soil. This confirms the results observed for K and Mg contents in the banana leaf (Table 1). The highest Ca and Mg contents were found in treatments using CRF. However, Fe and Mn contents were lower in the treatments using CRF, probably due to the higher pH values observed.

Fruits yield, mass of bunches and number of bunches per stem was virtually the same for all treatments (Table 3). There was an exception for the treatment in which the fertilization was split into five applications. The fruits yield was inferior to that obtained by the treatment with seven split applications, probably because it received the lowest dose of fertilizer until fruit filling (Table 3). The fruits yield with a single application of CRF at the dose 900 g plant^{-1} or 600 g plant^{-1} did not differ significantly from banana plants submitted to conventional fertilization. This demonstrates an interesting alternative, because it reduces manpower and lowers the risks of failing to perform fertilization, in the rainiest periods such as December-February. It is also an efficient alternative to minimize possible impacts to the environment according to Shaviv (2001).

Table 3 - Average fruit production and plant characteristics in function of treatments (Sete Barras. SP, Brazil)

Treatments	Bunch mass	Fruit Yield	No. of bunches per stem	Weight of the 2nd bunch	Number of fruits	Fruit diameter	Fruit length
	kg	t ha-1		kg		mm	mm
CRF 900 g	32.7 ab	60.8 ab	10.0 ab	3.9 a	20.8 a	39.2 a	261 a
CRF 600 g	33.2 ab	61.8 ab	9.8 ab	4.1 a	22.3 a	39.4 a	259 a
CF 3 x 400 g	33.6 ab	62.5 ab	9.8 ab	4.2 a	23.0 a	39.6 a	257 a
CF5 x 240 g	31.8 b	59.1 b	9.5 b	4.0 a	22.1 a	39.9 a	258 a
CF 7 x 170 g	35.4 a	65.8 a	10.4 a	4.1 a	22.5 a	39.7 a	261 a
CV (%)	6.02	6.02	4.72	9.94	9.62	1.66	2.39
LSD	3.09	3.09	0.23	0.62	3.28	3.2	9.5

Means followed by the same letter do not differ by t test (LSD) at 5%. CRF - controlled-release fertilizer Polyblen® 14-07-27; CF - conventional fertilizer 14-07-28, CV= coefficient of variation.

CONCLUSIONS

Fertilization using a controlled-release fertilizer at 75% or 50% of the dose of conventional fertilizer allowed obtaining the same fruit yield and maintaining the same adequate nutritional status of banana cv. Grande Naine as the fertilization using conventional fertilizer split into three, five or seven applications.

The fertilization with a controlled-release fertilizer made the soil less acidic than the conventional fertilizer, regardless of split applications, and kept P and K concentrations in the soil suitable for the cultivation of bananas.

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REFERENCES

Alva, A.K. (1992) - Differential leaching of nutrients from soluble vs. controlled-release fertilizers. *Environmental Management*, vol. 16, n. 6, p. 769-776. https://doi.org/10.1007/BF02645667

Borges, A.L. (2004) - *Recomendação de Adubação para a Bananeira.* Rio de Janeiro: Embrapa. 4p.

Carpena, R.M.; Ritter, A.; Socorro, A.R. & Perez, N. (2002) - Nitrogen evaluation and fate in a Canary Islands (Spain) sprinkler fertigated banana plot. *Agricultural Water Management*, vol. 52, n. 2, p. 93-117. https://doi.org/10.1016/S0378-3774(01)00131-7

CIIAGRO (2016) - *Centro Integrado de Informações Agrometeorológicas*. [cit. 2018.09.17] http://www.ciiagro.sp.gov.br/.

Costa, J.R. (2003) - *Técnicas experimentais aplicadas às ciências agrárias.* Rio de Janeiro: Embrapa Agrobiologia. 102 p.

FAO (2018) - *FAOSTAT: Produção.* Food And Agriculture Organization. [cit. 2018.09.20]. http://faostat.fao.org.

Fan, X.; Li, Y. & Alva, A. (2011) - Effects of temperature and soil type on ammonia volatilization from slow-release nitrogen fertilizers. *Communications in Soil Science and Plant Analysis*, vol. 42, n. 10, p. 1111-1122. https://doi.org/10.1080/00103624.2011.566957

Furlaneto, F.P.B.; Martins, N.A.; Camolesi, M.R. & Esperancini, M.S.T. (2007) - Análise econômica de sistemas de produção de banana (*Musa* sp.), cv. Grande Naine, na região do Médio Paranapanema, Estado de São Paulo. *Científica*, vol. 35, n. 2, p. 188-195.

Girardi, E.A.; Mourão Filho, F.A. & Alves, A.S.R. (2010) - Mudas de laranjeira 'valência' sobre dois porta-enxertos e sob diferentes manejos de adubação. *Revista Brasileira de Fruticultura,* vol. 32, n. 3, p. 855-864. http://dx.doi.org/10.1590/S0100-29452010005000082

IBGE (2018) - *Sistema IBGE de recuperação automática*. [cit. 2018.09.20]. http://www.sidra.ibge.gov.br/bda/tabela/protabl.asp.

Malavolta, E.; Vitti, G.C. & Oliveira, A.S. (1997) - *Avaliação do estado nutricional das plantas: princípios e aplicações.* POTAFOS (Associação brasileira para pesquisa da potassa e do fosfato). 317 p.

Mascarenhas, H.A.A.; Tanaka, R.T.; Carmello, Q.A.C.; Gallo, P.B. & Ambrosano, G.M.B. (2000) - Calcário e potássio para a cultura da soja. *Scientia Agricola*, vol. 57, n. 3, p. 445-449. http://dx.doi.org/10.1590/S0103-90162000000300012

Neto, S.P.M.; Gonçalves, J.L.M.; Rodrigues, C.J.; Geres, W.L.A.; Ducatti, F. & Aguirre Junior, J.H. (2003) - Produção de mudas de espécies arbóreas nativas com combinações de adubos de liberação controlada e prontamente solúveis. *Revista Árvore*, vol. 27, n. 6, p.779-789. http://dx.doi.org/10.1590/S0100-67622003000600004

Prasertsak, P.; Freney, P.G.; Denmead, O.T. & Prove, B.G. (2001) - Fate of urea nitrogen applied to a banana crop in the wet tropics of Queensland. *Nutrient Cycling in Agroecosystems*, vol. 59, n. 1, p. 65-73. https://doi.org/10.1023/A:1009806826141

Raij, B.V.; Andrade, J.C.; Cantarella, H. & Quaggio, J.Á. (2001) - *Análise química para avaliação da fertilidade de solos tropicais*. IAC. 285p.

Shaviv, A. (2001) - Advances in Controlled Release of Fertilizers. *Advances in Agronomy*, vol. 71, n. 1, p. 1-49. https://doi.org/10.1016/S0065-2113(01)71011-5

Silva, J.T.A.; Borges, A.L.; Carvalho, J.G. & Damasceno, J.E.A. (2003) - Adubação com potássio e nitrogênio em três ciclos de produção da bananeira Prata Anã. *Revista Brasileira de Fruticultura*, vol. 25, n. 1, p. 152-155. http://dx.doi.org/10.1590/S0100-29452003000100042

Silva, P.H.M.; Poggiani, F.; Silva, A.A.; Ithamar Neto, I.P. & Paula, R.C. (2015) - Mortalidade, crescimento e solução do solo em eucalipto com aplicação de fertilizante de liberação lenta. *Cerne*, vol. 21, n. 3, p. 473-481. http://dx.doi.org/10.1590/01047760201521031860

Teixeira, L.A.J.; Spironello, A.; Quaggio, J.A. & Furlani, P. R. (1997) - Banana. *In:* Raij, B.V.; Cantarella, H.; Quaggio, J.A. & Furlani, A.M.C. (Eds.) - *Recomendações de adubação e calagem para o Estado de São Paulo*, 2ed., Instituto Agronômico/Fundação IAC. p.131-132. (Boletim Técnico, 100).

Teixeira, L.A.J.; Natale, W.; Neto, J.E.B. & Martins, A.L.M. (2007) - Nitrogênio e potássio em bananeira via fertirrigação e adubação convencional-atributos químicos do solo. *Revista Brasileira de Fruticultura*, vol. 29, n. 1, p. 43-152. http://dx.doi.org/10.1590/S0100-29452007000100031

Teixeira, L.A.J.; Raij, B.V. & Bettiol Neto, J.E. (2008) - Estimativa das necessidades nutricionais de bananeiras do subgrupo Cavendish cultivadas no Estado de São Paulo. *Revista Brasileira de Fruticultura*, vol. 30, n. 2, p. 540-545. http://dx.doi.org/10.1590/S0100-29452008000200047