REVISTA BRASILEIRA DE
FRUTICULTURA
Published by the Brazilian Society of Fruit Crops
ISSN 0100-2945

Soils And Plant Nutrition

Original Article - Edited by: David Ferreira Lopes Santos

Nutritional demand of 'Grande Naine' and 'Prata Comum' banana bunches in two growing seasons

Cibelle Tamiris de Oliveira[1], Danilo Eduardo Rozane[2], Levi Godke Faber Pavarin[2], Henrique Shiniyti Akamine[2], Silvia Helena Modenese Gorla da Silva[2], Juliana Domingues Lima[2]

[1]Federal University of Paraná (UFPR), Curitiba – PR, Brazil.
[2]"Júlio de MesquitaFilho" São Paulo State University (UNESP), Registro – SP, Brazil.
*Corresponding author, e-mail: danilo.rozane@unesp.br

Abstract: The quantification of nutrients accumulated and exported by banana bunches provides information on the crop nutritional requirements. Thus, the aim of this work was to determine the nutritional demand of 'Grande Naine' and 'Prata Comum' banana bunches in the region of Vale do Ribeira, state of São Paulo. Bunch sampling was carried out in six harvest seasons, summer, and winter. The results of dry matter production and nutrient accumulation in bunches were submitted to analysis of variance. Relative growth rates (TCR), organogenic net accumulation (TALON), export and order of nutrient accumulation in bunches were estimated. K and N were the nutrients most accumulated and exported by both cultivars. In harvest period 5 (commercial harvest), more dry matter was produced in the summer and more nutrients were accumulated in the winter. The highest TCR values were observed between periods 2 and 3 in the summer and between 0 and 1 in the winter, but it did not always follow TALON. The results obtained are important to adapt the nutritional management of these cultivars to the study region, especially in relation to the growing season, due to the longer permanence of the bunch on the plant in the winter and greater demand for nutrients until commercial harvest.

Index terms: *Musa spp.*; nutrient accumulation; nutrient export.

Revista Brasileira de Fruticultura, v.44, n.5, e-430. DOI: https://dx.doi.org/10.1590/0100-29452022430
Received 31 Mar, 2021 ● Accepted 23 Aug, 2022 ● Published Sep/Oct, 2022

Demanda nutricional de cachos de bananeiras 'Grande Naine' e 'Prata Comum', em duas épocas de cultivo

Resumo: A quantificação dos nutrientes acumulados e exportados pelos cachos da bananeira fornece informações sobre as exigências nutricionais da cultura. Deste modo, o objetivo deste trabalho foi determinar a demanda nutricional de cachos de bananeiras 'Grande Naine' e 'Prata Comum', no Vale do Ribeira, Estado de São Paulo. Realizou-se a amostragem dos cachos em seis períodos de coleta, no verão e inverno. Os resultados de produção de matéria seca e o acúmulo de nutrientes nos cachos foram submetidos à análise de variância. Estimaram-se as taxas de crescimento relativo (*TCR*), a acumulação líquida organogênica (*TALON*), a exportação e a ordem de acúmulo de nutrientes pelos cachos. O K e o N foram os nutrientes mais acumulados e exportados pelas duas cultivares. No período de coleta 5 (colheita comercial), foi produzida mais matéria seca no verão e acumulados mais nutrientes no inverno. As maiores *TCRs* foram observadas entre os períodos 2-3 no verão e 0-1 no inverno, porém a mesma nem sempre acompanhou a *TALON*. Os resultados obtidos são importantes para adequar o manejo nutricional dessas cultivares na região de estudo, principalmente em relação às épocas de cultivo, devido à maior permanência do cacho na planta no inverno e maior demanda de nutrientes até à colheita comercial.

Termos para indexação: *Musa spp.*; acúmulo de nutrientes; exportação de nutrientes.

Introduction

Brazil is the world's fourth largest banana producer, with production of approximately 6.8 million tons; however, in the world productivity ranking, the country occupies the 61st place, with 14.8 t ha^{-1} (FAO, 2021). The low banana productivity in the country is often a result of the nutritional management used in commercial orchards such as inadequate supply of nutrients for the crop (DEUS et al., 2018) due to underutilization of soil and plant tissue analysis (DEUS et al., 2020a).

The banana tree demands expressive and constant amounts of nutrients for its development and its nutritional requirement varies according to the cultivar, being, in general, potassium (K) and nitrogen (N) the nutrients most demanded by the plant, being directly related to vegetative and reproductive growth, fruit production and quality (ROMERO; ZAMORA, 2006; BORGES; SILVA, 2012; RATKE et al., 2012).

Determining the amount of nutrients accumulated by the crop, as well as their export, provides information on the nutritional demands during plant development, indicating the appropriate times for the addition of essential elements, allowing better nutritional management planning (ROZANE et al., 2011) and enabling adaptation to greater crop productive potential.

Several studies have evaluated dry matter production and nutrient accumulation in banana organs, including bunches at just one time of the year, considering irrigated cultivation in the northeastern region of the country (SOARES et al., 2008; HOFFMANN et al., 2010a; HOFFMANN et al., 2010b; SOARES et al., 2011; DEUS et al., 2020a; DEUS et al., 2020b). However, this information can only be used in fertilization programs for places with water conditions similar to those found in these studies, thus limiting nutritional management in predominantly non-irrigated areas, a condition observed in one of the main bananas producing regions in Brazil, the Vale do Ribeira – SP.

In this way, quantifying the nutritional demand of bunches of different banana cultivars in non-irrigated conditions, considering more than one growing season, will allow obtaining reliable information to assist in the adjustment of more efficient fertilization programs. Thus, this study aimed to evaluate the growth, accumulation, and export of nutrients during the development of 'Grande Naine' and 'Prata Comum' banana bunches, in the winter and summer, in the region of Vale do Ribeira, state of São Paulo.

Material and Methods

The experiment was carried out in two commercial production plots of 'Grande Naine' and 'Prata Comum' banana trees in the municipality of Sete Barras, region of Vale do Ribeira, state of São Paulo. According to the Köppen classification system, the climate is Af – humid tropical with no dry season (ALVARES et al., 2013), with average annual rainfall of 1500 mm.

The plot with 'Grande Naine' banana had 5 hectares and spacing between plants of 2.0 x 2.0 m; the plot with 'Prata Comum' banana had 4 hectares and spacing between plants of 2.0 x 2.5 m. In order to evaluate the initial soil chemical characteristics (Table 1), 20 simple subsamples were collected at the experiment implementation (02/11/2015), in each plot, in the 0.0 – 0.20 m layer, in the banana fertilization region. Soil samples were dried in an oven at 45ºC, sieved through 2 mm mesh and analyzed according to methodology proposed by Raij et al. (2001). Phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) concentrations were determined using the ion exchange resin method; sulfur ($S\text{-}SO_4^{-2}$) was turbidimetrically extracted with calcium phosphate; pH in $CaCl_2$; organic matter (OM) by colorimetry; H+Al with SMP buffer solution; Al in KCl; boron (B) extracted via hot water; and copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) in DTPA at pH 7.3.

Table 1. Soil chemical attributes in plots cultivated with 'Grande Naine' and 'Prata Comum' banana trees at depth of 0.0-0.20 m.

	Cultivars	
	Grande Naine	**Prata Comum**
pH $CaCl_2$	6.4	4.9
MO (g dm^{-3})	22	33
P (g dm^{-3})	176	102
K*	2.3	2.0
Ca*	88	46
Mg*	52	25
H+Al*	15	19
Al*	0	0
SB*	142.3	73.0
CTC*	157.3	92.0
V (%)	91	79
B*	1.72	0.63
Cu*	1.8	2.6
Fe*	20	55
Mn*	23	140
Zn*	5.6	5.0
$S\text{-}SO_4$*	4	9

* $mmol_c$ dm^{-3}

The experimental design used was completely randomized (CRD), with four replicates, in a 2 x 6 factorial scheme, totaling 12 treatments. Factors corresponded to six harvest periods, during bunch development, in two seasons, summer and winter. The first harvest (period 0) was performed when plants started to produce the bunch; the second (period 1) was performed when it was possible to visualize a female bunch and fruit (female flowers) discovered by bracts; the third (period 2) was performed when it was possible to visualize three female bunches and fruits discovered by bracts; the fourth (period 3) was performed when it was possible to visualize all female bunches and fruits, which occurred when the first male bunches started to open; the fifth (period 4) was performed when the bunch was at 50% of its development, that is, in half the time for its harvest; and the sixth collection (period 5) was performed when the commercial harvest of bunches was carried out, that is, as soon as fruits of bunch two still had corners, corresponding to the "¾ lean" maturation degree (MOREIRA, 1999).

The first harvest was established as day zero and, from there, the days for the bunch to reach the subsequent harvest period until its commercial harvest were counted. 'Grande Naine' reached, in days, the harvest periods in summer and winter, respectively, period 0 (0 days), period 1 (7 and 3 days), period 2 (10 and 11 days), period 3 (14 and 20 days), period 4 (64 and 82 days) and period 5 (108 and 123 days); 'Prata Comum' reached period 0 (0 days), period 1 (7 and 6 days), period 2 (10 and 14 days), period 3 (14 and 21 days), period 4 (109 and 63 days) and period 5 (150 and 118 days).

The cultural management in both plots followed the technical recommendations for the region, highlighting that Sigatoka control was carried out in a preventive way, with aerial fungicide applications and in period 3 (beginning of the opening of the first male bunches), the operation to remove male rachis from bunches was performed.

Bunches (fruit and stalk) harvested in each period were washed, placed in paper bags, and taken to drying in a forced air ventilation oven at 65°C, until reaching constant mass. Subsequently, samples were weighed to determine the total dry matter mass and ground in Willey mill for later determination of nutrient contents, as indicated in Bataglia et al. (1983). In the last period, to determine the dry matter production and nutrient content, samples were analyzed by separating the stalk from the fruit. At this stage, nutrients were analyzed separately, as it is common, after removing bunches, to return the stalks to the production area, where parts of extracted nutrients can be returned to the system.

Nutrient accumulation in the bunch was calculated by the product between the nutrient content and the dry matter mass in each evaluation period. In the last period, the nutrient accumulation in the bunch was determined by the product of the nutrient content in the stalk and fruit by its respective proportion of total dry matter mass. Nutrient accumulations in stalk and fruits were summed to estimate the total value in the bunch.

Nutritional indexes were estimated using the formula proposed by Welbank (1962):

$$TCR = \frac{\ln M_2 - \ln M_1}{t_2 - t_1}$$

where: TCR – relative growth rate; M_1 and M_2 - bunch dry matter mass at times t_1 and t_2, respectively.

$$TALON = \frac{(N_2 - N_1)\,(\ln M_2 - \ln M_1)}{(t_2 - t_1)\,(M_2 - M_1)}$$

where: TALON – rate of organogenic net accumulation in the nutrient; N_1 and N_2 – amount of nutrient accumulated in the bunch at times t_1 and t_2, respectively; M_1 and M_2 – bunch dry matter mass at times t_1 and t_2, respectively.

Data were submitted to analysis of variance (F test) with the aid of the R software, version 4.0.3 (R CORE TEAM, 2021), using the ExpDes.pt package and the fat2.dic function, for CRD experiment with two factors. When there was interaction between factors harvest season and period (significant F at 1 or 5%), mean test (Tukey at 5%) and regression study were performed. The model that resulted in significance by the F test and that best represented the dry matter and nutrient accumulation over the evaluation periods was used.

Results and discussion

The results of soil analysis, sampled at the experiment implementation (Table 1), did not indicate nutritional restriction for ‘Grande Naine’ and ‘Prata Comum’ cultivars, and the nutrient concentrations presented interpretation levels ranging from medium to very high for the crop (RAIJ et al., 1997). The productivity of cultivars, in the summer and winter, exceeded the national (14.8 t ha^{-1}), state (20.5 t ha^{-1}) and regional (21.5 t ha^{-1}) averages (FAO, 2021; IEA, 2021). In the summer, bunch productivity, in fresh mass, indicated at harvest (period 5) was 67.3 t ha^{-1} for 'Grande Naine' and 37.8 t ha^{-1} for 'Prata Comum' cultivars, higher in the winter, 62.0 t ha^{-1} and 30.0 t ha^{-1}, respectively.

The total dry matter productivity of 'Grande Naine' bunches was 10.7 and 10.6 t ha^{-1} in the summer and winter, respectively. In 'Prata Comum' cultivar, these values were 6.9 t ha^{-1} in the summer and 5.0 t ha^{-1} in the winter. In dry matter production (PMS) and nutrient accumulation (AC), due to the separation between fruits and stalks, no differences were observed in the participation of the latter between growing seasons, inferring that, on average, the stalk is responsible for 4.0% of the dry matter and 7.5% of the total nutrients present in the bunch, a fact that corroborates Hoffmann et al. (2010a) and Hoffmann et al. (2010b), who reported that in six banana cultivars, the stalk was responsible for less than 10% of the dry matter present in the bunch.

Analysis of variance showed significant interactions (Table 2) of variables dry matter production (PMS) and nutrient accumulation (AC) in 'Grande Naine' and 'Prata Comum' banana bunches as a function of harvest seasons (E) and periods (P). However, only B in 'Grande Naine' and Mn and Zn in 'Prata Comum' did not show significant E x P interactions. Variables with significant effects were submitted to the mean test and regression equation adjustment to verify significant differences and observe the behavior of PMS and AC in the summer and winter during bunch development.

In general, no significant differences were observed in PMS and AC in the summer and winter for 'Grande Naine' and 'Prata Comum' until the third harvest period (Table 3). In the summer, both cultivars exhibited higher PMS values in the commercial harvest (period 5), with difference for winter being approximately 0.2 kg for ‘Grande Naine’ cultivar and 0.9 kg for ‘Prata Comum’ cultivar. The AC of 'Prata Comum' cultivar (Table 3) showed behavior similar to PMS, with higher averages observed for N, P, K, Ca and Mg in the summer, in the last harvest period. However, the opposite was observed for 'Grande Naine' cultivar (Table 3) in the same period, with higher AC values for N, P, K, Ca, S, Cu, Fe, Mn, and Zn, in the winter.

Table 2. Analysis of variance (F test and coefficients of variation - CV) of variables dry matter (DM) and N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, and Zn accumulation in 'Grande Naine' and 'Prata Comum' banana bunches, considering factors harvest season - E (summer and winter) and period - P (0, 1, 2, 3, 4 and 5).

Variable analyzed	'Grande Naine'				'Prata Comum'			
	E	P	E x P	CV (%)	E	P	E x P	CV (%)
MS	14.0*	3940.5*	6.6*	5.6	64.4*	432.8*	29.2*	14.7
N	2.2^{ns}	505.3*	7.9*	11.0	27.2*	65.8*	13.8*	15.7
P	123.1*	727.6*	127.3*	12.2	37.9*	94.3*	14.4*	15.7
K	58.4*	233.1*	42.1*	22.4	108.3*	144.7*	12.51*	17.2
Ca	9.8*	130.3*	19.3*	22.1	5.2**	38.5*	3.2**	15.2
Mg	4.0*	268.1*	3.9*	17.5	67.9*	210.2*	17.7*	13.9
S	323.7*	705.1*	267.8*	15.0	18.2*	114.4*	36.6*	16.9
B	2.5^{ns}	86.5*	1.45^{ns}	33.3	0.03^{ns}	196.3*	23.8*	12.0
Cu	0.5^{ns}	60.6*	2.6**	33.6	1.0^{ns}	76.3*	20.6*	30.4
Fe	148.5*	281.8*	156.8*	21.4	0.5^{ns}	13.8*	4.7*	33.4
Mn	4.6**	28.8*	5.6*	44.1	54.4*	35.9*	2.3^{ns}	19.2
Zn	10.2*	26.0*	6.3*	55.0	1.3^{ns}	91.6*	2.3^{ns}	16.7

ns, **, *: non-significant and significant at p<0.05 and p<0.01, respectively.

Table 3. Average dry matter production (MS) and N, P, K, Ca, Mg, S (g kg^{-1}), B, Cu, Fe, Mn, Zn (mg kg^{-1}) accumulation values in harvest seasons (summer and winter) and periods (0, 1, 2, 3, 4 and 5) in 'Grande Naine' and 'Prata Comum' banana bunches.

	Variables	Seasons	Periods					
			0	1	2	3	4	5
'Grande Naine'	MS	Summer	185.5a	301.75a	338.5a	567.0a	2932.5a	4551.5a
		Winter	216.5a	301.5a	402.25a	454.0a	2618.0b	4367.0b
	N	Summer	4.8a	7.4a	8.0a	11.0a	24.5a	38.0b
		Winter	5.8a	7.4a	9.3a	9.0a	21.7b	45.1a
	P	Summer	0.7a	1.0a	1.0a	1.4a	3.9a	6.0b
		Winter	0.9a	1.0a	1.4a	1.2a	3.4a	12.8a
	K	Summer	11.1a	16.1a	19.6a	31.7a	82.5a	130.5b
		Winter	14.7a	20.2a	27.4a	31.4a	91.7a	297.6a
	Ca	Summer	1.1a	1.9a	2.1a	3.2a	4.2a	6.2b
		Winter	0.9a	0.8b	1.1b	1.2b	2.0b	9.3a
	Mg	Summer	0.7a	1.1a	1.2a	1.7a	5.1a	8.0a
		Winter	0.8a	1.1a	1.4a	1.2a	3.5b	7.9a
	S	Summer	0.3a	0.4a	0.5a	0.6a	1.4a	2.7b
		Winter	0.4a	0.5a	0.7a	0.6a	1.6a	9.6a
	B	Summer	6.2^{ns}	10.4^{ns}	13.0^{ns}	19.1^{ns}	57.2^{ns}	89.8^{ns}
		Winter	6.2^{ns}	8.5^{ns}	12.6^{ns}	12.4^{ns}	36.3^{ns}	92.3^{ns}
	Cu	Summer	1.6a	2.6a	2.6a	3.2a	8.7a	12.7b
		Winter	1.8a	2.2a	3.8a	2.6a	6.4a	16.6a
	Fe	Summer	6.9a	10.9a	20.7a	24.7a	70.2a	58.2b
		Winter	8.7a	19.6a	14.5a	18.5a	67.1a	294.4a
	Mn	Summer	15.3a	35.0a	33.0a	39.9a	70.6a	100.0b
		Winter	18.1a	23.5a	50.5a	44.1a	53.1a	197.1a
	Zn	Summer	5.2a	7.7a	7.7a	9.5a	22.4a	22.2b
		Winter	9.5a	10.5a	14.6a	10.6a	18.2a	80.2a

(to be continued)

Table 3. Average dry matter production (MS) and N, P, K, Ca, Mg, S (g kg^{-1}), B, Cu, Fe, Mn, Zn (mg kg^{-1}) accumulation values in harvest seasons (summer and winter) and periods (0, 1, 2, 3, 4 and 5) in 'Grande Naine' and 'Prata Comum' banana bunches. (continuation)

	Variables	Seasons	Periods					
			0	1	2	3	4	5
'Prata Comum'	MS	Summer	262.8a	353.5a	382.3a	489.0a	2164.0a	3540.0a
		Winter	292.6a	422.2a	432.6a	409.3a	956.1b	2587.9b
	N	Summer	6.3a	8.2a	8.5a	8.4a	16.0a	24.1a
		Winter	6.7a	9.6a	9.0a	7.1a	9.0b	15.1b
	P	Summer	0.9a	1.5a	1.6a	1.5a	3.5a	4.5a
		Winter	1.2a	1.5a	1.4a	1.2a	1.7b	3.2b
	K	Summer	12.3a	25.8a	28.0a	27.3a	64.8a	77.2a
		Winter	10.1a	12.6b	13.3b	13.1b	23.0b	66.6b
	Ca	Summer	2.2a	3.4a	3.6a	4.1a	6.3a	6.0a
		Winter	2.6a	3.5a	3.4a	3.4a	6.0a	4.3b
	Mg	Summer	0.9a	1.6a	1.6a	1.8a	5.0a	6.5a
		Winter	0.9a	1.4a	1.4a	1.5a	2.8b	4.4b
	S	Summer	0.4a	0.7a	0.7a	0.6a	1.0a	1.3b
		Winter	0.6a	0.7a	0.7a	0.6a	0.6a	2.7a
	B	Summer	9.5b	15.7b	17.7b	16.8a	48.0a	50.7b
		Winter	15.0a	24.3a	23.5a	13.7a	27.3b	55.3a
	Cu	Summer	1.83a	3.3a	3.1a	2.8a	5.2a	7.9b
		Winter	2.00a	2.4a	2.0a	1.5a	2.2b	16.4a
	Fe	Summer	7.4a	13.3b	20.9a	14.2a	32.0a	36.9a
		Winter	15.0a	32.1a	15.7a	13.9a	18.6b	38.3a
	Mn	Summer	19.4^{ns}	52.1^{ns}	41.8^{ns}	56.4^{ns}	72.3^{ns}	72.3^{ns}
		Winter	15.9^{ns}	23.7^{ns}	27.9^{ns}	31.5^{ns}	58.0^{ns}	50.5^{ns}
	Zn	Summer	7.0^{ns}	11.8^{ns}	11.9^{ns}	10.9^{ns}	27.9^{ns}	32.6^{ns}
		Winter	10.6^{ns}	13.2^{ns}	14.0^{ns}	12.2^{ns}	22.7^{ns}	35.2^{ns}

Means followed by same letters, between harvest seasons, do not differ from each other by the Tukey test at p<0.05; ns: not significant in E x P interactions.

K and N were the most accumulated nutrients and Cu the least accumulated nutrient in 'Grande Naine' and 'Prata Comum' bunches during all seasons and harvest periods; however, the accumulation of the other nutrients varied according to bunch development. In the last harvest period in the summer, both cultivars showed similar nutrient accumulation order (K > N > Mg > Ca > P > S > Mn > B > Fe > Zn > Cu); however, in the winter, this order was changed among P, Ca, Mg, S, B, Fe and Mn nutrients. The high and constant K accumulation during bunch development corroborates observations of Soares et al. (2008), who emphasize that banana trees have high and continuous absorption of this nutrient until harvest.

Except for calcium and manganese accumulation in 'Prata Comum' cultivar, the other nutrients exhibited quadratic behavior for both cultivars at both harvest seasons (Figures 1. 2 and 3), also following the behavior of dry matter production in bunches. Some functions with quadratic behavior showed decrease in PMS and AC after the beginning of harvest (period 0 - beginning of bunch emission) until periods 1 (opening of the first female bunch) and 2 (opening of the third female bunch), later resuming growth until harvest period 5 (commercial harvest). The production and 50% dry matter and nutrient accumulation in the entire bunch cycle, in general, was reached until periods 3 and 4. However, in the winter, these values were higher than in the summer, indicating that at this season, the bunch takes longer to produce and accumulate half of the total dry matter and nutrients.

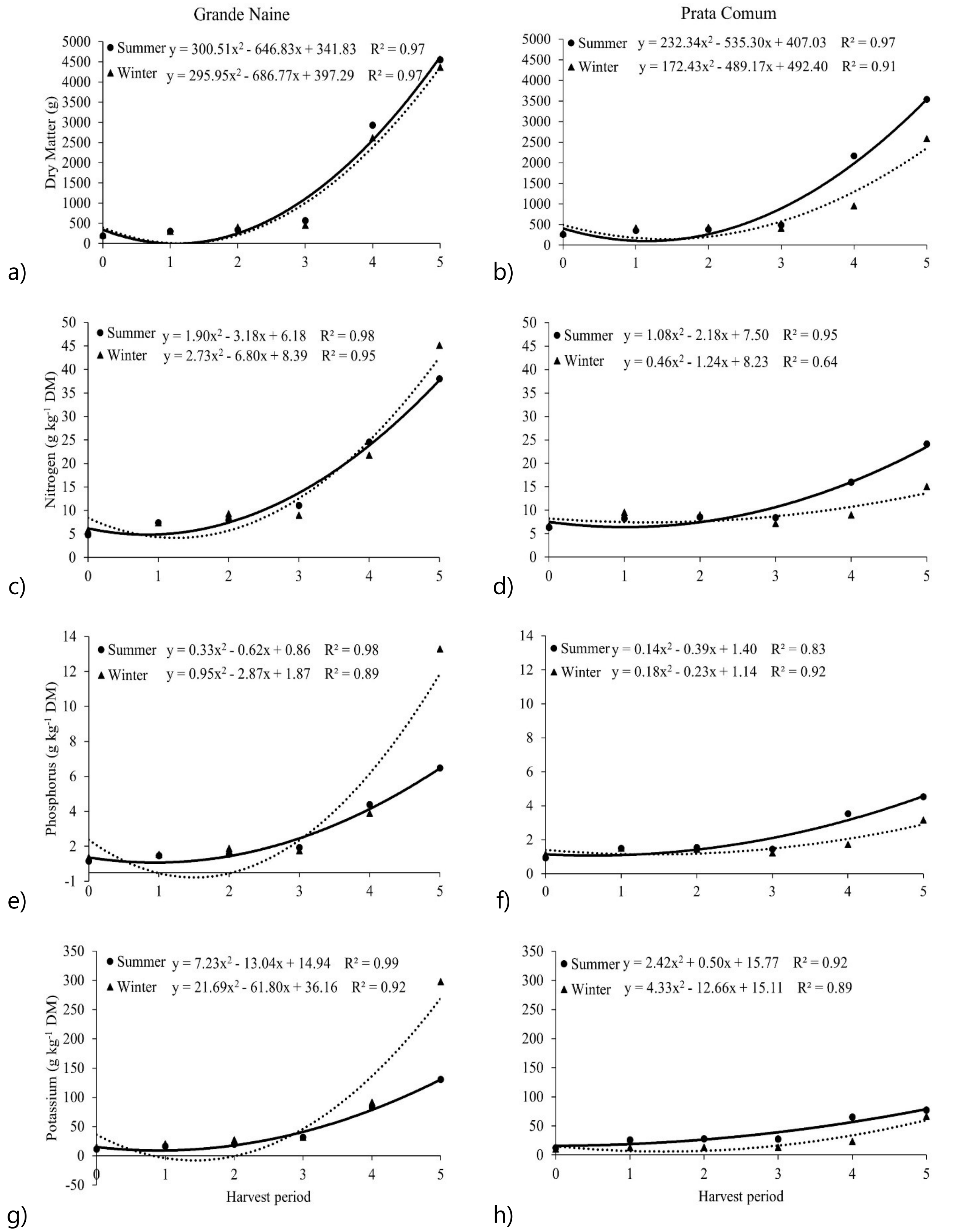

Figure 1. Effects of harvest seasons and periods (0, 1, 2, 3, 4 and 5) on the dry matter (a) (b), nitrogen (c) (d), phosphorus (e) (f) and potassium (g) (h) accumulation in 'Grande Naine' and 'Prata Comum' banana bunches.

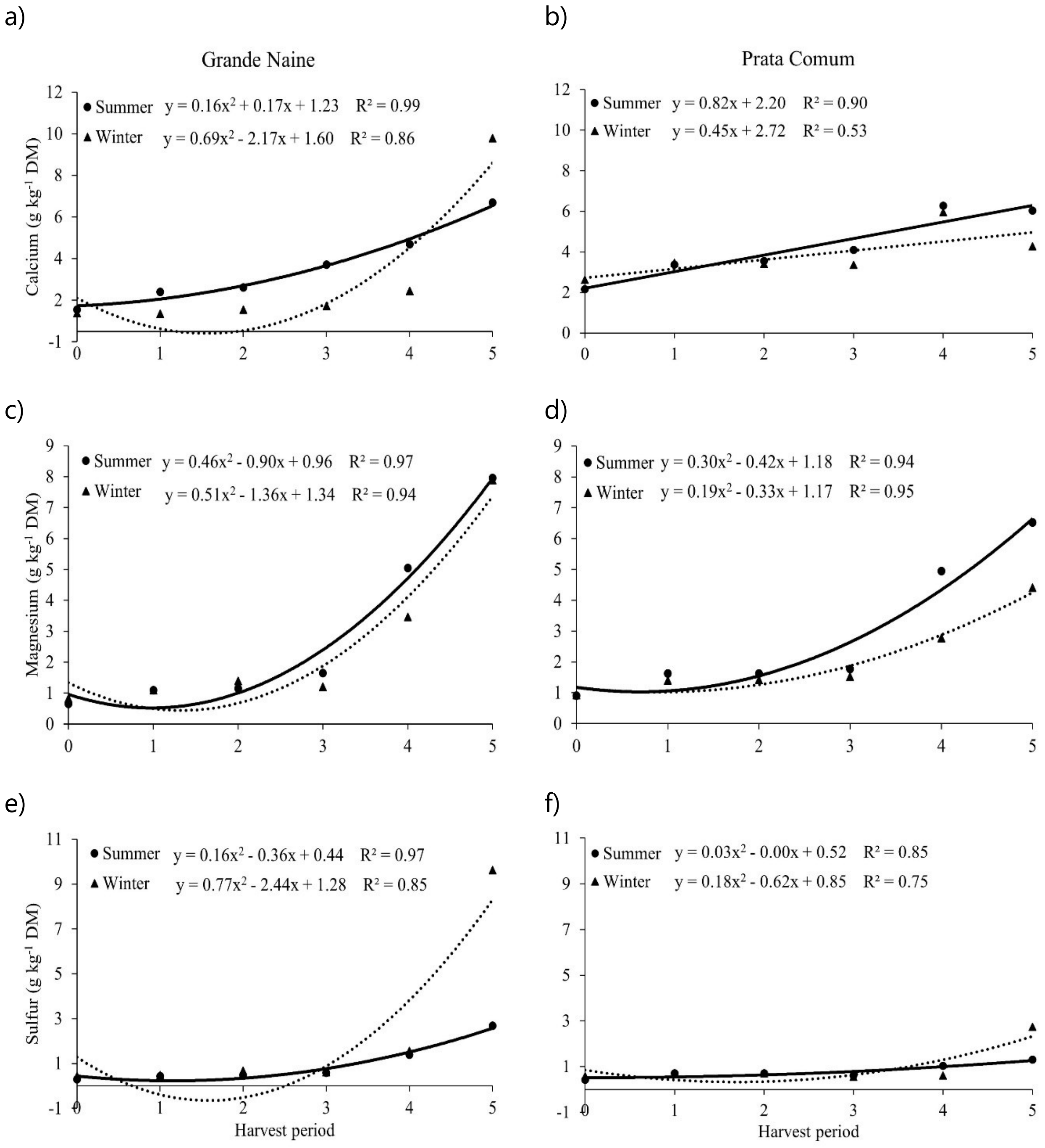

Figure 2. Effect of harvest seasons and periods (0, 1, 2, 3, 4 and 5) on calcium (a) (b), magnesium (c) (d) and sulfur (e) (f) accumulation in 'Grande Naine' and 'Prata Comum' banana bunches.

In harvest period 4 (bunch with 50% development), the operation of removing the male rachis from bunches was performed. This procedure, standard for the crop, aims to increase the bunch yield (SOUTO et al., 2001), allowing fruits to make better use of nutrients that would be used in the male rachis development (LICHTEMBERG; LICHTEMBERG, 2011). Thus, higher PMS and AC values after period 4, as well as the higher growth, are explained by the better use of photoassimilates for bunch development.

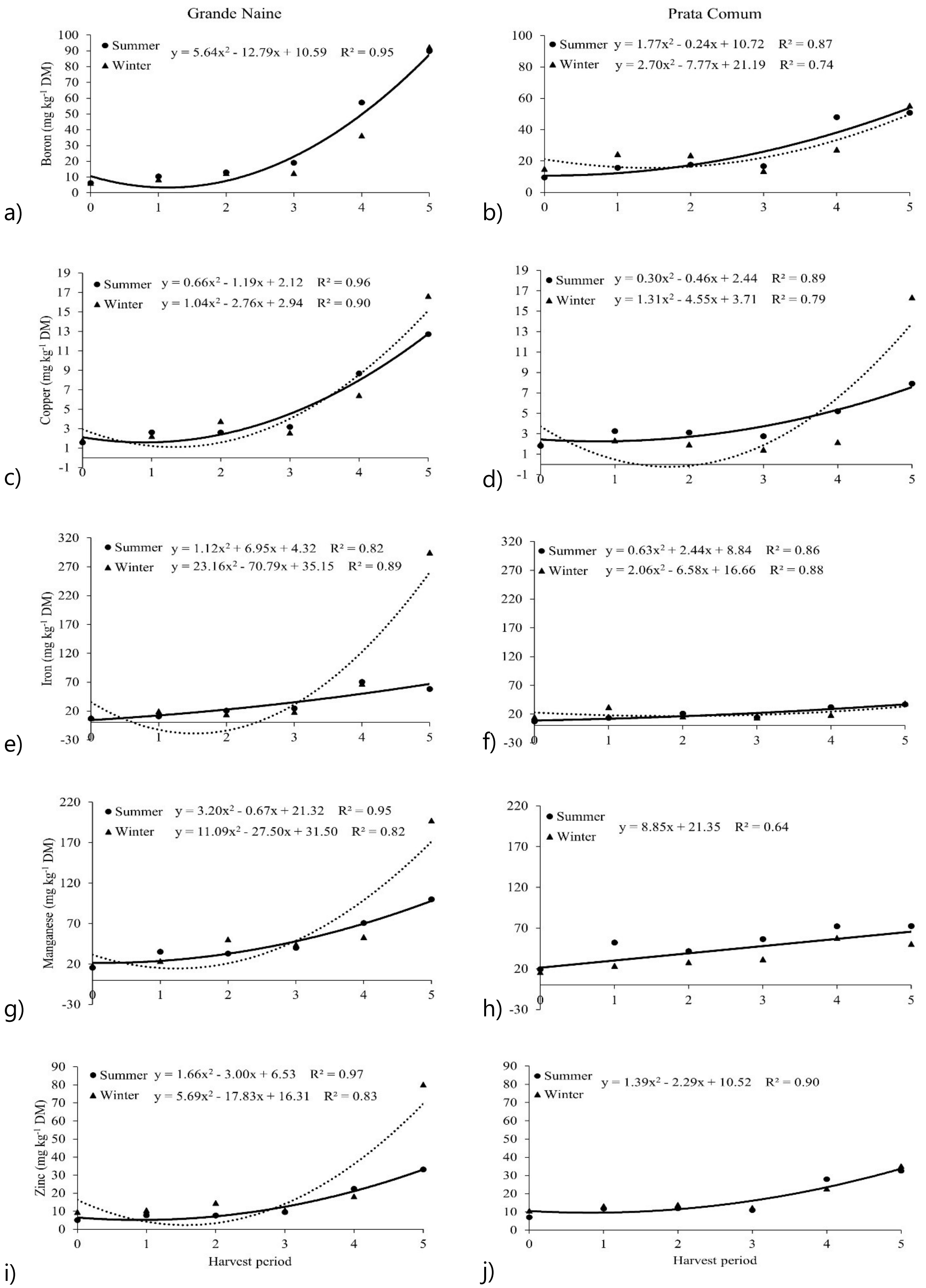

Figure 3. Effect of harvest seasons and periods (0, 1, 2, 3, 4 and 5) on boron (a) (b), copper (c) (d), iron (e) (f), manganese (g) (h) and zinc (i) (j) accumulation in 'Grande Naine' and 'Prata Comum' banana bunches.

The highest yields and final PMS occurred in the summer for both cultivars; however, the highest final AC values were observed in the winter for all nutrients in 'Grande Naine' and only for S, B, Cu Fe and Zn in 'Prata Comum' cultivar, facts that may have been caused by the low rainfall, temperatures and radiation found in the winter period, which causes a decrease in the photosynthetic activity and, consequent conversion into dry matter mass, with greater nutrient accumulation in the bunch. In addition, bunches emitted in the winter tend to remain longer on the plant to reach the harvest point; thus, leading to greater nutrient accumulation. Rodriguez-Zapata et al. (2015) highlight that low temperature is one of the factors that limit crop establishment in certain latitudes, because in addition to increasing the time for bunch development, also exposes it to temperatures that can cause damage to fruits.

The relative growth rate - TCR (Table 4), which expresses the increase in dry matter mass per mass unit already existing in a time interval, showed similar behavior for both cultivars in the periods under study. The highest TCR values in the summer and winter were observed between harvest periods of 2-3 and 0-1, respectively.

In general. TALON (Table 4) did not always follow TCR, corroborating what was observed by some authors such as Alves et al. (2011) in the study on the absorption rate of cauliflower cultivated in substrate; Rozane et al. (2011) when evaluating seedling production of two starfruit cultivars; and Rozane et al. (2013) in the study on nutrient accumulation in starfruit rootstocks grown in nutrient solution.

Some nutrients showed negative TALON values (Table 4) for both cultivars, which indicates that the nutrient did not stop accumulating, but that there was less accumulation compared to the previous period, with greater water allocation in fruits. In the winter. 'Grande Naine' cultivar showed higher nutrient allocation (TALON) in bunches between harvest periods 0 and 1 for N, P, K, Mg, B, Cu and Fe and 'Prata Comum' showed higher rate in the same period for all nutrients.

In the winter. the export of nutrients by 'Grande Naine' fruits, considering the return of stalks to the production area after harvest, was higher for all nutrients (Table 4). In the summer, the nutrient export order for this cultivar was: K > N > Mg > P > Ca > S > Mn > B > Fe > Zn > Cu; and in the winter, the order was: K > N > P > S > Ca > Mg > Fe > Mn > B > Zn > Cu. Nutrients such as P, K, Ca, S, Fe, Mn and Zn were exported twice as much in the winter than in the summer.

'Prata Comum' cultivar showed the opposite behavior for some nutrients. that is, it exported more N, P, K, Ca, Mg and Mn in the summer than in the winter (Table 4). The order of nutrient export for this cultivar in the summer was: K > N > Mg > Ca > P > S > Mn > B > Fe > Zn > Cu; and in the winter, the order was: K > N > Mg > Ca > P > S > B > Mn > Fe > Zn > Cu. Nutrients S and Cu were exported twice as much in the winter than in the summer.

The highest export values of K and N were also observed in other studies: 22.6 kg N ha^{-1} and 63.6 kg K ha^{-1} for 'Prata Anã' and 40.4 kg N ha^{-1} and 154.3 kg K ha^{-1} for 'Grande Naine' (SOARES et al., 2008); 25.7 kg N ha^{-1} and 199.9 kg K ha^{-1} for 'Prata Anã' and 31.4 kg N ha^{-1} and 127.9 kg K ha^{-1} for 'Grande Naine' (HOFFMANN et al., 2010a; HOFFMANN et al., 2010b), both in irrigated cultivation areas in the state of Ceará. However, the absolute values for these nutrients differed in relation to those of the present study (Table 4), being higher for the rainfed condition.

Table 4. Relative growth rate (TCR). organogenic net accumulation rate (TALON) and nutrient export (N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, and Zn) for 'Grande Naine' and 'Prata Comum' cultivars in the summer and winter seasons

'Grande Naine' (Summer)

Interval (days)	TCR	TALON										
		N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
0-7	69.0	1.52	0.18	2.91	0.49	0.26	0.08	2.49	0.62	2.35	12.03	1.52
7-10	39.3	0.65	0.08	3.71	0.22	0.06	0.04	2.62	-0.05	9.58	-2.42	-0.07
10-14	129.5	1.76	0.22	6.91	0.62	0.29	0.07	3.50	0.33	2.41	4.01	1.03
14-64	32.9	0.19	0.03	0.71	0.01	0.05	0.01	0.53	0.08	0.64	0.43	0.18
64-108	10.0	0.08	0.01	0.29	0.01	0.02	0.01	0.20	0.02	-0.08	0.18	0.07
Export		88.3	12.6	274.2	11.6	18.3	5.1	203.5	30.7	122.4	207.8	76.6

'Grande Naine' (Winter)

Interval (days)	TCR	TALON										
		N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
0-3	114.6	2.12	0.21	7.28	-0.04	0.34	0.06	3.05	0.58	14.00	7.39	1.44
3-11	36.2	0.67	0.12	2.58	0.07	0.11	0.08	1.49	0.55	-1.65	9.61	1.45
11-20	13.1	-0.10	-0.04	1.02	0.05	-0.05	-0.02	-0.06	-0.31	1.04	-1.48	-1.03
20-82	28.3	0.17	0.03	0.80	0.01	0.03	0.01	0.31	0.05	0.64	0.12	0.10
82-123	12.5	0.17	0.07	1.47	0.05	0.03	0.06	0.40	0.07	1.63	1.03	0.44
Export		110.8	31.7	737.0	23.1	19.4	23.9	228.1	41.2	732.6	491.0	199.2

'Prata Comum' (Summer)

Interval (days)	TCR	TALON										
		N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
0-7	42.7	0.88	0.28	6.33	0.59	0.33	0.13	2.91	0.68	2.75	15.26	2.22
7-10	24.7	0.25	0.04	1.73	0.12	0.01	-0.03	1.68	-0.16	6.95	-9.44	0.04
10-14	62.6	-0.04	-0.07	-0.35	0.33	0.07	-0.06	-0.53	-0.22	-3.88	8.05	-0.57
14-109	15.7	0.07	0.02	0.35	0.02	0.03	0.00	0.29	0.02	0.17	0.15	0.16
109-150	11.9	0.07	0.01	0.11	0.00	0.01	0.00	0.02	0.02	0.04	0.00	0.04
Export		45.7	8.4	139.4	10.6	12.6	2.4	95.8	15.4	65.6	131.8	60.7

'Prata Comum' (Winter)

Interval (days)	TCR	TALON										
		N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
0-6	64.8	1.37	0.17	1.31	0.43	0.22	0.06	4.61	0.20	8.41	4.04	1.32
6-14	2.5	-0.16	-0.03	0.21	-0.02	0.01	-0.01	-0.26	-0.12	-4.81	1.20	0.23
14-21	-8.3	-0.62	-0.07	-0.11	-0.02	0.03	-0.05	-3.39	-0.18	-0.71	1.09	-0.61
21-63	20.4	0.07	0.02	0.37	0.10	0.05	0.00	0.51	0.03	0.18	0.98	0.39
63-118	18.0	0.07	0.02	0.48	-0.02	0.02	0.02	0.32	0.16	0.22	-0.09	0.14
Export		27.7	5.8	115.4	7.8	8.3	5.1	105.8	31.4	68.3	94.2	64.4

Conclusion

In the summer. ‘Grande Naine’ and ‘Prata Comum’ cultivars present higher dry matter production in the commercial harvest. However, the highest TCR values are observed between periods 2 and 3 in the summer, and between 0 and 1 in the winter, for both cultivars.

K and N are the most accumulated nutrients and Cu the least accumulated in 'Grande Naine' and 'Prata Comum' bunches, both in the summer and winter. The order of nutrient export for ‘Grande Naine’ cultivar is K > N > Mg > P > Ca > S > Mn > B > F > Zn > Cu, in the summer and K > N > P > S > Ca > Mg > Fe > Mn > B > Zn > Cu, in the winter. The order of ‘Prata Comum’ exports is K > N > Mg > Ca > P > S > Mn > B > Fe > Zn > Cu, in the summer and K > N > Mg > Ca > P > S > B > Mn > Fe > Zn > Cu, in the winter.

References

ALVARES, C.A.; STAPE, J. L.; SENTELHAS, P. C.; GONÇALVES, J. L. M.; SPAROVEK, G. Koppen’s climate classification map for Brazil. **Meteorologische Zeitschrift**, Stuttgart, v.22, n.6, p.711-728, 2013.

ALVES, A. U.; PRADO, R. M.; CORREIA, M. A. R.; GONDIM, A. R. O.; CECÍLIO FILHO, A. B.; POLITI, L. S. Couve-flor cultivada em substrato: marcha de absorção de macronutrientes e micronutrientes. **Ciência e Agrotecnologia**, Lavras, v.35, n.1, p.45-55, 2011.

BATAGLIA, O. C.; FURLANI, A. M. C.; TEIXEIRA, J. P. F.; FURLANI, P. R.; GALLO, J. R. Métodos de análise química de plantas. Campinas: Instituto Agronômico, 1983. 48p. (Boletim Técnico. 78).

BORGES, A. L.; SILVA, J. T. A. Diagnose foliar na cultura da banana. In: PRADO, R. M. (Ed.). **Nutrição de plantas – diagnose foliar em frutíferas**. Jaboticabal: Unesp, 2012. p.199-226.

DEUS, J. A. L.; NEVES, J. C. L.; CORRÊA, M. C. M.; PARENT, S. E.; NATALE, W.; PARENT, L. E. Balance design for robust foliar nutrient diagnosis of “Prata” banana (*Musa spp*.). **Scientific Reports**, v.8, p.1-7, 2018.

DEUS, J. A. L.; NEVES, J. C. L.; LIMA NETO, A. J.; NATALE, W.; ALVAREZ V., V. H.; ALBUQUERQUE, F. M. R. Partitioning of macronutrients and nutritional efficiency in fertigated prata banana. **Revista Brasileira de Fruticultura,** Jaboticabal, v.42, n.4, p.1-13, 2020a.

DEUS, J. A. L.; NEVES, J. C. L.; SOARES, I.; ALVAREZ V., V. H.; LIMA NETO, A. J.; ALBUQUERQUE, F. M. R.; SANTOS, L. L.; NATALE, W. Multivariate selection and classification of mathematical models to estimate dry matter partitioning in the fertigated Prata banana in the Northeast Brazil**. Field Crops Reasearch,** v.255, 2020b.

FOOD AND AGRIULTURE ORGANIZATION OF THE UNITED NATIONS (FAO). Faostat. **Crop production data**. Disponível em: http://www.fao.org/faostat/en/#data/QC. Acesso em: 28 jan. 2021.

HOFFMANN, R. B.; OLIVEIRA, F. H. T.; SOUZA, A. P.; GHEYI, H. R.; SOUZA JÚNIOR, R. F. Acúmulo de matéria seca e de macronutrientes em cultivares de bananeira irrigada. **Revista Brasileira de Fruticultura**, Jaboticabal, v.32, n.1, p.268-275, 2010a.

HOFFMANN, R. B.; OLIVEIRA, F. H. T.; GHEYI, H. R.; SOUZA, A. P.; ARRUDA, J. A. Acúmulo de matéria seca. absorção e exportação de micronutrientes em variedades de bananeiras sob irrigação. **Ciência e Agrotecnologia**, Lavras, v.34, n.3, p.536-544, 2010b.

INSTITUTO DE ECONOMIA AGRÍCOLA (IEA). Secretaria de Agricultura e Abastecimento. **Estatísticas da produção paulista**. Disponível em: http://ciagri.iea.sp.gov.br/nia1/subjetiva.aspx?cod_sis=1&idioma=1. Acesso em 28 jan. 2021.

LICHTEMBERG, L. A.; LICHTEMBERG, P. S. F. Avanços na bananicultura brasileira. **Revista Brasileira de Fruticultura**, Jaboticabal, v. especial, p.26-36, 2011.

MOREIRA, R. S**. Banana: teoria e prática de cultivo**. 2ed. São Paulo: Fundação Cargill, 1999. (CD-ROM).

R CORE TEAM. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. 2021. Disponível em: www.R-project.org/.

RAIJ, B. V.; ANDRADE, J. C.; CATARELLA, H.; QUAGGIO, J. A**. Análise química para avaliação da fertilidade de solos tropicais**. Campinas: IAC, 2001. 285p.

RAIJ, B. V.; CANTARELLA, H.; QUAGGIO, J. A.; FURLANI, A. M. C. **Recomendações de adubação e calagem para o Estado de São Paulo**. 2ed. Campinas: Instituto Agronômico/Fundação IAC, 1997. 285p.

RATKE, R. F.; SANTOS, S. C.; PEREIRA, H. S.; SOUZA, E. D.; CARNEIRO, M. A. C. Desenvolvimento e produção de bananeiras Thap Maeo e Prat-anã com diferentes níveis de adubação nitrogenada e potássica. **Revista Brasileira de Fruticultura**, Jaboticabal, v.34, n.1, p.277-288, 2012.

RODRÍGUEZ-ZAPATA, L. C.; GIL, F. L. E.; CRUZ-MARTÍNEZ, S.; TALAVERA-MAY, C. R.; CONTRERAS-MARÍN, F.; FUENTES, G.; SAURI-DUCH, E.; SANTAMARÍA, J. M. Preharvest foliar applications of glycine-betaine protects banana frutis from chilling injury during the postharvest stage. **Chemical and Biological Technologies in Agriculure**, v.2, n.8, p.1-10, 2015.

ROMERO, J. O.; ZAMORA, O. P. Tensión de humedad del suelo y fertilización nitrogenada em plátano (Musa AAA Simmonds) cv. Gran Enano. **Agrociencia,** v.40, p.149-162, 2006.

ROZANE, D. E.; PRADO, R. M.; NATALE, W.; ROMUALDO, L. M.; SOUZA, H. A.; SILVA, S. H. M. G. Produção de mudas de caramboleiras 'B-10' e 'Golden Star': I – Parâmetros biológicos. **Revista Brasileira de Fruticultura**, Jaboticabal, v.33, n.4, p.1300-1307, 2011.

ROZANE, D. E.; PRADO, R. M.; NATALE, W.; ROMUALDO, L. M.; FRANCO, C. F. Caracterização biométrica e acúmulo de nutrientes em porta-enxertos de caramboleira cultivada em solução nutritiva. **Revista Ciência Agronômica**, Fortaleza, v.44, n.3, p.426-436, 2013.

SOARES, F. A. L.; GHEYI, H. R.; OLIVEIRA, F. H. T.; FERNANDES, P. D.; ALVES, A. N.; SILVA, F. V. Acúmulo, exportação e restituição de nutrientes pelas bananeiras 'Prata-anã' e 'Grande Naine'. **Ciência Rural,** Santa Maria, v.38, n.7, p.2054-2058, 2008.

SOARES, F. A. L.; ALVES, A. N.; GHEYI, H. R.; UYEDA, C. A. Acúmulo de matéria seca e distribuição de nutrientes em duas cultivares de bananeiras irrigadas com água moderadamente salina. **Revista Brasileira de Ciências Agrárias**, Recife, v.6, n.2, p.321-330, 2011.

SOUTO, R. F.; RODRIGUES, M. G. V.; MENEGUCCI, J. L. P. Efeito da retirada da inflorescência masculina na precocidade da colheita e produção da bananeira 'Prata-anã'. sob irrigação na região norte de Minas Gerais. **Revista Brasileira de Fruticultura**, Jaboticabal, v.23, n.2, p.257-260, 2001.

WELBANK, P. J. The effects of competition with Agropyron repens and of nitrogen and water supply on the nitrogen content of Impatiens parviflora. **Annals of Botany**, v.26, p.361-373, 1962.