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Fluctuations of Production and Quality of Bananas Under Marginal Tropical Climate

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Abstract

The knowledge of the inter-seasonal fluctuations in characteristics of fruit quality and production is important for management of plants, prediction of yield and marketing strategies. This study aims to evaluate how the climatic conditions prevailing in the month of harvest impact bunch mass and variability of the size and color of the banana fruit 'Nanica' and 'Prata' cultivated under marginal tropical climate. The experiments were carried in Registro, Ribeira Valley region, São Paulo, Brazil, in a completely randomized design with 24 treatments (months of bunch harvest) and ten replications, for each cultivar. Cyclic seasonal fluctuations in production were found in for the two cultivars, with the lowest bunch mass (BM), fruit size consistently recorded between July and February associated with lower global solar radiation (Rad) and temperature (T) of the harvest month, but not precipitation (Ppt). The extension of monthly fluctuations in BM were similar to 'Prata' (18.95±3.31 kg) and 'Nanica' (29.51±4.69 kg). Independent of the harvest month, there was a trend of greater variability for fruit length (FL) and lower for fruit diameter (FD) between fruits of the different positions in the bunch. The correlations between Rad or T of harvest month with BM, FL, FD and SL were all positive. For both cultivars, the shelf life (SL) was longer for fruits of the last hand. There were also positive correlations between Rad or T with SL. The decrease of peel color characteristics of the 'Nanica' fruit was associated with cold fronts from autumn to spring and chilling injury, with higher intensity in the last hand.

Keywords: chilling, climate transition, cold fronts, *Musa* spp., seasonality, Ribeira Valley

1. Introduction

Banana (*Musa* spp., Musaceae family) is one of the most important fruit crops cultivated in more than 130 tropical and subtropical countries (El-Mahdy et al., 2018). Its fruits play an important role in the healthy nutrition of all ages (Fu et al., 2018).

Banana is a plant of tropical origin, that under sufficient water supplies, growth and yield are mainly determined by temperature (Robinson & Saúco, 2012). Moderate temperature (20-30 °C) is an essential requirement for appropriate vegetative growth, fruit development and maximum yield (Robinson & Saúco, 2012). Chilling (temperatures lower than 20 °C) is one of the factors that limits the establishment of banana plantations at certain latitudes, and has an impact on the growth and development of plants, yield and fruit quality (Zapata et al., 2015).

Brazil is a very large country with a diverse climate, with latitude ranges from 5º N to 33º S (Pommer & Barbosa, 2009), however with most of this territory considered adequate for banana cultivation. Because of this, banana is cultivated throughout the Brazilian territory, occupying an area of approximately 467 thousand ha in 2017, with an estimated production of 7,185 million tons of fruits (Martins & Turco, 2018). Brazil stands out among world producers of banana, but her production is almost entirely targeted at the domestic market due to its large population and high per capita consumption, however, exports are growing (Coltro & Karaski, 2019).

Ribeira Valley situated in southeastern Brazil, between the south of São Paulo and the north of Paraná state (located between 23.78° S and 25.30° S latitudes), it is one of the main banana producing regions of Brazil. The production of the region has as target market the greater São Paulo, the largest metropolitan region in Brazil, which has about 21.2 million inhabitants and one of the ten most populous metropolitan regions in the world (Coltro & Karaski, 2019).

In general, the Ribeira Valley climate is tropical without dry season (Af) (Alvares et al., 2013), considered ideal for banana cultivation as there is plenty of heat and high humidity (Coltro & Karaski, 2019). Besides Af, some cities that make up the region exhibit other climatic types, such as, the climate tropical with dry winter (Aw), humid subtropical with hot summer (Cfa) (Alvares et al., 2013) and tropical of monsoon (Am) (Rolim et al., 2007), which interferes differently in the productive potential of the region. In addition, the region also presents a marginal tropical climate, characterized by the recurrent occurrence of chilling in plants and fruits still in the field, promoted by the entry of non-occasional cold fronts of autumn and spring.

The banana cv. Nanica (*Musa* spp. AAA group, Cavendish subgroup, cv. Nanica) and banana cv. Prata (*Musa* spp. AAB group, Prata subgroup) are the main genotypes grown in the region, corresponding respectively to 70% and 21% of the fruits marketed (Colto & Kurashi, 2019). 'Prata' bananas are valued in the Brazilian market due to their attractive organoleptic characteristics, cold tolerance, even when exposed to low temperatures (10 °C) in postharvest, contributes to the potential of these fruit to with stand long-term storage (Der Agopian et al., 2011), more resistant to postharvest injuries and diseases (Colto & Kurashi, 2019). For these reasons, began to be exported to Europe recently (Colto & Kurashi, 2019). 'Prata' banana is clone tolerant to cool conditions in yield (Crane et al., 2005), while 'Nanica' less tolerant (Lima et al., 2018), with great potential for export.

Bunch mass, banana size or fresh weight, peel color and pulp composition is under the control of complex interactions between genotype, environmental factors (radiation, temperature, precipitation, soil moisture, altitude, soil fertility, air moisture, stress etc) and farming practices (irrigation, hand pruning, bagging *etc*).

For banana, the size (length and diameter) and color are important criteria for quality and acceptability. The developmental status (age) and size of banana fruit varies across the bunch because of differences in the time when the flowers of the inflorescence emerge (Davey, 2007) what contributes to yield variability as the whole bunch is harvested at the same time (Jullien et al., 2001a). The peel color is precise indicator of the degree of maturation of the fruit.

The knowledge of the inter-seasonal fluctuations in these characteristics, as well as in the production itself is important for management of critical phases of plant development and fruit quality in field, as well as for accurate prediction of the weekly yield and marketing strategies. This study aims to evaluate how the climatic conditions prevailing in the month of harvest impact bunch mass and variability of the size and color of the banana fruit 'Nanica' and 'Prata' cultivated under marginal tropical climate.

2. Method

2.1 Plant Material and Experimental Area

The research was conducted on two commercial production farms, located at Registro, state of São Paulo, Brazil, 24º29′15″ S latitude, 47º50′37″ W longitude and 25 m above sea level. The climate of the region according to the Köppen's classification is Af; tropical without dry season (Alvares et al., 2013). The soil is classified in the Brazilian System of Classification of Soils as Haplic Cambisol (Embrapa Solos, 2013).

The banana cv. Prata (*Musa* spp. AAB group, Prata subgroup) was planted in 2011 in a density of 1333 plants ha^{-1} and banana cv. Nanica (*Musa* spp. AAA group, Cavendish subgroup, cv. Nanica), in 2012 in a density of 1600 plants ha^{-1}, both using pest-free banana tissue-cultured plants. All treatments necessary for good production were carried out.

2.2 Experimental Design

The bunch mass was evaluated adopting a completely randomized design with 24 treatments (months of bunch harvest) and ten replications, for each cultivar. Fruit size, peel color and shelf life was evaluated adopting the experimental design split-plot considering in the plot, the month of harvest of the bunch, and in the subplot, three positions of fruit in the bunch, the proximal (hand 1), medium (hand 4) and distal (last hand), with ten replicates.

Fruit size, peel color and shelf life was evaluated adopting the experimental design split-splot considering in the plot, the month of harvest of the bunch, and in the subplot, the positions of fruit in the bunch, with ten replicates.

2.3 Procedures and Evaluations

Monthly, in the last week of monthly, were collected ten bunches of each cultivar. The sampling was randomly, adopting as criterion for harvest the minimum diameter of 3 mm in the fruits of the last hand. The bunch mass, the average diameter and length of fruits of hand 1, hand 4 and last hand of each bunch were all determined. The mass of bunches was evaluated in digital scale, while the length and the diameter of the fruit, respectively, were evaluated with tape measure and digital caliper.

The fourth hand of bunch was stored in a chamber at 25 °C without ethylene treatment until the complete maturation of fruits or when the peel color was completely yellow, corresponding to stage 6 of the Von Loesecke scale (1950). At this moment, the shelf life of fruits and peel color were determinate.

The shelf life corresponded to the number of days needed for the fruit to reach full maturation. The color of the peel of the green and ripe fruit was measured at four locations around equatorial region on each fruit using a colorimeter (CR-400, Minolta, Tokyo, Japan) calibrated using a standard white plate. The illuminant was D65 and color was measured using the CIE L*a*b* system. L* denotes brightness (0 = black and 100 = white) and chromatic co-ordinates a* (+a* = green and -a*= red), b* (+b* = yellow and -b* = blue). The hue angle (h^o) and chromaticity (C*) were calculated by the equations below:

$$h^o = \tan^{-1}(b^*/a^*) \tag{1}$$

$$C^* = (a^{*2} + b^{*2})^{1/2} \tag{2}$$

Hand 4 was stored at 25 °C and 85-95% relative humidity up to stage 6 of the Von Loeseck scale (1950) was reached for shelf life determination and analyses in maturity.

Also were collected data in a meteorological station near the experimental area, such as monthly-accumulated global solar radiation (Rad), monthly-accumulated precipitation (Ppt), maximum daily monthly-averaged air temperature (Tmax), minimum daily monthly-averaged air temperature (Tmin), maximum daily monthly-occurred air temperature (Tmaxm), minimum daily monthly-occurred air temperature (Tminm).

2.4 Statistical Analysis

The statistical analysis were carried out with software Sisvar 4.2 (Ferreira, 2011). Data from the two cultivars were submitted separately to the Bartlett test and analysis of variance followed by the F-test. The differences in means for positions in the bunch were compared by Tukey's test. Pearson's correlation coefficients (r) were calculated between variables and measured significance by t-test.

3. Results

3.1 Cultivar Prata

The average fruit length (FL) was 18.71±1.36 cm, and the interaction between harvest month and fruit position in the bunch was significant. Regardless of position, the longest fruits were harvested in Oct/14, and the shortest in Jul/13 (Figure 1). In hand 1, length ranged from 18.00 to 24.07 cm, in hand 4, from 16.10 to 22.83 cm, and in the last hand, from 15.17 to 21.43 cm, which indicates variation of 6 cm in the different positions. However, there was great variation in FL for the three positions in the bunch, depending on the harvest month: absence of difference (6 months); fruits of hand 1 and hand 4, which did not differ from each other and were longer than fruits of the last hand (5 months); fruits of hand 1 were longer than fruits of hand 4 and last hand, which did not differ from each other (4 months); and difference between the three positions (9 months).

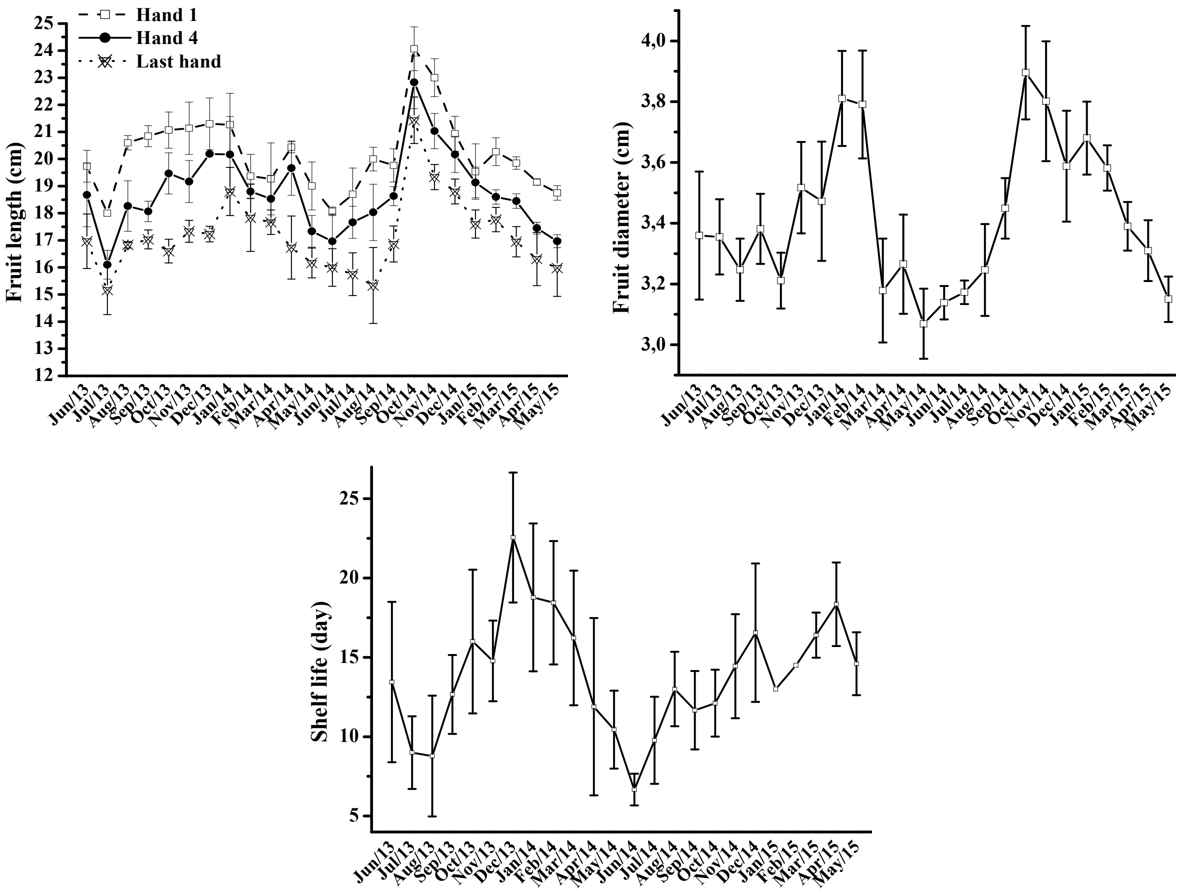


Figure 1. Effect of the harvest month or the interaction of harvest month and position in the bunch on the length fruit, diameter fruit and shelf life of fruits of the 'Prata' banana

Note. Vertical bars represent the standard deviation of the mean (for length n = 10 and for diameter and shelf life n = 30).

The average fruit diameter (FD) was 3.42±0.24 cm, influenced by the isolated effects of fruit position in the bunch and harvest month. There was no variation between hand 1 (3.46±0.30 cm) and hand 4 (3.47±0.29 cm), which presented FD greater than fruits of the last hand (3.39±0.31 cm) ($p < 0.05$). The reduction in FD values between hand 1 and last hand was only 2.19%, and the minimum standard adopted (3.00 cm) was exceeded only in harvest of Mar/14 (Figure 1). As for length, the average FD value was higher in Oct/14 (3.90 cm) and lower in May/14 (3.07 cm).

Bunch mass (BM) varied between the different harvest months from 14.01 to 24.76 kg, with average value of 18.95±3.31 (Figure 2). Despite differences in BM between Jun/13-May/14 (20.08 kg) and Jun/14-May/15 production cycles (17.83 kg), these were not significant ($p = 0.10$) (Figure 3). There were also no significant differences between cycles for FL in the three bunch positions (hand 1, $p = 0.99$; hand 4, $p = 0.84$ and last hand, $p = 0.59$), as well as for average FD ($p = 0.54$).

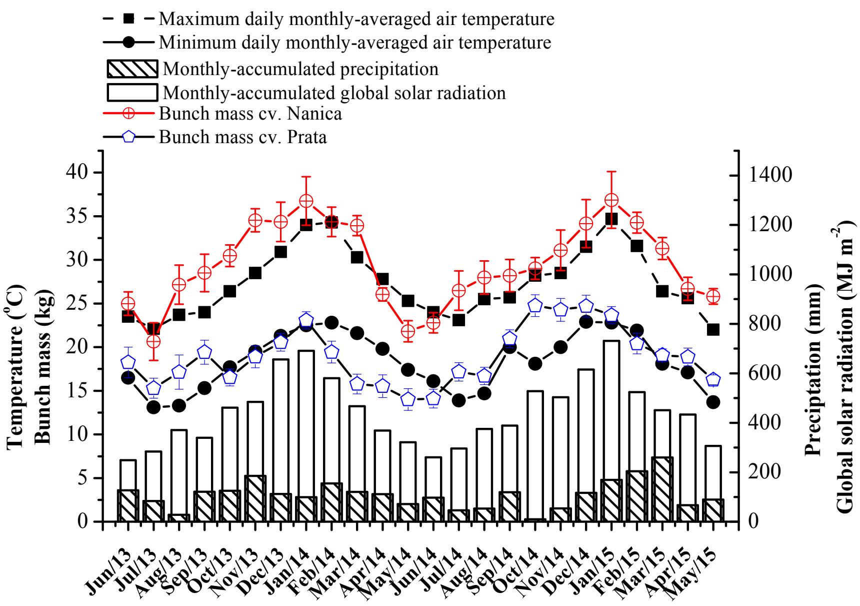
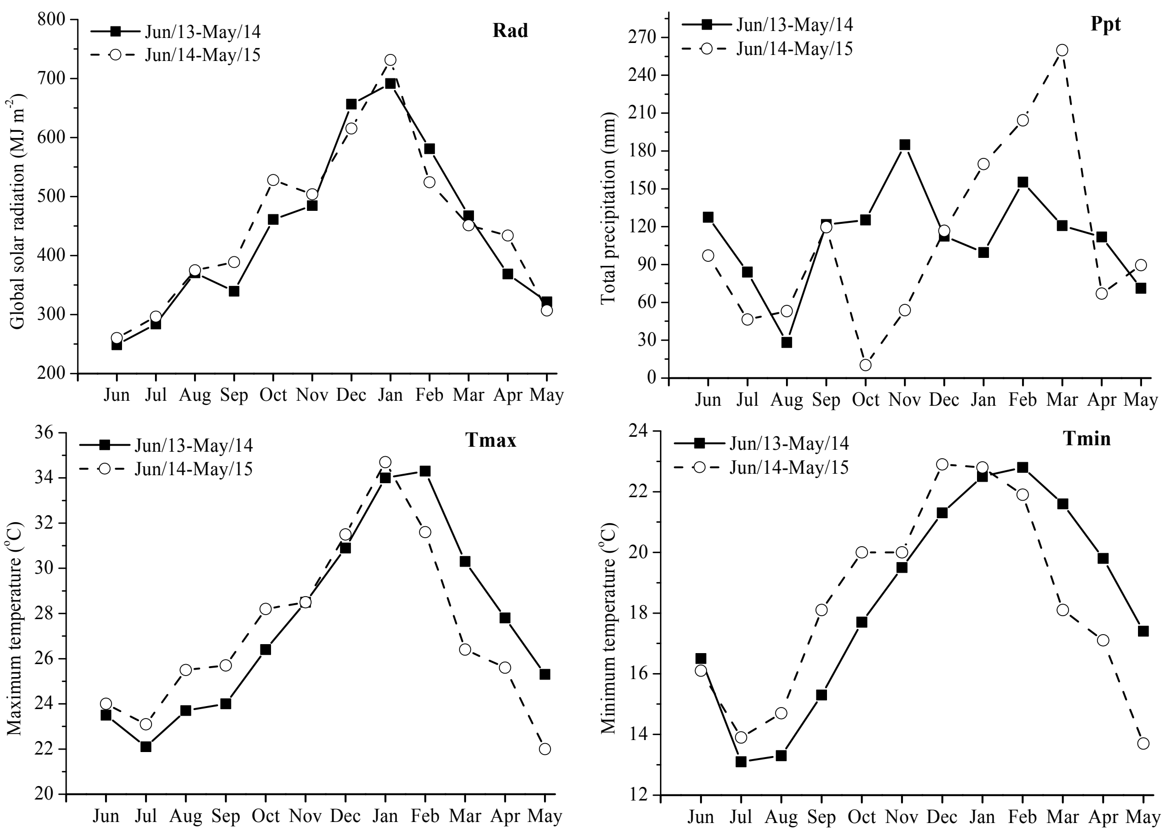


Figure 2. Climate conditions and means with standard deviations of bunch mass harvested during the experimental period

Note. Vertical bars represent the standard deviation of the mean (n = 10).



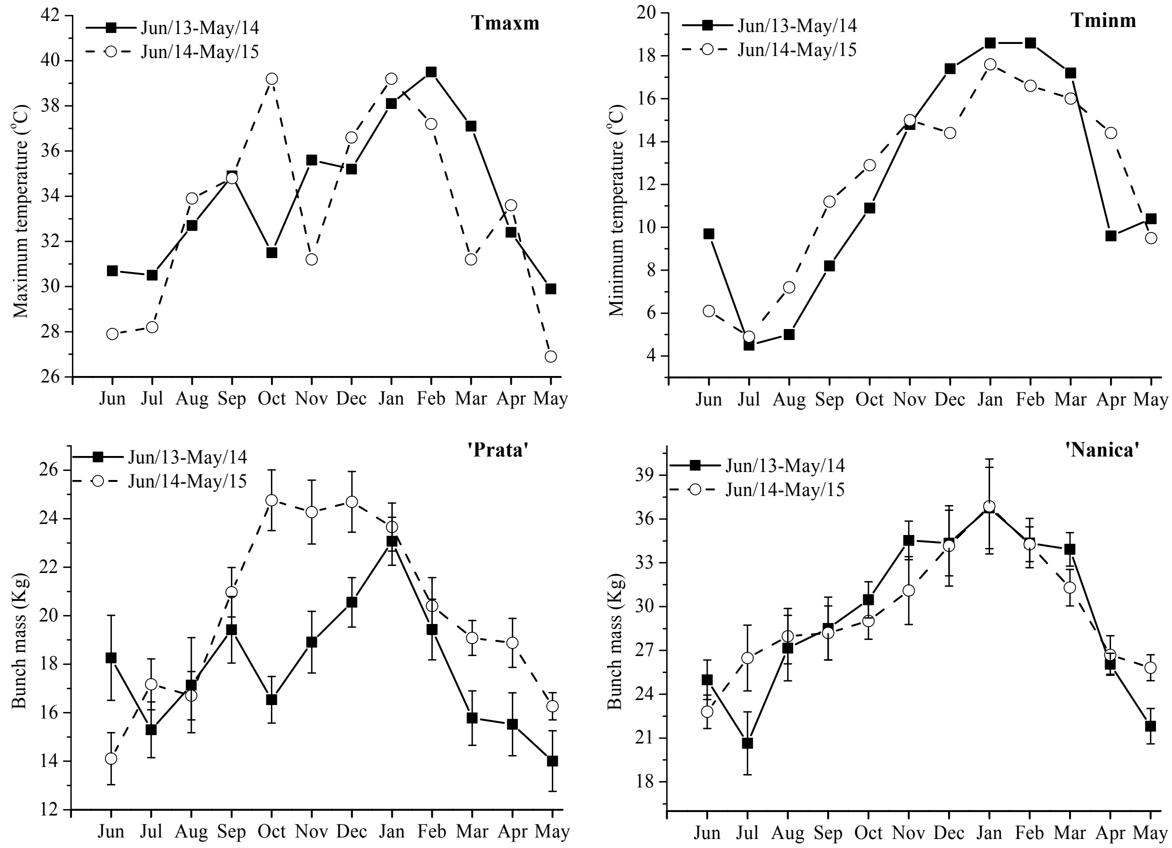


Figure 3. Monthly-accumulated global solar radiation (Rad), monthly-accumulated precipitation (Ppt), maximum daily monthly-averaged air temperature (Tmax), minimum daily monthly-averaged air temperature (Tmin), maximum daily monthly-occurred air temperature (Tmaxm), minimum daily monthly-occurred air temperature (Tminm), bunch mass of 'Prata' and 'Nanica' banana

Note. Vertical bars represent the standard deviation of the mean (n = 10).

BM positively correlated with all climatic variables of the harvest month, except for precipitation (Ppt) (Table 1), which also did not show significant correlation with FL or FD. Rad was the climatic variable with the strongest correlation with BM (r = 0.71) ($p < 0.05$). Except for FL in hand 1, which was only significantly influenced by Rad, FL in the other hands and the average FD showed significant correlations with Rad, Tmax, Tmin, Tmaxm and Tminm, and there was a trend of stronger correlation with Rad (Table 1).

Table 1. Correlation of Pearson (r) between climatic variables and variables of bunch production, size and color of fruit peel of 'Prata' banana (n = 240)

	BM	FLH1	FLH4	FLLH	FD	SL
Rad	**0.71**	**0.45**	**0.65**	**0.66**	**0.76**	**0.67**
Ppt	0.13	-0.08	-0.01	0.18	0.33	0.36
Tmax	**0.60**	0.32	**0.61**	**0.66**	**0.73**	**0.59**
Tmin	**0.57**	0.30	**0.59**	**0.69**	**0.69**	**0.60**
Tmaxm	**0.62**	0.40	**0.58**	**0.64**	**0.66**	**0.46**
Tminm	**0.59**	0.28	**0.51**	**0.66**	**0.65**	**0.79**

Note. Marked coefficients are significant at $p < 0.05$.

Rad, monthly-accumulated global solar radiation; Ppt, monthly-accumulated precipitation; Tmax, maximum daily monthly-averaged air temperature; Tmin, minimum daily monthly-averaged air temperature; Tmaxm, maximum daily monthly-occurred air temperature; Tminm, minimum daily monthly-occurred air temperature.

BM, bunch mass; FLH1, fruit length of hand 1; FLH4, fruit length of hand 4; FLLH, fruit length of last hand; fruit diameter; SL, shelf life.

Shelf life (SL) was influenced by the harvest month and fruit position in the bunch in an isolated way ($p < 0.05$). SL ranged from 6.67 to 22.56 days, with average value of 13.92 days, and the month with the highest value was Oct/14, and the lowest was May/14 (Figure 2). Regarding position, fruits of hands 1 and 4 did not differ regarding SL, which had mean value of 12.93 days, which was slightly longer when compared to the last hand, which matured in 14.60 days ($p < 0.05$). SL did not differ between production cycles (Jun/13-May/14 and Jun/14-May/15) ($p = 0.52$). All climatic variables, except for precipitation, showed positive correlations with SL (Table 1).

Peel color characteristics were independent of fruit position in the bunch and varied depending on the harvest month for brightness (L*) from 72.30 to 76.05, chromaticity (C*) from 46.34 to 60.25, or hue angle (h^o) from 85.82 to 89.96 (Figure 4), without showing significant abnormalities and correlations with isolated climatic variables. Peel color characteristics also did not vary between the first and second production cycles (L*, $p = 0.15$; C*, $p = 0.63$ and h^o, $p = 0.09$).

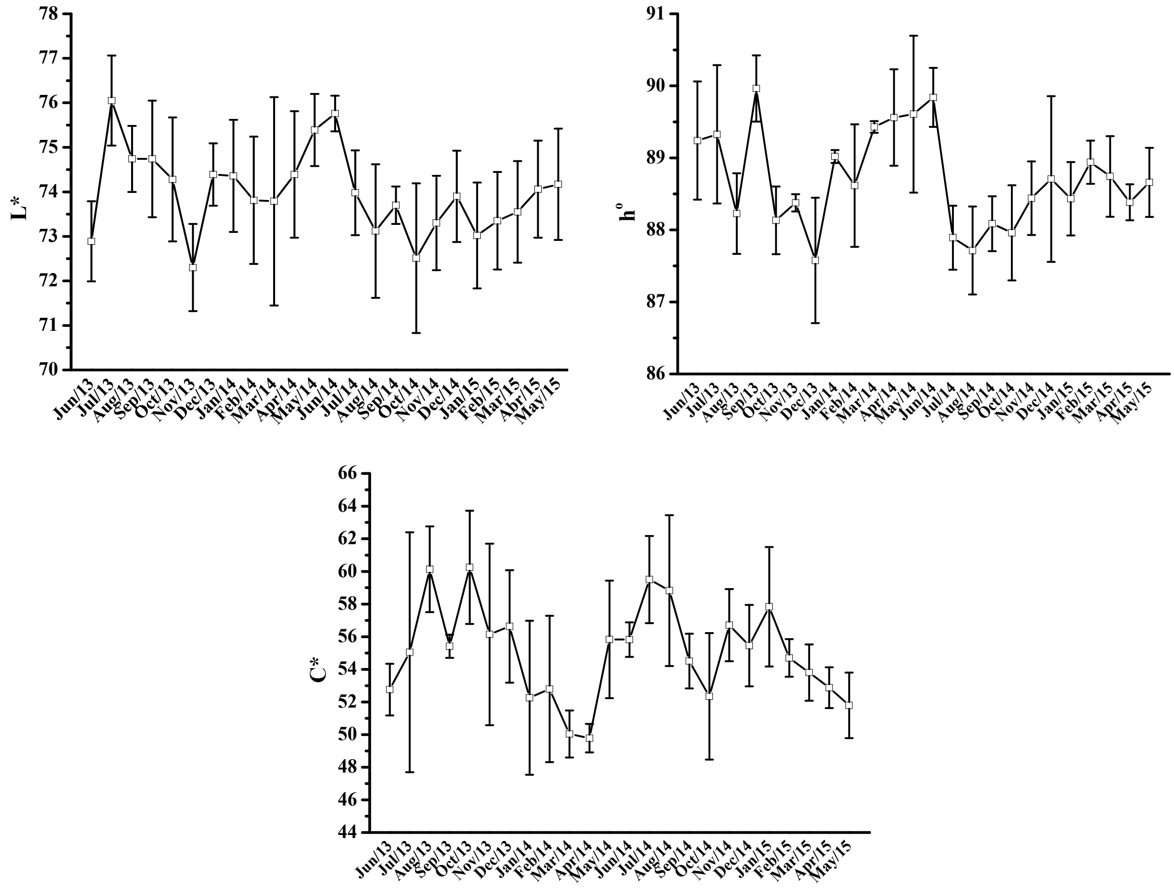


Figure 4. Effect of harvest month on brightness (L*), hue angle (h^o) and chromaticity (C*) of banana peel 'Prata'

Note. Vertical bars represent the standard deviation of the mean (n = 30).

3.2 Cultivar Nanica

FL had mean value of 22.95±1.81 cm. There was no difference in the length of fruits of hand 1 (25.12±2.13 cm) and hand 4 (23.93±2.19 cm), which were superior to that of the last hand (20.50±1.3 cm) ($p < 0.05$). Along the bunch, FL reduction was 18.39%. In May/14, the shortest fruits (19.12 cm) were harvested, while the longest fruits in Dec/13 (26.27 cm), with variation of 7.15 cm (Figure 4). The difference between Jun/13-May/14 and Jun/14-May/15 production cycles were not significant ($p = 0.61$).

The average FD had mean value of 3.38± 0.19 and variation coefficient of 5.62% cm and ranged from 2.68 to 4.03 cm, indicating that not all bunches exhibited standard diameter (3.00 cm) in the last hand. The average diameter of hand 1 (3.46±0.25 cm) did not differ from that of hand 4 (3.44±0.22 cm), which were higher than the last hand, (3.20±0.2 cm) ($p < 0.05$). There was a reduction of 7.51% between hand 1 and the last hand. The lowest FD values were observed in May/14, Aug/13 and Oct/13, and the highest in Jan/14, Nov/14 and Dec/14, which did not differ ($p < 0.05$) (Figure 4). There was no difference between Jun/13-May/14 and Jun/14-May/15 production cycles ($p = 0.15$).

BM varied between the different harvest months from 20.65 to 36.86 kg, with average value of 29.51±4.69 (Figure 2), which results in average productivity of 47.22 kg ha^{-1}. Jul/13 and Jan/15 were the months, respectively, with lower and higher average BM. There were no differences in the BM for the production cycles Jun/13-May/14 (29.46 kg) and Jun/14-May/15 (29.55 kg) ($p = 0.96$) due the small differences in climatic conditions (Figure 3).

The strongest correlation established between climatic conditions of the harvest month and BM was found for radiation (r = 0.91**), followed by Tmax, Tminm, Tmin and Tmaxm (Table 2), whereas Ppt did not present significant correlation. Regardless of fruit position in the bunch, LF and DF increased with increasing Rad and T; however, with no significant correlation with Ppt (Table 2).

Table 2. Correlation of Pearson (r) between climatic variables and variables of bunch production, size and color of fruit peel of 'Nanica' banana (n=240)

	BM	FL	FD	h°H1	h°H4	h°LH	L*H1	L*H4	L*LH	C*H1	C*H4	C*LH	SL
Rad	**0.91**	**0.73**	**0.74**	0.22	**0.53**	**0.68**	0.25	**0.54**	**0.59**	0.06	0.33	0.26	**0.63**
Ppt	0.32	0.14	0.47	0.29	**0.56**	**0.58**	0.37	**0.46**	**0.46**	0.24	0.40	0.40	0.16
Tmax	**0.87**	**0.57**	**0.57**	0.29	**0.53**	**0.69**	0.36	**0.54**	**0.61**	0.09	0.36	0.30	**0.54**
Tmin	**0.79**	**0.48**	**0.60**	**0.47**	**0.71**	**0.75**	**0.52**	**0.69**	**0.71**	0.31	**0.52**	**0.51**	**0.48**
Tmaxm	**0.75**	**0.44**	**0.37**	0.14	**0.43**	**0.69**	0.12	0.36	**0.45**	-0.07	0.23	**0.43**	**0.61**
Tminm	**0.83**	**0.49**	**0.62**	**0.52**	**0.75**	**0.75**	**0.59**	**0.75**	**0.76**	0.36	**0.57**	**0.56**	**0.50**

Note. Marked coefficients are significant at $p < 0.05$.

Rad, monthly-accumulated global solar radiation; Ppt, monthly-accumulated precipitation; Tmax, maximum daily monthly-averaged air temperature; Tmin, minimum daily monthly-averaged air temperature; Tmaxm, maximum daily monthly-occurred air temperature; Tminm, minimum daily monthly-occurred air temperature.

BM, bunch mass; FL, fruit length; fruit diameter; h°H1, hue angle of hand 1; h°H4, hue angle of hand 4; h°LH, hue angle of last hand; L*H1, brightness of hand 1; L*H4, brightness of hand 4; L*LH, brightness of last hand; C*H1, chromaticity of hand 1; C*H4, chromaticity of hand 4; C*LH, chromaticity of last hand; SL, shelf life.

SL ranged from 11.44 to 32.33 days, with average value of 22.95±5.57 days. The SL of the last hand (25.15 days) was higher than that of hand 1 (21.10 days) and hand 4 (21.62 days), which did not differ from each other. SL was higher in fruits harvested in months with higher T and Rad and lower in the other months of the year (Figure 5). Correlations between SL and Tmax, Tmin, Tminm, Tmaxm and Rad were positive and significant (Table 2). There were no differences in SL between Jun/13-May/14 and Jun/14-May/15 production cycles ($p = 0.19$).

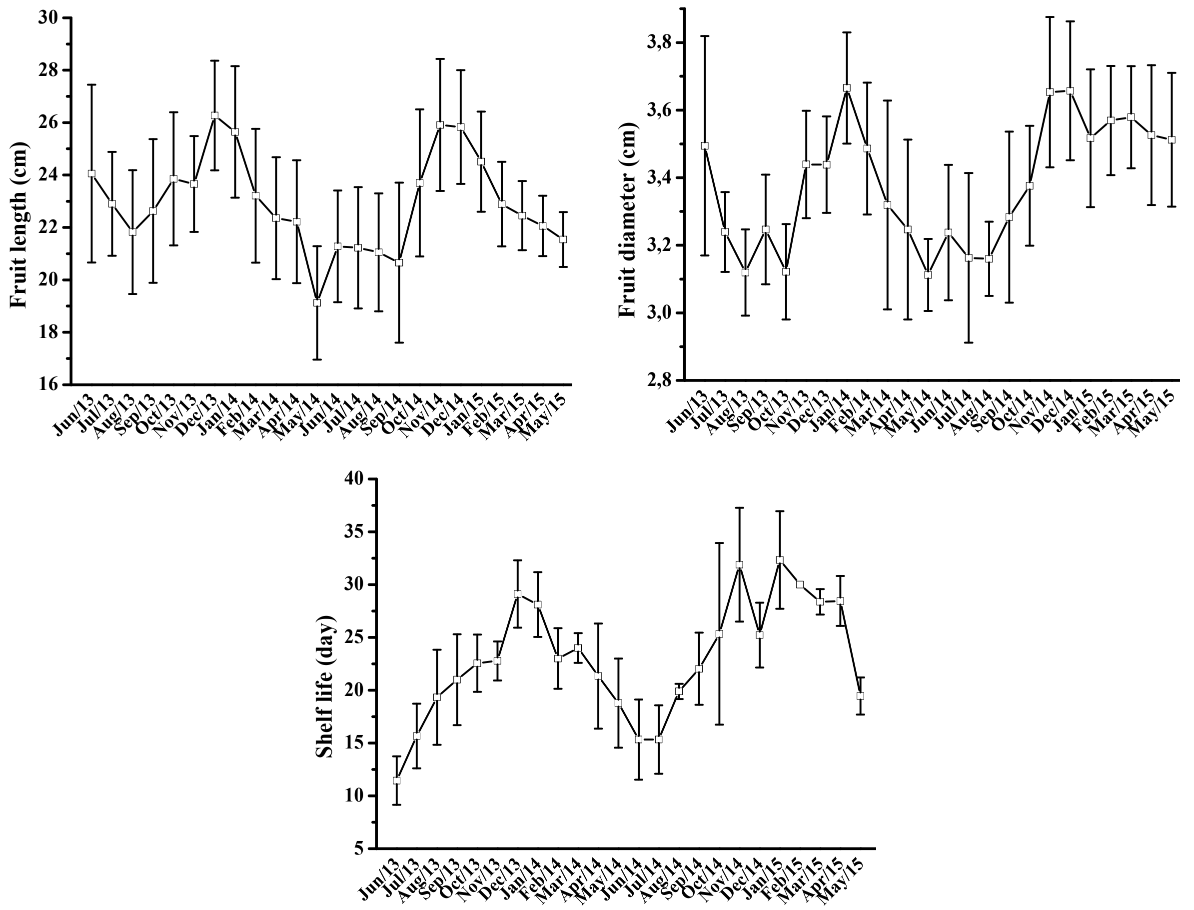


Figure 5. Effect of the harvest month on the fruit length, fruit diameter and shelf life of fruits of the 'Nanica' banana (n = 30)

Note. Vertical bars represent the standard deviation of the mean (n = 30).

L* and h^o of peel, regardless of fruit position in the bunch, tended to have similar response as a function of the harvest month, that is, they were higher in warmer months and lower in colder months with less radiation availability (Figure 6).

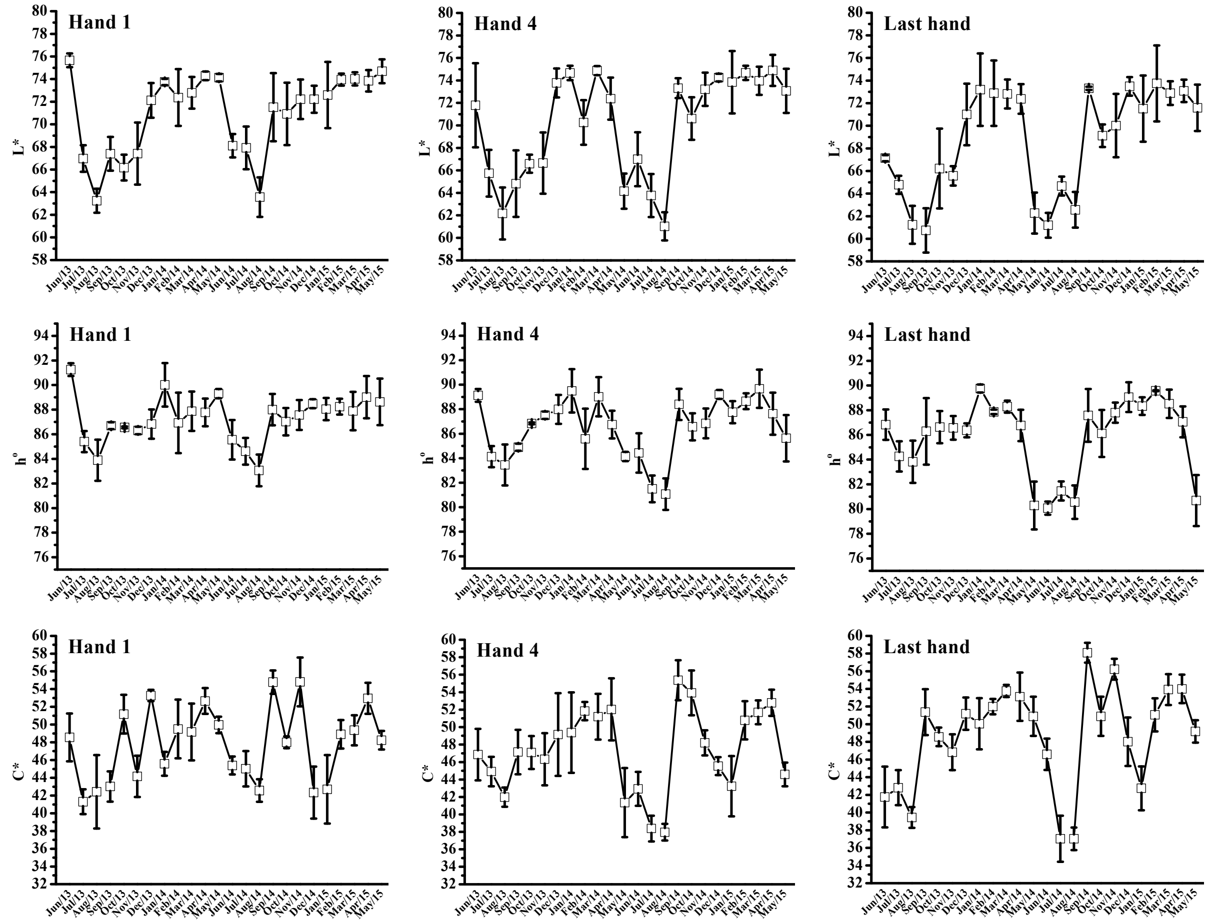


Figure 6. Effect of interaction of harvest month and position in brightness (L*), hue angle (h°) and chromaticity (C*) of banana peel 'Nanica' (n = n10)

Note. Vertical bars represent the standard deviation of the mean (n = 30).

L*, C* and h° varied as a function of fruit position in the bunch (Figure 6). L*P1 had mean value of 70.91±3.61 and ranged from 63.24 to 75.66, while L*P4, 70.06±4.60 varied from 61.02 to 74.89, and L*LH, 68.64±4.68, from 60.74 to 73.75. Similar response was observed for h°, and the mean value for hand 1 was 87.29±1.89, with values between 83.06 and 91.25, for hand 4, value was 86.51±2.45, with values between 81.07 to 89.67 and for the last hand, value was 85.86±3.06, with values ranging from 80.08 to 89.75. C* had average value close to 47.50 for the three positions, ranging from 41.30 to 54.81 in hand 1, from 37.96 to 55.37 in hand 4 and from 37.02 to 58.09 in the last hand. Symptoms of cold damage in the peel of fruits harvested during cold months were observed. There were no differences between May/13-Jun/14 and May/14-Jun/15 production cycles (p = 0.19) for the color characteristics of peel L* (L*H1, p = 0.61; L*H4, p = 0.26; L*LH, p = 0.25), C* (C*H1, p = 0.84; C*H4, p = 0.87; C*LH, p = 0.92) and h° (h°H1, p = 0.84; h°H4, p = 0.87; h°LH, p = 0.92).

Regardless of fruit position in the bunch, peel color characteristics showed high and positive correlations with Tminm, followed by Tmin (Table 2). Low Tmimm indicates the occurrence of cold fronts from autumn to spring (Figure 3).

4. Discussion

The climatic condition imposes two distinct growth periods for both cultivars, one from August to January, which coincides with the increase of Rad, Tmax and Tmin and, as a consequence, higher BM and size, and another from February to July, which due to the decline of climatic variables, results in a decrease in fruit production (Figures 2 and 3). However, despite the bunch mass fluctuation, the average yield estimated by Coltro and Karaski (2019) for the region of 13 ton ha^{-1} for 'Prata' and 25 ton ha^{-1} for 'Nanica' was exceeded in all months evaluated.

The fact that the differences between Rad, Tmax and Tmin, but not Ppt, were small between the production cycles (Jun/13-May/14 and Jun/14-May/15) and insufficient to promote significant differences in BM, fruit size, peel color and SL (Figures 1, 2, 3, 4, 5 and 6). This suggests that fluctuations in production and quality due to the climatic variations were cyclical.

The growth limitation from February to July indicates strong source limitation in autumn and winter, which agrees with the positive linear correlations between Rad and prevailing Tmax and Tmin in harvest month, bunch mass and fruit size (Tables 1 and 2). Three causes contribute to the high seasonality in radiation: geographic position of the region (latitude), solar declination and the hour angle, which results in photoperiod variation from 10.6 to 13.4 hours (Martins et al., 2012). In addition to the autumn and winter in the region, increase the frequency of cloudy and cloudy days (Lima et al., 2016).

T as a consequence of Rad exhibited similar variation (Figure 2), and has strong influence on the metabolic process rate; therefore, the second factor influencing fruit size. However, Ppt showed low correlations with fruit growth variables (Tables 1 and 2) and the humid climate (Alvares et al., 2013) provided high water availability, on average 3.61 mm day^{-1}, with rain occurring in about 50.48% of the experimental period, in addition to the fact that the soil of the experimental area is clayey (Embrapa Solos, 2013), which contributes to the water storage.

The fact that Pearson correlation coefficients (r) between BM, FL and FD with Rad are always higher than with Tamx and Tmin (Tables 1 and 2), indirectly reinforces the hypothesis that there was a source limitation in the production of photoassimilates for fruit growth.

As previously mentioned, the difference in fruit size in the different positions is due to age difference. The low pulp cell number and FL at the end of cell division may be due to increased competition for assimilates among fruits when cell division occurs in distal fruits (Jullien et al., 2008b). The variation in fruit size can be intensified by the source/sink ratio (Jullien et al., 2001b), therefore being influenced by climatic conditions (Jullien et al., 2001a).

However, the conditions prevailing in the harvest month have greater influence on the cell filling rate (Jullien et al., 2008a) and not on the number of cells of the fruit itself, which was established in floral differentiation.

Cell filling influences the time between bunch flowering and harvesting, a development phase that occurs after cell division, which is related to starch accumulation (Jullien et al., 2008a). In this study; however, it was not possible to accurately estimate the role of cell division and cell filling in the final bunch mass and fruit size.

For 'Prata' banana, where LF depended concomitantly on harvest month and fruit position in the bunch, fruits in the basal portion were not always longer than those in the distal bunch, indicating that young fruits may grow as much as younger ones. This avoids the need for classification before marketing. Nevertheless, significant correlations were detected between Rad and FL. For 'Nanica' fruits, regardless of harvest month, fruits of hand 1 and hand 4 exhibited the same length and were superior to fruits of the last hand. The adoption of bunch trimming *(i.e.* fruit pruning) can ensure size uniformity and best commercial standard. There is the interest in longer fruits of 'Prata' banana for qualify for export. Adopting the minimum commercial diameter of 3.00 cm for harvest, variations within the bunch were lower than the length for both cultivars, and 'Nanica' exhibited the greatest variations.

Different from this study, in which reduction in fruit size with the decrease of Rad, Tmax and Tmin was observed, Bugaud et al. (2009) observed negative correlation between pulp dry weight accumulation in fruit and mean daily temperature during bunch growth. The fruit filling rate, which is a factor determining dry matter accumulation, should decrease with increasing temperature when photosynthesis is a limiting factor.

Shelf life is greatly dependent on the type of cultivar, regardless of post-harvest conditions (Nunes et al., 2013). For both cultivars, SL of fruits collected from the top and bottom of the bunch showed different values and was dependent on the harvest month; the same response was observed by Moradinezhad et al. (2007) for banana 'Williams' cultivar.

The positive correlations between SL and Tmax, Tmin or Rad of harvest month corroborate the fact that SL increases with the fastest fruit growth in the bunch. These results are a consequence of time interval between flowering and harvest, which in the region is always shorter for bunches that grow in the spring and summer due to the higher T, and Rad availability promotes cell filling, unlike bunches formed in colder months. Jullien et al. (2008) observed a decreasing exponential relationship between SL and accumulated °Cd from inflorescence emergence or fruit diameter, or fruit age. These relationships were closer under differing growth conditions, including under shading, that is, under reduced source:sink ratio and, thus, fruit growth rate, by reducing the light incidence.

Color varied with the harvest month, which is mainly consequence of Rad availability on the surface of the peel and T. For 'Prata' cultivar, variables L*, C* and h^o presented a discrete tendency of decrease in colder months and lower Rad availability. For 'Nanica' cultivar, decreases were more pronounced and had greater amplitude in the last part of the bunch. This response is consistent with the low tolerance of 'Nanica' banana to cold stress when compared to 'Prata' banana (Lima et al., 2018). The dependence of the position of the fruit on the bunch is a consequence of the movement of cold air by convection within the canopy and the opening of the bagging material in the distal portion of the bunch (Harvey, 2006).

For 'Nanica' cultivar, the temperature limit for cold stress in the field is 12 ^{o}C (Lima, 2018), which was reached in the Jun/13-May/14 production cycle in the months from April to October, and in the Jun/14-May/15 production cycle in the months from May to September (Figure 2). For 'Prata' cultivar, the temperature limit for cold stress is considered to be lower than 5 ^{o}C, reached in the first production cycle in July and August, while in the second cycle, it was only reached in July, which is in agreement with the smaller variation in the peel color characteristics as a function of the harvest month. Although fruits harvested in the first production cycle were submitted to stress more frequently than in the second cycle, there were no significant differences between cycles for any peel color characteristic, which can be explained by the fact that the stress intensity also depends on the exposure time (Harvey, 2006).

Bugaud et al. (2007) verified that the climatic conditions during banana growth. i.e., daily temperature and accumulated rainfall had high impact on ripe banana color cultivated in different geographical locations of Martinique and periods (wet, dry and intermediate). However, the color study was performed only on fruit pulp.

5. Conclusion

In Ribeira Valley, under marginal tropical climate in Brazil, cyclic seasonal fluctuations in bunch mass and fruit size were found for both cultivars, with a reduction of about 16.5% in average production between February and July, associated with lower global solar radiation and temperature, but not precipitation. Additionally, there is a reduction in the color characteristics of 'Nanica' fruit peel associated with cold fronts and chilling occurrence, with higher intensity in the last hand, which does not occur in 'Prata' fruit.

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