Revista Ciência Agronômica, v. 55, e20228571, 2024
Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE
www.ccarevista.ufc.br

Scientific Article
ISSN 1806-6690

Multivariate analysis of vegetative growth and productivity in cultivars of the Cavendish subgroup of the banana[1]

Ricardo Firetti[2], Adriana Novais Martins[3]*, Eduardo Suguino[4], Patrícia Helena Nogueira Turco[5], Humberto Sampaio Araújo[6]

ABSTRACT - The aim of this study was to evaluate agronomic performance in cultivars of the Cavendish banana under the soil and climate conditions of the microregion of Assis in the state of São Paulo over three production cycles. The experiment was set up at the Fazenda São José Farm, Água do Pau d´Alho, in Palmital, São Paulo. The Grande Naine, IAC2001 and FHIA02 cultivars were evaluated, considering the following variables: cultivar; plant height; pseudostem perimeter; number of leaves at flowering and harvest; number of days from planting to flowering, from planting to harvest, and from flowering to harvest; weight of the bunch, stalk and fruit per bunch; number of hands per bunch; productivity of the fruit and pulp; weight and number of fingers on the second hand; weight, length and diameter of the finger; pulp diameter; and weight and thickness of the peel. The data were subjected to multivariate statistical techniques (principal component factor analysis, tree clustering, two-way joining, and correspondence). The results showed the extraction of three principal factors that accounted for 89.63% of the total variance of the characteristics under analysis: banana production (Factor 1), vegetative development (Factor 2), and cultivars and fruit diameter (Factor 3). The productive performance of the FHIA02 cultivar was homogeneous and inferior to that of the other cultivars, as seen in the two-way joining cluster analysis. Only the Grande Naine and IAC2001 cultivars are recommended for cultivation in the micro-region of Assis, São Paulo, with Grande Naine showing the largest fruit and, especially, the largest pulp diameter.

Key words: Cluster analysis, Agronomic performance, Regional economy, *Musa* sp.

DOI: 10.5935/1806-6690.20230064
Editor-in-Chief: Prof. Alek Sandro Dutra - alekdutra@ufc.br
*Author for correspondence
Received for publication 10/08/2022; approved on 30/05/2023
[1]This work was partially financed by the Banana Bernardes Company (Palmital, São Paulo, Brazil)
[2]URPD de Presidente Prudente, APTA Regional/SAASP, Presidente Prudente-SP, Brazil, rfiretti@sp.gov.br (ORCID ID 0000-0002-1998-253X)
[3]URPD de Marília, APTA Regional/SAASP, Marília-SP, Brazil, adriana.martins@sp.gov.br (ORCID ID 0000-0002-9809-7116)
[4]Centro de Pesquisa de Cana, IAC/SAASP, Ribeirão Preto-SP, Brazil, eduardo.suguino@sp.gov.br (Orcid ID 0000-0002-0686-4446)
[5]Sede, APTA Regional/SAASP, Campinas-SP, Brasil, pturco@sp.gov.br (Orcid ID 0000-0002-7092-1900)
[6]URPD de Andradina, APTA Regional/SAASP, Andradina-SP, Brasil, humberto.araujo@sp.gov.br (Orcid ID 0000-0001-6651-2816)

INTRODUCTION

The banana (*Musa* sp.) is one of the most important crops worldwide, both in terms of production and cultivated area. The fruit is part of the staple diet of various tropical countries, such as Costa Rica, Panama, Colombia and Venezuela, among others, and is an important source of income for farmers (FAO, 2020; OLIVARES *et al*., 2022).

In Brazil, the banana is the second most important fruit after the orange, not only because of the high volume produced, but also because of its consumption and commercialisation in the country (SEJAS, 2021); a fruit that stands out for its many uses, not only traditional, but also medicinal and nutritional, rich in carbohydrates, and an excellent source of potassium, in addition to its high energy potential (GERUM; SANTANA; ROCHA, 2020; IICA, 2021; RANJHA *et al*., 2020).

Banana production in 2019 was approximately 116 million tons worldwide (FAOSTAT, 2022), where Brazil was the fourth largest producer, with 6.99 million tons (AGRIANUAL, 2022). The state of São Paulo currently produces most of the bananas in the country, with an estimated productivity of 1.07 million tons per year (AGRIANUAL, 2022; TURCO; MARTINS; PINATTI, 2021).

Average productivity in the country is considered low (15.0 t ha^{-1}), especially compared to that of India (35.2 t ha^{-1}) and China (25.2 t ha-1), which are the main producers worldwide (AGRIANUAL, 2022).

Phytosanitary problems, inadequate management, and the reduced number of cultivars with high productive potential adapted to the environmental growing conditions, contribute to the low productivity of Brazil (LIMA *et al*., 2018).

The main types of banana present in commercial plantations in Brazil are Prata, Maçã, Cavendish and Terra. The decision for choosing a cultivar for planting depends mainly on the consumer market and whether the fruit is destined for fresh consumption or for industry. (SILVA; VALE; PEREIRA, 2019).

The regionalisation of banana cultivars, characterised by their agronomic performance in different environments, is fundamental to improving productivity, but also to identifying genetic materials that are tolerant to the main pests and diseases of the crop: precocious, with low height and better vegetative development, in order to improve banana farming in various regions of Brazil (BORGES *et al*., 2011; LIMA *et al*., 2018; ROQUE *et al*., 2014).

The microregion of Assis in the state of São Paulo began cultivating the banana in the 1980s, focusing on production of the Maçã cultivar; however, with the spread of Panama disease, the cultivar became unviable and was gradually replaced by cultivars of the Cavendish banana (CAMOLESI *et al*., 2012).

During the 2016/17 campaigns of the most-recent Census of Agricultural Production Units (LUPA Project) carried out by the Department of Agriculture and Supply (SAA), through the Coordinating Body for Integral Technical Assistance (CATI) and the Institute of Agricultural Economy (IEA), there were 923 ha in the region cultivated with the banana, 321.7 of which were in the district of Palmital (SÃO PAULO, 2019), showing the importance of the region that was chosen for the trial.

Unlike univariate statistics, a set of multivariate techniques has the aim of understanding different phenomena using a wide spectrum of variables that are to be analysed together (MARQUES, 2018). According to Hair *et al*. (2009), multivariate statistics makes possible an in-depth understanding of the interrelations that exist between the variables that make up a given experiment or set of data.

Such techniques, with emphasis on principal component factor analysis and cluster analysis, have been used in research on the banana with different objectives, ranging from genetic evaluations (BRANDÃO *et al*., 2013), diagnostics of soil fertility and nutrition in banana plantations (GUIMARÃES; GOD, 2021), plant health (THANGAVELU *et al*., 2021), agronomic characterisations and evaluations (GUECO *et al*., 2020), fruit quality (GIUGGIOLI; PEANO; SILVA, 2020), economic viability (PAULA *et al*., 2018), and purchase decisions in the modern market (ISTIQOMATIN; SETIADI; EKOWATI, 2021).

The importance of cluster formation when examining research using factor analysis is due to elements included in these sets that explain, at least in theory, how the variables are related to the factors being analysed (MATOS; RODRIGUES, 2019).

The aim of this study was a comparative analysis of vegetative development and production indicators in cultivars of the Cavendish subgroup of the banana (IAC2001, Grande Naine and FHIA 02), seeking to identify which materials are most suitable for planting in the microregion of Assis, in the state of São Paulo.

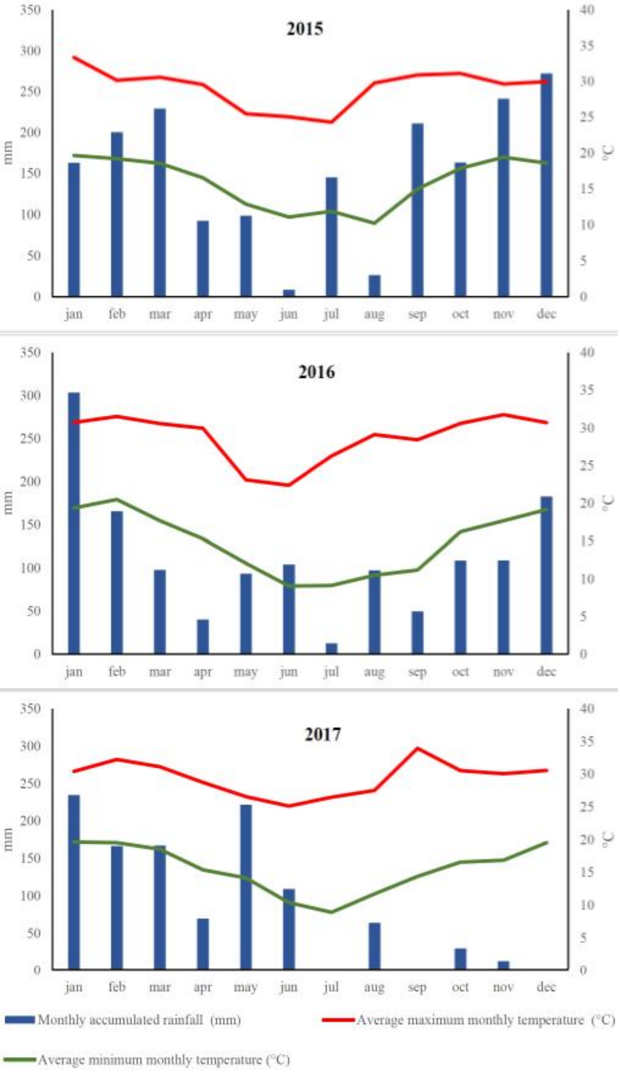
MATERIAL AND METHODS

The experiment was conducted at the Fazenda São José Farm, Água do Pau d´Alho, in Palmital, São Paulo (SP) (22º 49´ N, 50º 16´ S, altitude 400 m), in a dystroferric Red Latosol with a very clayey texture (75% clay, 19% silt, 6% sand). The climate is type Cfa (Koeppen), i.e. moderately humid, no dry season, with rainfall during the driest month exceeding 30 mm. The accumulated monthly rainfall (mm) and average maximum and minimum temperatures (°C) from 2015 (planting) to 2017 (harvest of the third production cycle) are shown in Figure 1.

Cultivars of the Cavendish subgroup of the banana (Table 1) were evaluated during the three initial production cycles. The experimental design was of randomised blocks with four replications. Each plot consisted of five plants, spaced 2.5 m apart, with 3.5 m between rows, giving a total of 1,140 plants per hectare.

The following parameters were evaluated: a) plant height (m): obtained with the aid of a tape measure at the time the bunch was emitted, referring to the distance between ground level and the exit point of the stalk; b) pseudo-stem perimeter (m): obtained with the aid of a tape measure 30 cm from ground level at the time the bunch was emitted; c) number of leaves at flowering: determined by counting the number of functional living leaves (50% or more of the leaf blade green in colour) on the mother plant at the time of flowering; d) number of leaves at harvest: determined by counting the number of functional living leaves on the mother plant at the time of harvesting the bunch; e) number of days from planting to flowering; f) number of days from planting to harvest; g) number of days from flowering to harvest; h) weight of the bunch (kg): referring to the weight of the recently harvested bunch, obtained using a platform scale with a capacity of 50 kg and accuracy of 10 g; i) number of hands per bunch: determined by counting the number of hands per bunch at the time of harvest; j) weight of the stalk (kg): obtained using a platform scale with a capacity of 15 kg and accuracy of 5 g; k) weight of the fruit per bunch (kg): obtained using a platform scale with a capacity of 50 kg and accuracy of 10 g; l) weight of the second hand (hand 2) of the bunch (kg): obtained using a scale with a capacity of 5 kg and accuracy of 1 g; m) number of fingers on the second hand (hand 2) of the bunch; n) average weight of the fingers (g): obtained using a precision scale with a capacity of 620 g and accuracy of 0.02 g, weighing the three central fingers from the second hand of the bunch; o) average finger length (cm): obtained with the aid of a tape measure marked in mm, measuring the length of the external part of the three central fingers from the second hand of the bunch; p) finger diameter (mm): obtained using a digital calliper with a precision of 0.01 mm, measured on the middle part of the three central fingers from the second hand of the bunch; q) pulp diameter (mm): obtained using a digital calliper with a precision of 0.01 mm, measured on the middle part of the three central fingers from the second hand of the bunch, after cutting the fingers transversely; r) thickness of the peel (mm); obtained using a digital calliper with a precision of 0.01 mm, measuring the middle part of the three central fingers from the second hand of the bunch, after cutting the fingers transversely; s) weight of the peel (g): obtained using a precision scale with a capacity of 620 g and accuracy of 0.02 g, evaluating the three central fingers from the second hand of the bunch; t) weight of the pulp (g): obtained using a precision scale with a capacity of 620 g and accuracy of 0.02 g, evaluating the three central fingers from the second hand of the bunch; u) pulp weight to finger weight ratio: determined by dividing the pulp weight of the finger by the total weight of the finger (pulp + peel); v) fruit productivity (t ha^{-1}): determined by multiplying the weight of the fruit per bunch by the number of plants per hectare (1,140 plants ha^{-1}); x) pulp productivity (t ha^{-1}): result of subtracting the values for fruit peel from fruit productivity.

Figure 1 - Accumulated rainfall (mm) and average maximum and minimum temperatures from 2015 to 2017. Palmital, SP



Source: CIIAGRO (2022)

Table 1 - Description of the banana cultivars evaluated in Palmital, SP, from 2015 to 2017

Cultivar	Group	Subgroup	Description
Grande Naine	AAA	Cavendish	Small size, mutation of ‘Nanica’, susceptible to Yellow and Black Sigatoka and Panama Disease (R4T)
IAC 2001	AAA	Cavendish	Somaclonal variation of the Nanicão cultivar, tolerance to Yellow Sigatoka
FHIA 02	AAAB	Cavendish	Williams x SH33-93 hybrid resistant to Yellow and Black Sigatoka and susceptible to Panama Disease

Source: Lima *et al.* (2005), Garruti *et al.* (2012), Weber *et al.* (2017), Nomura *et al.* (2017) e Lima *et al.* (2018)

The data analysed in the sample plots were tabulated so as to total 45 observations (15 for each cultivar), disregarding the production cycle to which they belonged. They were then standardised, and analysed using the following multivariate statistical techniques (HAIR *et al*., 2009): principal component factor analysis; tree clustering analysis; two-way joining cluster analysis; and correspondence analysis. The analyses were carried out using the STATISTICA 13 statistical software (TIBCO, USA). The correlation between selected variables grouped in the same factor was also calculated (SWEENEY *et al*., 2015).

Principal component factor analysis: its main purpose being to reduce the number of variables by extracting factors. The following were used: raw varimax orthogonal rotation, choice of the number of factors based on Eigenvalues greater than 1.0, loading scores of 0.70, and independent factor naming and analysis. To improve visualisation, factor scores equal to or greater than ± 0.70 were marked in bold in the table that includes these results.

Correspondence Analysis (CA): carried out from the intersection between variables of the same factor, using graphs for better visualisation. To facilitate visualising the correspondences, the data collected from some of the variables under analysis were tabulated and organised into four frequency classes.

Tree clustering analysis was applied to data of the genetic materials under study, with the grouping variable comprising the set of variables that made up Factor 1 and those that made up Factor 2, both extracted by principal component factor analysis. The complete linkage clustering algorithm was chosen using the Euclidean distance. To represent the resulting groupings graphically, a dendrogram (hierarchical tree) was used, displayed as a profile diagram, with observations referring to the genetic materials listed along the horizontal axis while the scale appears along the vertical axis.

Two-way joining cluster analysis allows viewing, by means of a discrete colour scale, the grouping and result of crossing the observed variables expressed by statistical frequency class (TURCO *et al*., 2013, 2014). It allows, along the vertical, analysis of the differentials between each variable under evaluation and, along the horizontal, differentiation of the values obtained in each observation (case). The greater the variation in colour, the greater the heterogeneity. As with the previous clustering technique, the variables making up Factor 1 and Factor 2 were used independently.

RESULTS AND DISCUSSION

The characteristics analysed in the three production cycles of the banana cultivars were standardised and submitted to principal component factor analysis, giving three principal factors that represent 89.6% of the total variance of the sample. According to Hair *et al.* (2009), in the applied social sciences “it is not uncommon to consider a solution that explains 60% of the total variance (and in some cases even less) as satisfactory”.

During the analytical process, some variables were excluded as they did not obtain a factor score (eigenvalue) greater than 0.70, as also described in Hair *et al.* (2009). The choice of this type of count (factor score) is justified, as it is calculated based on the factor loadings of the evaluated parameters that make up the factor, in order to avoid the repetition of any information (NIRAZAWA; OLIVEIRA, 2018). This was done with the following variables: number of fingers on hand 2, thickness of the peel, plant height, number of leaves at harvest, number of days between flowering and harvest, stem weight, and pulp:finger ratio. The factors and their correlated variables are shown in Table 2.

The factors were then labelled, taking into account the variables with the highest loadings. It is important to note that the signs of the factor loadings (positive or negative) are interpreted in the same way as any other correlation coefficient, i.e. for each factor, concordant signs mean that the variables are positively correlated.

Table 2 - Factors extracted in the analysis, and correlation with the evaluated variables (highlighted in bold) of the three cultivars of the Cavendish banana (IAC 2001, Grande Naine and FHIA 02). Palmital, SP

Variable	Factor 1*	Factor 2*	Factor 3*
cultivar	0.066291	0.000837	-0.974590
weight of the bunch	0.844596	0.495857	0.090904
number of hands per bunch	0.117055	0.819643	0.113185
weight of the fruit per bunch	0.851102	0.477516	0.102674
fruit productivity	0.851102	0.477516	0.102674
pulp productivity	0.877874	0.394670	0.196066
weight of hand 2	0.952917	-0.046806	0.033354
weight of the finger	0.948837	0.089274	0.243873
finger length	0.894398	-0.338353	0.148046
fruit diameter	0.503732	-0.093040	0.831440
pulp diameter	0.480937	-0.058380	0.838550
weight of the peel	0.728171	0.365623	-0.284346
weight of the pulp	0.923196	0.030304	0.327038
pseudostem diameter	0.416721	0.782768	-0.199159
number of leaves at flowering	0.113930	0.760423	-0.299016
number of days from planting to flowering	0.077479	0.947584	-0.007019
number of days from planting to harvest	0.077065	0.948082	-0.012374
Explored Variance	7.625291	4.788549	2.824472
Proportion of Total Variance	0.448547	0.281679	0.166145

*Factor 1 – Production; Factor 2 – Vegetative development and phenology; Factor 3 – Cultivars and fruit quality. Source: research results

Bearing in mind the composition of the factor loadings of the extracted factors, the following labels were chosen: Factor 1 = Production; Factor 2 = Vegetative development and phenology; Factor 3 = Cultivars and fruit diameter.

Factor 1, labelled 'Production' (44.85% of the variance), includes the variables with the highest loadings (internal correlations): 'weight of hand 2', 'weight of the finger' and 'weight of the pulp'. Additionally, it is important to point out the high values, greater than 0.84, of the factor scores obtained by the other variables that make up the factor, such as 'finger length', 'weight of the bunch', 'weight of the fruit per bunch', 'fruit productivity' and 'pulp productivity'. The exception was 'weight of the peel', which had an eigenvalue of 0.72. According to Matos and Rodrigues (2019), as the defined factor score calculates the variance in each of the variables in relation to the evaluated parameter, when this value is low it tends to be ignored, as it does little to explain the calculations and is seen as redundant information.

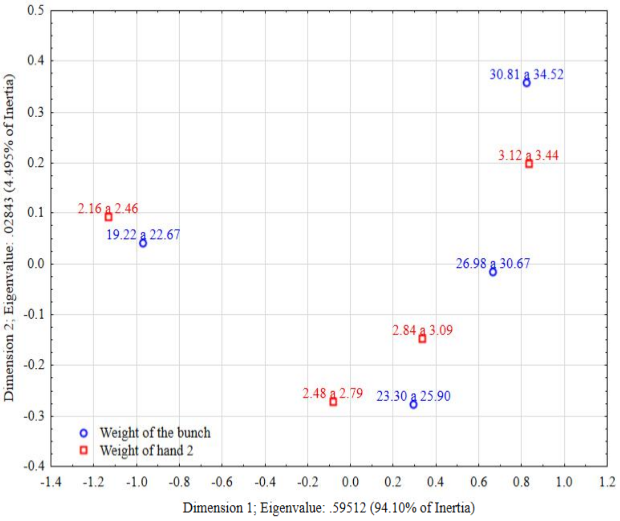
In order to help interpret and observe the behaviour of the variables that comprise Factor 1, correspondence analyses were carried out between 'weight of the bunch' and "weight of hand 2', 'weight of the bunch' and 'finger length', and 'fruit productivity' and 'pulp productivity' (Figures 2, 3 and 4).

To facilitate visualisation and graphical interpretation, the data obtained in the field were organised into four response classes. Figure 2 shows the correspondence between the response classes of the variable "weight of the bunch": (A) 19.22 to 22.67 kg, (B) 23.30 to 25.90 kg, (C) 26.98 to 30.67 kg, and (D) 30.81 to 34.52 kg; and "weight of hand 2": (A) 2.16 to 2.46 kg, (B) 2.48 to 2.79 kg, (C) 2.84 to 3.09 kg, and (D) 3.12 to 3.44 kg.

Notably, the classes of lower frequency in the variables under analysis have a more similar response (19.22 to 22.67 mm; 2.16 to 2.46 kg) while the higher response classes show similar behaviour, albeit with less accuracy (Figure 2).

Observing the correspondence in the response classes for 'weight of the bunch' and 'finger length', formed by (A) 17.3 to 18.3 cm, (B) 18.5 to 19.2 cm, (C) 20 to 20.7 cm, and (D) 21 to 22 cm (Figure 3), it can be seen that the two smallest frequency classes for 'finger length' show similar responses to the smallest class for 'weight of the bunch', while the last class for this variable (30.81 to 34.52 kg) is strongly related to the third response class for 'finger length' (20 to 20.7 cm), i.e. the hypothesis that heavier bunches necessarily have longer bananas (fingers) can be discarded. This is evident in the study conducted by Lima *et al*. (2018), where the D'Angola cultivar from the Terra group had the largest fruit among the materials under evaluation despite being one of the cultivars with the smallest bunches.

Figure 2 - Correspondence analysis between the variables 'weight of the bunch' and 'weight of hand 2'. Palmital, SP



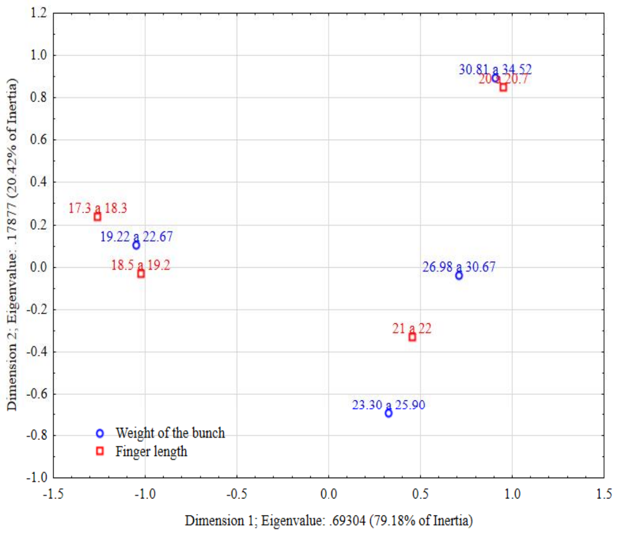
Source: research results

Concluding the analyses of Factor 1 (Production), the correspondence analysis between the variables 'fruit productivity', with (A) 19.96 to 23.79 kg ha^{-1}, (B) 24.49 to 28.02 kg ha^{-1}, (C) 28.65 to 32.27 kg ha^{-1}, and (D) 32.46 to 36.39 kg ha^{-1}; and 'pulp productivity', with (A) 14.25 to 17.44 kg ha^{-1}, (B) 18.53 to 20.26 kg ha^{-1}, (C) 21.2 to 24.11 kg ha^{-1}, and (D) 24.62 to 27.44, shows that the response classes show increasing similarity in each of the items and offer no surprises (Figure 4).

The tree clustering and two-way joining analyses carried out on the set of variables that made up Factor 1 (Production) clearly show that the productive behaviour of the experimental plots of the FHIA02 cultivar was homogeneous, with values generally below the results of the other cultivars for the three production cycles (Figure 5). This behaviour of the FHIA02 cultivar was also found by Almeida *et al*. (2019) in a study conducted in Goiânia, Goiás. The production parameters of the FHIA02 cultivar were lower than those of the other cultivars evaluated in the Cavendish subgroup (FHIA17 and Grande Naine).

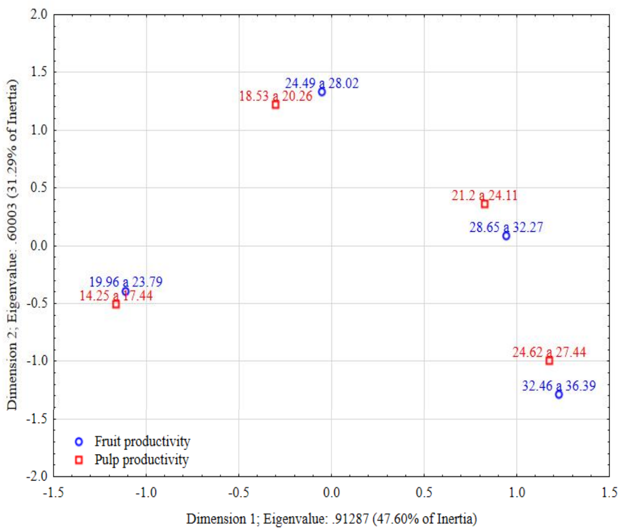
While Figure 5 shows the formation of three observation clusters (cut-off height for four points of linkage distance) in which the central cluster is formed exclusively by samples from the FHIA02 cultivar, Figure 6, shows that, due to the colour scale used (dark green for smaller and dark red for larger) the values achieved by FHIA02 were smaller than those obtained for the other two cultivars. These results are corroborated by Martins *et al*. (2022), where for each of the production variables under analysis, the FHIA02 cultivar had significantly lower results than the Grande Naine and IAC2001 cultivars.

Figure 3 - Correspondence analysis between the variables 'weight of the bunch' and 'finger length'. Palmital, SP



Source: research results

Figure 4 - Correspondence analysis between the variables 'fruit productivity' and 'pulp productivity'. Palmital, SP



Source: research results

It should be noted that the legend for the two-way joining cluster analysis does not reflect the absolute values obtained when measuring the experimental parameters, as the collected data went through a process of ‘standardisation’ that, according to Hair *et al*. (2009), “is a process in which the original variable is transformed into a new variable with a mean value of 0 and a standard deviation of 1”.

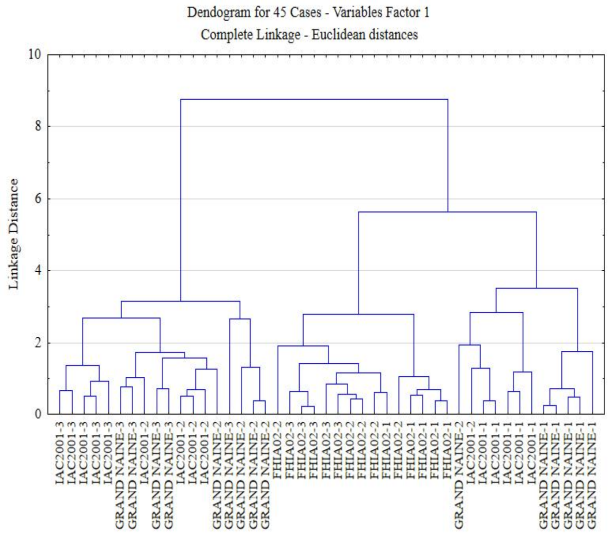
In some ways, these results corroborate the hypothesis that the Grande Naine and IAC2001 cultivars were more productive in the geographical microregion of Assis, São Paulo under the temperature and rainfall conditions of the period under analysis, agreeing with the analyses carried out by Martins *et al*. (2022).

Factor 2 represents vegetative development and phenology (28.17% of the total variance), which mainly aggregated the variables ‘number of days between planting and harvest’, ‘number of days between planting and flowering’, and ‘number of hands per bunch’, with eigenvalues (correlations) of 0.947, 0.948 and 0.819, respectively. In addition, ‘pseudostem diameter’ and ‘number of leaves at flowering’ also make up this second factor, but with factor scores of 0.782 and 0.760.

When analysing the correspondence between the variables ‘hands per bunch’, (1, 2, 3 or 4) and ‘number of leaves at flowering’: (A) 8 to 9 leaves, (B) 10 leaves, (C) 11 to 12 leaves, and (D) 13 to 14 leaves (Figure 7), there was similarity between the responses of the classes of lower value, i.e. there indeed seems to be a correspondence between the smallest number of leaves and a smaller number of hands in each bunch. In contrast, the greatest number of leaves at flowering appears, in this case, not to correspond necessarily to the greatest number of hands per bunch.

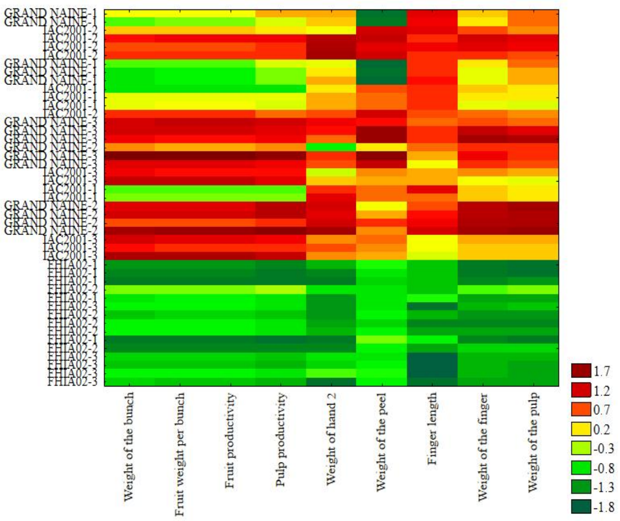
The tree clustering and two-way joining analyses that were based on the variables making up Factor 2 (Vegetative development and phenology) showed that the behaviour of the sampled units was mainly affected by the production cycle. As such, Figure 8 shows the

Figure 5 - Tree clustering analysis including variables from Factor 1 (Production). Palmital, SP



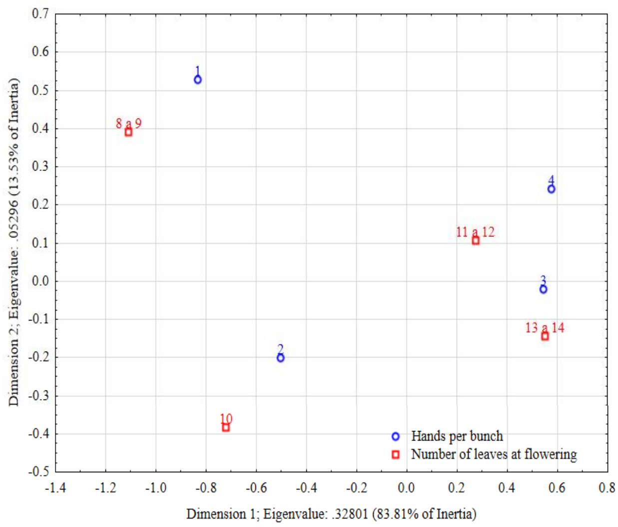
Source: research results

Figure 6 - Two-way joining cluster analysis including variables from Factor 1 (Production). Palmital, SP



Source: research results

Figure 7 - Correspondence analysis between the variables ‘hands per bunch’ and ‘number of leaves at flowering’. Palmital, SP

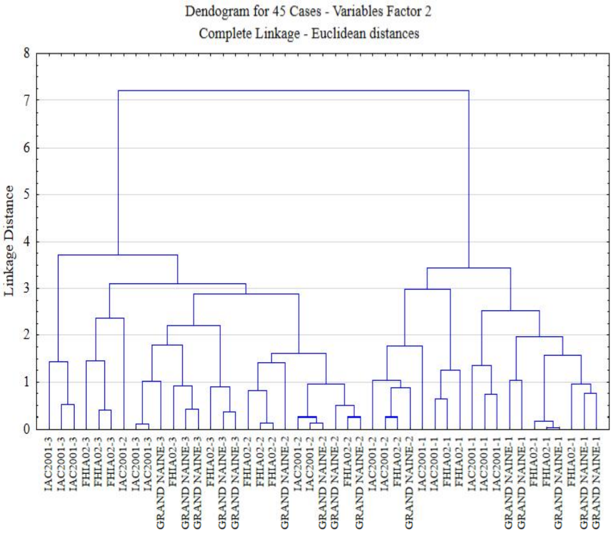


Source: research results

formation of two main groups of observations (cut-off height for four points of linkage distance), in which one of the clusters is formed mainly by the samples collected during Cycle 1 of the experiment.

From Figure 9 it can be seen that, due to the colour scale employed (dark green for smaller and dark red for larger), the values achieved by the observations collected during Cycle 1 for the three cultivars were for the most part smaller than those obtained for the other two cultivars, generating small clusters.

Figure 8 - Tree clustering analysis including variables from Factor 2 (Vegetative development and phenology). Palmital, SP



Source: research results

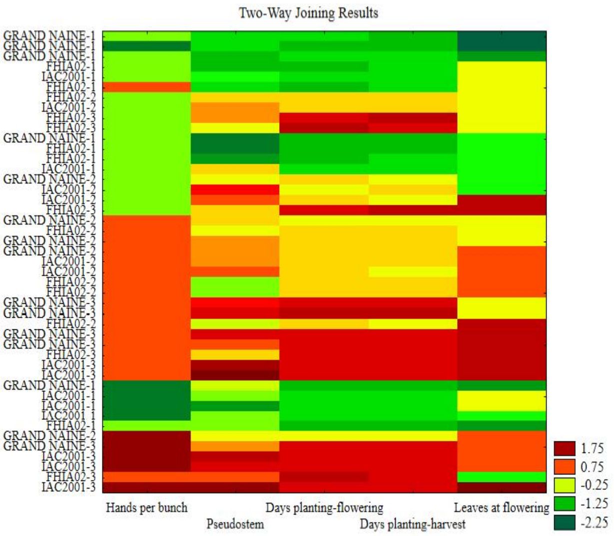
Factor 3 (Cultivars and fruit diameter), which represents 28.24% of the explained variance of the sample, is directly related to ‘Cavendish cultivars’, its principal significant variable, which has a negative loading (-0.974), together with ‘pulp diameter’ and ‘fruit diameter’ (0.838 and 0.831, respectively). The composition of this factor clearly denotes the relative importance of the cultivars in relation to fruit diameter.

To explore this relationship, two of the variables that make up the third factor were submitted to Correspondence Analysis. Again, to facilitate visualisation and graphical interpretation, the data obtained in collecting the variable ‘pulp diameter’ were organised into four response classes: (A) 30.43 to 31.88 mm, (B) 31.94 to 32.57 mm, (C) 33.81 to 34.69 mm, and (D) 34.84 to 36.29 mm.

It could be seen from Figure 10 that the largest pulp diameters (greater than 33.81 mm) were related to the GrandeNaine cultivar, while the smallest diameters corresponded to FHIA02, as observed by Martins *et al*. (2022).

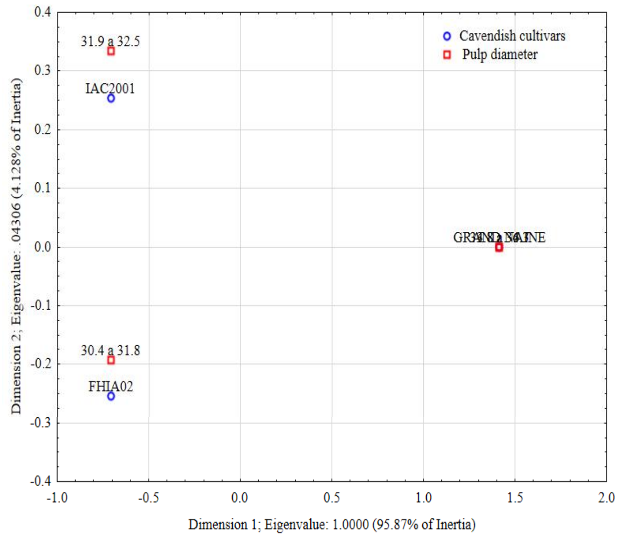
It should be noted that the cluster analyses are no longer relevant when explaining this third Factor in view of the reduced number of variables that it comprises and, especially, the results for similarity obtained in the correspondence analysis, with the formation of three very well-defined clusters. A similar result is described in Hair *et al*. (2009).

Figure 9 - Two-way joining cluster analysis including variables from Factor 2 (Vegetative development and phenology). Palmital, SP



Source: research results

Figure 10 - Correspondence analysis between the variables ‘Cavendish cultivars’ and ‘pulp diameter’. Palmital, SP



Source: research results

CONCLUSIONS

1. The Grande Naine and IAC2001 banana cultivars were more productive under the conditions found in the microregion of Assis, São Paulo, during the period under analysis;
2. Larger pulp diameters (greater than 33.81 mm) were obtained in the Grande Naine cultivar, and smaller diameters in the FHIA02 cultivar;
3. A smaller number of plant leaves is related to a smaller number of hands per bunch;
4. A greater number of leaves at flowering did not correspond to a greater number of hands per bunch.

ACKNOWLEDGEMENT

The authors wish to thank Edmar José Bernardes of the Bananas Bernardes Company and owner of the Fazenda São José Farm, Palmital, São Paulo, Brazil, for providing the area, inputs and resources for carrying out this research.

REFERENCES

AGRIANUAL. **Anuário da Agricultura Brasileira**. São Paulo: IFNP, 2022. 480 p.

ALMEIDA, G. Q. *et al.* Selection index via REML/BLUP for identifying superior banana genotypes in the central region of Goias state, Brazil. **Revista Ceres**, v. 66, n. 1, p. 26-33, 2019.

BORGES, R. S. *et al.* Avaliação de genótipos de bananeira no Norte do Estado do Paraná. **Revista Brasileira de Fruticultura**, v. 33, n. 1, p. 291-296, 2011.

BRANDÃO, L. P. *et al.* Descriptor selection for banana accessions based on univariate and multivariate analysis. **Genetics and Molecular Research**, v. 12, n. 2, p. 1603-1620, 2013.

CAMOLESI, M. R. *et al.* Desempenho de cultivares de bananeiras na região do Médio Paranapanema, São Paulo. **Semina: Ciência Agrárias**, v. 33, n. 1, p. 2931-2938, 2012.

CIIAGRO. **Dados meteorológicos**. 2022. Disponível em: http://www.ciiagro.sp.gov.br/def_0.html. Acesso em: 11 abr. 2022.

FAO. **Banana market**: review snapshot. 2020. Disponível em: http://www.fao.org/3/ca9212en/ca9212en.pdf. Acesso em: 1 mar. 2022.

FAOSTAT. **Crops and livestock products**. Rome, 2019. Disponível em: http://www.fao.org/faostat/en/#data/QCL. Acesso em: 11 abr. 2022.

GARRUTI, D. S. *et al.* Aceitação de cultivares de bananas resistentes à Sigatoka Negra junto ao consumidor da região Nordeste do Brasil. **Ciência Rural**, v. 42, n. 5, p. 948-954, 2012.

GERUM, A. F. A. A.; SANTANA, M. A.; ROCHA, S. L. Impactos da Covid-19 na bananicultura brasileira. Cruz das Almas: Embrapa Mandioca e Fruticultura, 2020.

GIUGGIOLI, N. R.; PEANO, C.; SILVA, T. M. Multivariate factor analysis (MFA) approach to evaluate the quality of stored Cavendish banana sourced from different geographical areas. Emirates Journal of Food and Agriculture, v. 32, n. 3, p. 204-212, 2020.

GUECO, L. S. *et al.* Characterization and agronomic evaluation of naturally occurring short-statured Saba banana in the Philippines. Philippine Journal of Science, v. 149, n. 3-a, p. 981-992, 2020.

GUIMARÃES, G. G. F; DEUS, J. A. L. Diagnosis of soil fertility and banana crop nutrition in the state of Santa Catarina. Revista Brasileira de Fruticultura, v. 43, n. 4, p. e-124, 2021.

HAIR JUNIOR, J. F. *et al.* **Análise multivariada de dados**. 6. ed. Porto Alegre: Bookman, 2009. 688 p.

IICA. **Banana**: um cultivo fundamental para a segurança alimentar que está sob ameaça. 2021. Disponível em: https://www.iica.int/pt/prensa/noticias/banana-um-cultivo-fundamental-para-seguranca-alimentar-que-esta-sob-ameaca. Acesso em: 18 mar. 2022.

ISTIQOMATIN, T.; SETIADI, A.; EKOWATI, T. Effect of marketing mix on consumer purchase decisions to buy Cavendish banana at modern markets in Semarang. **Journal of Agricultural Socioeconomics and Business – Agriecobis**, v. 4, n. 2, p. 120-132, 2021.

LIMA, E. C. S. *et al.* Desempenho agronômico de cultivares de bananas em dois ciclos produtivos em Tangará da Serra-MT. **Engenharia na Agricultura**, v. 26, n. 6, p. 497-506, 2018.

LIMA, M. B. *et al.* Avaliação de cultivares e híbridos de bananeira no Recôncavo Baiano. **Ciência Agrotecnologia**, v. 29, n. 3, p. 515-520, 2005.

MARQUES L. G. **Sistemas agrários e tipologia**: reflexões a partir do uso da análise estatística multivariada. 2018. Dissertação (Mestrado em Extensão Rural) – Universidade Federal de Santa Maria, Centro de Ciências Rurais, Programa de Pós-graduação em Extensão Rural, Santa Maria, 2018.

MARTINS, A. N. *et al.* Agronomic behavior of banana cultivars in the geographic microregion of Assis, São Paulo, Brazil. **Revista Brasileira de Fruticultura**, v. 44, n. 4, p. e-112, 2022.

MATOS, D. A. S.; RODRIGUES, E. C. **Análise fatorial**. Brasília: ENAP, 2019. 74 p.

NIRAZAWA, A. N.; OLIVEIRA, S. V. W. B. Indicadores de saneamento: uma análise de variáveis para elaboração de indicadores municipais. **Revista Brasileira de Administração Pública**, v. 52, n. 4, p. 753-763, 2018.

NOMURA, E. S. *et al.* Fertilization with nitrogen and potassium in banana cultivars 'Grand Naine', 'FHIA 17' and 'Nanicão IAC 2001' cultivated in Ribeira Valley, São Paulo State, Brazil. **Acta Scientiarum. Agronomy**, v. 39, n. 4, p. 505-513, 2017.

OLIVARES, B. O. *et al.* Correlation of banana productivity levels and soil morphological properties using regularized optimal scaling regression. **Catena**, v. 208, n. 105718, p. 1-11, 2022.

PAULA, J. A. A. *et al.* Economic and multivariate analysis of banana production (*Musa* sp.) cultivated in the semi-arid region of northeast Brazil. **International Journal of Advanced Engineering Research and Science (IJAERS)**, v. 5, n. 7, p. 10-18, 2018.

RANJHA, M. M. A. N. *et al.* A comprehensive review on nutritional value, medicinal uses, and processing of banana. **Food Reviews International**, v. 38, n. 2, p. 199-225, 2020.

ROQUE, R. L. *et al.* Desempenho agronômico de genótipos de bananeiras no recôncavo da Bahia. **Revista Brasileira de Fruticultura**, v. 36, n. 3, p. 598-609, 2014.

SÃO PAULO (Estado). Secretaria de Agricultura e Abastecimento do Estado de São Paulo. Instituto de Economia Agrícola. Coordenadoria de Desenvolvimento Rural Sustentável. **Projeto LUPA 2016/17**: Censo agropecuário do Estado de São Paulo. São Paulo: SAA: IEA: CDRS, 2019. Disponível em: http://www.cdrs.sp.gov.br/projetolupa/. Acesso em: 5 abr. 2022.

SEJAS, R. P. **Caracterização da produção de banana (*Musa* spp.) por agricultores familiares nos municípios de Miracatu e Sete Barras e análise de perspectivas via matriz Swot**. 2021. Dissertação (Mestrado em Engenharia de Produção) – Universidade Federal de São Carlos, Programa de Pós-graduação em Engenharia de Produção, Sorocaba, 2021.

SILVA, W. R.; VALE, L. S. R.; PEREIRA, D. R. M. Desempenho de cultivares de bananeira sob as condições edafoclimáticas de Ceres-GO. **Revista de Ciências Agrárias – Amazonian Journal of Agricultural and Environmental Sciences**, v. 62, n. 1, p. 1-6, 2019.

SWEENEY, D. J. *et al*. **Estatística aplicada à administração e economia**. 3. ed. São Paulo: CENGAGE Learning, 2015.

THANGAVELU, R. *et al*. Identifcation of sources resistant to a virulent Fusarium wilt strain (VCG 0124) infecting Cavendish bananas. **Scientific Reports**, v. 11, n. 3183, p. 1-14, 2021.

TURCO, P. H. N. *et al.* Connection between Technological Trajectory of the Coffee Sector and the Economic Growth of Brazilian Producing Regions. *In*: **54 th Congress of the European Regional Science Association**: "Regional development & globalisation: Best practices", 26-29 August 2014, St. Petersburg, Russia, European Regional Science Association (ERSA), Louvain-la-Neuve. 2014.

TURCO, P. H. N. *et al*. Trajetória tecnológica cafeeira no Brasil, 1924 a 2012. **Revista de Economia Agrícola**, v. 60, n. 2, p. 105-119, 2013.

TURCO, P. H. N.; MARTINS, A. N.; PINATTI, E. **Novo panorama da bananicultura brasileira**. São Paulo: AGRIANUAL, 2021. p. 163-167.

WEBER, O. B. *et al.* Performance of banana genotypes with resistance to black leaf streak disease in Northeastern Brazil. **Pesquisa Agropecuária Brasileira**, v. 52, n. 3, p. 161-169, 2017.