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Performance of Orange Graft/Rootstock Combinations by AMMI Analysis in Capitão Poço, Pará

Desempenho de Combinações Enxerto/Porta Enxertos de Laranja por Análise AMMI em Capitão Poço, Pará

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Abstract

Fruit production, especially citrus farming, is important to the Brazilian economy. However, the cultivation of fruit, such as orange, can be expanded in the northern region, with its almost continental dimensions. This generates many combinations due to soil and climate variations, producing genotype × environment interactions. The additive main effects and multiplicative interaction model (AMMI) graphical analysis is a methodology that enables the interpretation and understanding of interaction patterns in orange graft/rootstock combinations from a visual perspective. This study was carried out in the municipality of Capitão Poço, Pará, involving six graft/rootstock combinations in a randomized block design, with four replicates. The evaluated traits were the number of ripe fruits per plant (NF), plant height (ALT, in m), canopy volume before harvest (VAC, in m3), canopy volume after harvest (VDC, in m3), production efficiency (EP, ratio between production and canopy volume), and fruit production (PRO, in ton.ha^{-1}). The results showed that some combinations had positive contributions, while others had negative contributions. Considering all evaluated traits, graft/rootstock combination T10 [Citrandarin ‘San Diego’ (TSK × TRENG – 314)] stands out, with low stability in NF and PRO but stability in VAC, VDC, and EP). Combination T1 [Cravo Santa Cruz (*Citrus limonia* Osbeck)] showed promise regarding its positive contribution to the averages, but it did not present apparent stability.

Keywords: *Citrus sinensis* (L.) Osbeck. Graphical Analysis. Stability. Adaptability. Genetic Improvement of Perennials.

Resumo
A produção de frutos possui relevante importância dentro da economia brasileira e a citricultura se destaca, porém, a região Norte com dimensões quase continentais disponíveis para expansão do cultivo de frutas como a laranja, geram muitas combinações devido aos efeitos edafloclimáticos, produzindo efeitos intensos da chamada interação genótipos x ambientes. A Análise de Efeitos Principais Aditivos e Interação Multiplicativa (AMMI) é uma metodologia que viabiliza a interpretação e compreensão dos diferentes padrões de interação numa perspectiva visual sobre as combinações enxerto/porta enxertos de laranja. A pesquisa foi realizada no município de Capitão Poço, no Pará, envolvendo seis diferentes combinações enxerto/porta enxertos, delineados em bloco ao acaso, com quatro repetições. Os caracteres avaliados foram: NF: número de frutos maduros por planta; ALT: altura da planta, em m; VAC: volume da copa antes da colheita, em m^3; VDC: volume da copa depois da colheita, em m^3; EP: eficiência da produção, razão entre produção pelo volume de copa; PRO: produção de frutos, em $ton.ha^{-1}$. Os resultados mostram que existem combinações com contribuições positivas e com contribuições negativas. As conclusões considerando-se todos os caracteres avaliados é que se destaca a combinação enxerto/porta-enxerto T10 [Citrandarin ‘San Diego’ (TSK x TRENG – 314)], contudo com baixa estabilidade em NF e PRO e estabilidade nas demais características em que se destaca (VAC, VDC e EP) e a combinação T1 [Cravo Santa Cruz (*C. limonia* Osbeck)] mostra-se promissora quanto a contribuição positiva para as médias, porém não apresenta estabilidade aparente.

Palavras-chave: *Citrus sinensis* (L.) Osbeck. Análise Gráfica. Estabilidade. Adaptabilidade. Melhoramento Genético de Perenes.

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1 Introduction

According to Fonseca (2022), fruit production in general is important to the Brazilian economy, with production exceeding 41 million tons. However, the fruit cultivation area occupies only 0.3% of the national territory, comprising approximately 2.6 million hectares. The majority of this area, around 81%, is represented by small properties classified as family farming, totaling more than 940 thousand production units in all regions. In addition, fruit farming employed almost 200 thousand registered employees in 2021, representing an increase of 9% compared to 2020. The number of employees working in fruit farming in 2021 was 11.5% compared to the total agriculture-related job number (Fonseca, 2022).

Sweet orange [Citrus sinensis (L.) Osbeck.], which is native to Asia and represents the largest group of citrus cultivars cultivated in the world according to Melo (2021), belongs to the Rutaceae family, encompassing around 150 genera and 1600 species that are commonly cultivated throughout the world in temperate, tropical, and subtropical regions (Melo, 2021).

For citrus fruit and specifically oranges, the State of Pará produced 257 thousand tons in an area of 15,061 ha in 2023, generating an economic value of R$ 229 million, with an average yield of 17.1 tons/ha. Based on these quantities, Pará is the largest producer in the North, a region with a total area of 19,194 ha, producing 320 thousand tons and generating R$ 361 million, with a yield of 16,694 kg/ha (IBGE, 2025).

According to Fonseca (2022), the North regions (Amazonas, Acre, Roraima, Rondônia, Amapá, Pará, and Tocantins) together with the Central-West (Mato Grosso, Mato Grosso do Sul, Goiás, and Distrito Federal) represent more than half of the national territory, with around 52% of the area, totaling more than 440 million hectares. However, it produces only 13% of national production in an area of 616 thousand hectares, which is only 0.14% of its territorial extension (Fonseca, 2022), demonstrating that there is availability to expand production areas associated with fruit growing in these regions, including Pará.

However, the vast areas available for the expansion of fruit cultivation, such as orange production, have differing characteristics, showing variations in soil characteristics, altitude, rainfall, temperature, cultural practices, and pathogen occurrence, resulting in numerous distinct environments. According to Cruz *et al*. (2014), phenotype is a concept adopted by genetics that refers to the set of characteristics that an individual presents. The phenotype changes in different environments since the physiological responses of the genotype to environmental effects are represented by genotypic and environmental variance as well as the genotype × environment interaction (G×E), which affect plant performance (Cruz *et al*., 2014), making it difficult to identify the best materials for selection.

Considering the G×E interaction, the performance of individuals is imprecise when the environment changes due to the different reactions of the same set of genes with modifications in environmental factors (Muthoni; Shimelis; Melis, 2015). Since it reflects a physiological process inherent to each individual, there is no mechanism to prevent the emergence of differing results when G×E interactions occur (Adewale *et al*., 2010), hindering selections carried out by the breeder (Carvalho *et al*., 2016).

Its effect can only be determined by choosing genotypes that present broad adaptability and good stability (Cruz *et al*., 2014), and under these conditions, they can then be recommended for cultivation at different locations (Malosetti; Ribaut; Eeuwijk, 2013). According to Ramalho *et al*. (2012), the three ways to overcome the interaction are to select specific cultivar(s) for each environment (specific adaptability), select cultivar(s) with greater phenotypic stability (stability and broad adaptability), and recognize environmental stratifications (identifying groups of similar environments). However, it is necessary to apply some type of statistical or graphical analysis involving the genetic materials and the environments in question to choose one of these methods.

Additive main effects and multiplicative interaction model (AMMI) analysis represents a recent and important alternative for graphical exploration, with its increasing use in G×E interaction studies in plant species (Karimizadeh *et al.*, 2016). This methodology enables the interpretation and understanding of the different interaction patterns of the genotypes and environment from a visual perspective and offers better estimates of genotypic responses in different environments (Dias *et al.*, 2014).

Specifically in relation to the genetic improvement of orange trees, there is a search for cultivars, scions, rootstocks, and their positive interactions (Oliveira *et al.*, 2014); however, the process is quite time-consuming and costly due to intrinsic biological and physical characteristics. Among the peculiarities of orange tree studies, the following stand out: the size of the field experiments, the long reproductive cycle, production oscillations, generational overlap, and trait expression over time (Viana; Resende, 2014). Therefore, the objective of this study was to identify orange graft/rootstock combinations with the best response in terms of precocity, adaptability, and stability based on the effects of G×E interactions.

2 Material and Methods

The experiment was conducted in the rural area of the municipality of Capitão Poço, located in the northeastern region of the state of Pará, on a property called Fazenda Lima (01°44’47” S and 47°03’34” W). The municipality of Capitão Poço has a temperature range that varies from 25.7 to 26.9°C, with an annual average of 26.2 °C (Silva *et al.*, 2011). Based on the Köppen classification, the climate of the region is Am (highland tropical), with annual precipitation of approximately 2500 mm, a short dry season between September and November (monthly precipitation of approximately 60 mm), and relative humidity between 75 and 89% in the months with the least and most precipitation, respectively (Schwart, 2007).

The rootstock seedlings were produced in an environment with 50% shade from seeds from the active germplasm bank of Embrapa Cassava and Fruits (Cruz das Almas, Bahia, Brazil). When the rootstocks reached the appropriate diameter (about 1 cm), inverted T-type budding was performed using “pear” orange buds from a nursery located in Santa Luzia, 15 km from the municipality of Capitão Poço, PA. Of the 16 previously identified materials, only six (Table 1) had an adequate quantity for structuring the experimental area at the time of planting. These were then planted in a randomized block design, with 4 replicates and 6–10 live plants per plot, resulting in a stand of 230 plants.

Table 1 - Identification of rootstocks with sweet orange “pera” [*Citrus sinensis* (L.) Osbeck]. Lima Farm, Capitão Poço, PA

Number	Description
T1	Cravo Santa Cruz (*C. limonia* Osbeck)
T7	Híbrido LVK (limoeiro ‘Volkameriano’ *C. volkameriana* V. Ten. & Pasq.) x LCR (limoeiro ‘Cravo’) - 010
T10	Citrandarin ‘San Diego’ (TSK x TRENG – 314)
T12	BRS Pompeu (TSKC x CTSW - 028)
T13	TSKC {tangerineira ‘Sunki’ comum [C. sunki (Hayata) hort. ex Tanaka]} x CTSW [citrumelo ‘Swingle’ *C. paradisi* Macfad. x *Poncirus trifoliata* (L.) Raf.] - 033
T16	Citrandarin ‘Riverside’ (TSKC x TRENG – 264)

Source: research data.

Specific cultural practices for citrus cultivation were carried out in accordance with farm practices, such as monitoring and eliminating unwanted plants, crowning the plants, and using mulch. Fertilization was performed according to Lima Farm’s nutritional program, with 1 kg of thermophosphate (20% P2O5) and 1 kg of 09-09-19 NPK formulation per year.

The evaluations began when the plants had been in the field for three years, and the following characteristics were evaluated: number of ripe fruits per plant (NF), count of harvested fruits per plant; plant height (ALT), measured from the base of the stem to the last pair of leaves, in m; canopy volume before harvest (VAC), in m3; and canopy volume after harvest (VDC), in m^3. During fruit development, branches become heavier and bent, and consequently, there is an apparent decrease in canopy volume. The data used to calculate the volume were the plant height (m) and canopy diameter (m), according to the equation by Zekri (2000): V=2/3 π (D/2)2 × H, where V is the volume (m^3), R is the canopy radius (m), and H is the plant height (m). The production efficiency (EP) was calculated by dividing the production value by the canopy volume. Fruit production (PRO) was determined as the sum of the weights of all fruit from the useful area of each treatment (estimated in $ton.ha^{-1}$). The years corresponded to the harvests in 2019, 2020, and two harvests in 2021, named 2021a for the harvest at the beginning of the year and 2021b for the harvest at the end of the year.

AMMI graphical analysis was carried out, as described by Duarte and Vencovsky (1999), according to the model: $Y_{ij} = \mu + g_i + a_j + \sum_{k=1}^{n} \lambda_k \gamma_{ik} \alpha_{jk} + \rho_{ij} + \bar{\varepsilon}_{ij}$, where Y_{ij} represents the mean response of the repetitions of the i-th graft/rootstock combination (i = 1, 2, 3, ..., g) in the j-th year (j = 1, 2, 3, ..., a); μ is the mean of all combinations in all years (general mean); g_i is the main effect of the graft/rootstock combination "i"; a_j is the main effect of year "j" and λ_k, γ_{ik} e α_{jk} refers to the terms of the singular decomposition (SVD), also called principal component analysis (PCA), of matrix $GA_{gxa}=\{(ga)_{ij}\}$, which represents the "pattern" referring to the interaction of combination "i" with year "j" and the deviations from additivity of the data (Yij) in relation to the main effects gi and aj; ρ_{ij} is the additional noise to be eliminated in the analysis in relation to the $(ga)_{ij}$ term routinely taken as the interaction itself; and is the average experimental error at the level of replicate means, which is assumed to be i.i.d.~N(0, σ2).

AMMI analysis comprises two sequential steps: 1) estimation of the main effects, in the additive part of the model (general mean, effects of graft/rootstock combinations, and years), adjusted according to the analysis of variance (ANOVA), producing a non-additivity residual, $(g\hat{a})_{ij} = Y_{ij} - \bar{Y}_{i.} - \bar{Y}_{.j} + \bar{Y}_{..}$, in the ordinary least squares estimates from $(ga)_{ij}$; and 2) estimation of the interaction (multiplicative part of the model), adjusted through the DVS or PCA applied to the matrix GEgxa=$\{(g\hat{a})_{ij}\}$, determining the part "standard" (being the interaction – AMMI interaction) and "noise", which should be ignored in addition to the ANOVA residual.

The statistical treatment of the data, including ANOVA and stability and adaptability analyses through AMMI graphical analysis, was performed using R program version 3.4.1 (R CORE TEAM, 2020).

3 Results and Discussion

ANOVA (Table 2) showed that all genetic treatments, years, and genotype × year (G×E) interactions presented significant effects. Thus, some graft/rootstock combinations had better vegetative behavior and productivity compared to the set of materials evaluated, and some showed inferior performance. The presence of different performances is an indication that the genetic selection process can continue within a citrus breeding program.

Table 2 - Summary of analysis of variance in vegetative and productive characteristics in graft/rootstock combinations. Years (E); repetitions within years [R(E)]; graft/rootstock combination (G). Lima Farm, precocity

	GL	NF	ALT	VAC	VDC	EP	PRO
A	3	325362**	4.29**	3422.5**	2502.3**	380.63**	234.49**
R(E)	12	13410**	0.23*	76.9**	91.0**	2.87*	2.14*
G	5	48200**	3.49**	549.2**	633.0**	6.07**	7.28**
G×E	15	17056**	0.04**	22.5**	21.3**	2.37**	5.69**
Res	822						
CV		118.98	14.13	42.63	42.70	95.22	109.62
Mean		42.45	2.57	9.61	9.58	1.36	4186.3

Source: research data.

There was a significant effect for G×E interactions in all variables evaluated. The interaction is a complicating factor for the selection process, as it results in imprecision about the real performance of the plants in the face of environmental changes, causing different reactions as new conditions are provided.

Although the existence of this interaction is undesirable, this phenomenon distinguishes superior individuals possessing specific adaptability and broad stability under certain conditions (Carias *et al.*, 2016).

Following the classification presented by Gomes (1990), the experimental coefficients of variation for ALT, VAC, and VDC were within the range of values considered normal, although the latter two were high but acceptable due to their quantitative genetic control.

The scale developed by Gomes (1990) was not developed for perennial species. An appropriate coefficient of variation (CV) classification for citrus should consider intrinsic peculiarities associated with the genetic control of the trait under study, the number of replicates implemented in the area, and the experimental design adopted. Although there is little information on the genetic control of traits in citrus cultivars, most are heterozygous and polygenic, with their inheritance controlled by many genes (Oliveira *et al*., 2014).

The production components in citrus are characteristics of polygenic quantitative genetic control, conditioned by several gene complexes; therefore, phenotypic performance is greatly affected by environmental conditions (Cruz, 2012). Thus, the high experimental CV for NF, EP, and PRO obtained here can be considered normal.

The results of the principal component analysis are presented in Table 3. The sum of effects of the first two axes (PC1 and PC2) were above 99%, which is much higher than necessary to explain the total variation due to genetic effects. According to Yang *et al.* (2009), there must be a minimum sum of 60% of the total variance in the first two principal components. The value obtained for the present study is also higher than that obtained by Carvalho *et al.* (2020), who found that the first two axes explained 66.71% of the variation.

Table 3 - Percentage (P), cumulative percentage (PC), and mean square (QM) of the first three component axes for NF and ALT and two axes for the other characteristics. Lima Farm, orange precocity

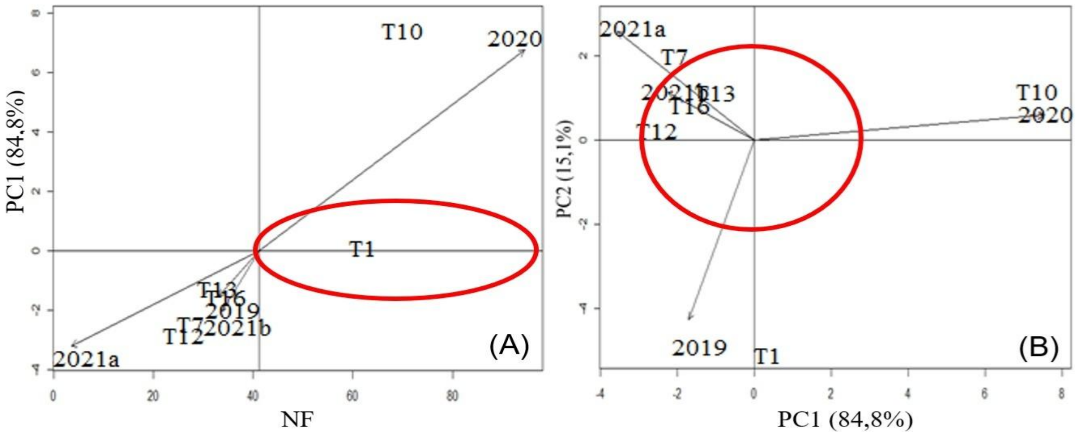
		P	PC	QM
NF	PC1	84.8	84.8	3417.59**
	PC2	15.1	99.9	854.06*
	PC3	0.1	100.0	8.331^{ns}
ALT	PC1	62.7	62.7	0.0067**
	PC2	36.5	99.2	0.0054*
	PC3	0.8	100.0	0.0002^{ns}
VAC	PC1	89.9	89.9	3.44*
	PC2	10.1	100.0	0.58^{ns}
VDC	PC1	88.5	88.5	3.14*
	PC2	11.5	100.0	0.61^{ns}
EP	PC1	61.8	61.8	0.282*
	PC2	38.2	100.0	0.261^{ns}
PRO	PC1	99.8	99.8	23099566*
	PC2	0.2	100.0	52706^{ns}

Significance of FGollob Test, ns: not significant; *: significant at 5%; **: significant at 1%.
Source: research data.

The F_{Gollob} test showed that the NF and ALT characteristics in the first two axes and VAC, VCD, EP, and PRO in the first axis were significant, indicating that the analysis adopting the AMMI2 model contained all variations generated only by genetic and environmental effects and essentially related to the interaction. This disregards the effects called noise or stochastic effects, which only generate confusion in the interpretation of the analyses (Maia *et al*., 2019). Thus, the adoption of the AMMI2 model is considered adequate in a study of the G×E interaction in a dataset.

In the AMMI1 graphical analysis (Figure 1), for NF, the materials with the best stability were close to the horizontal axis, and the fraction to the right had a positive contribution to the average. Here, T1 performed best in the AMMI1 model, and T10 showed low stability but a positive contribution to the average and apparent specificity to the conditions of 2020. When performing AMMI2 analysis, the T1 treatment, which was promising, showed low stability, which is undesirable. T10 continued to have specificity for the year 2020, and the other treatments were concentrated in a block, with very similar behavior to each other (Figures 1A and 1B). The lack of confirmation of the behavior in AMMI1 of the genetic materials when performing AMMI2 analysis indicates that the first axis was not able to capture most of the contribution to the average and that the second axis also had an important share. Here, the concentration of genetic material, with the exception of T1 and T10, did not resemble that observed by Carvalho *et al*. (2020), Huang *et al*. (2020), Ferrer *et al*. (2022), or Singh *et al*. (2023).

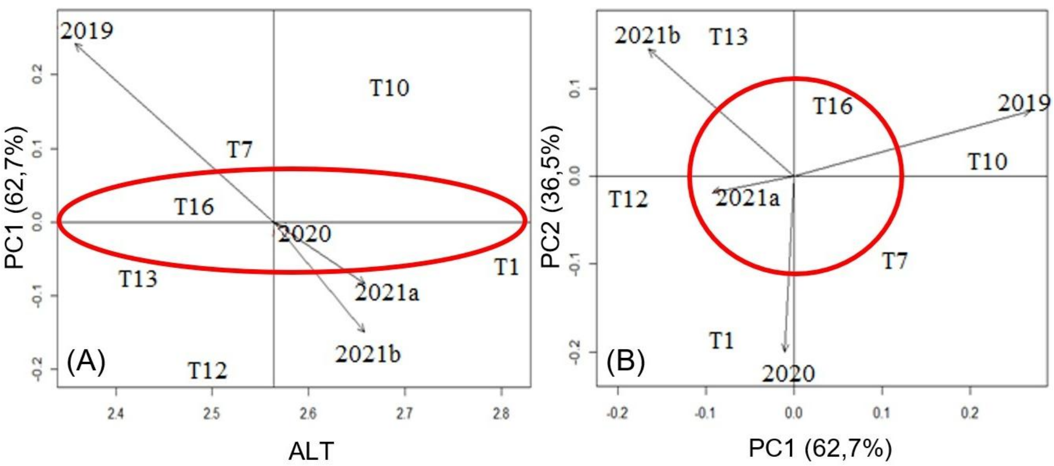
Figure 1 - AMMI analysis for the number of fruit (NF) characteristic: A) Biplot AMMI1, Means (x) vs PC1 (y); and B) Biplot AMMI2, PC1 (x) vs PC2 (y), with environments corresponding to years for graft/rootstock combinations in orange trees. Years are identified numerically, and combinations are identified as T, followed by the number



Source: research data.

As shown in Figures 2A and 2B, the rootstock with the greatest stability in ALT was T16; however, it had a negative contribution to the average, but if smaller trees are of interest, this represents an excellent material, as does T13. T1 had better stability, with a positive contribution to the average in the AMMI1 model, and productivity should then be verified.

Figure 2 - AMMI analysis for the plant height (ALT) trait: A) Biplot AMMI1, Means (x) vs PC1 (y); and B) Biplot AMMI2, PC1 (x) vs PC2 (y), with environments corresponding to years for graft/rootstock combinations in orange trees. Years are identified numerically, and combinations are identified as T, followed by the number



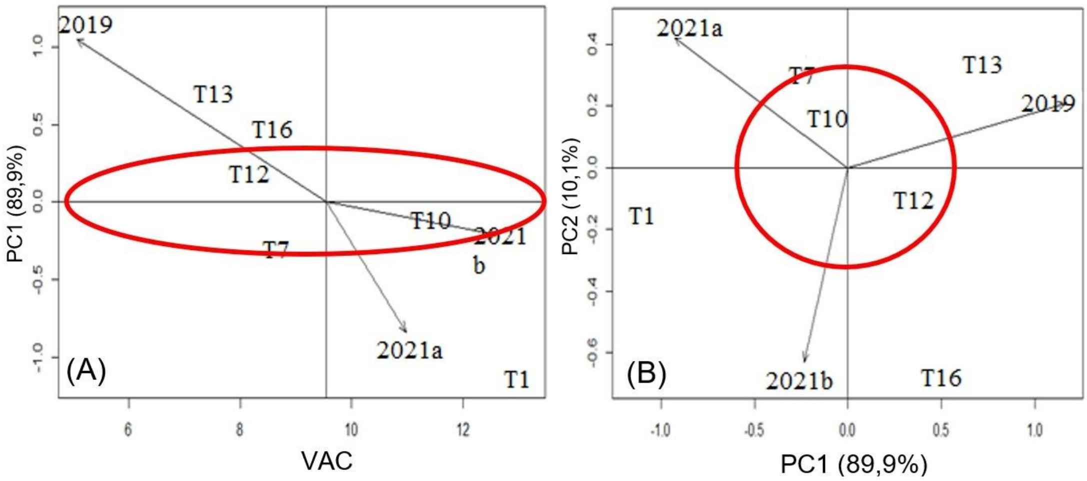
Source: research data.

The addition of the second axis (AMMI2) confirmed the behavior observed in the AMMI1 model, showing that the portion captured by the first axis was sufficient to explain the behavior of the genetic materials evaluated. This dispersion in both the AMMI1 and AMMI2 models was consistent with that obtained by Carvalho *et al*. (2020), Huang *et al*. (2020), Ferrer *et al*. (2022), and Singh *et al*. (2023).

The volume of the crown had a direct effect on the productive efficiency of each rootstock in combination with the crown, reflecting the weight of fruit on the branches. When there are many, the branches become heavier and arch downwards, reducing the volume of the crown; therefore, it is inversely proportional to its production (Schinor *et al.*, 2013).

For VAC in the AMMI1 analysis, the T10 material was considered promising, with apparent stability. T1 also had a positive contribution to the average but with low stability. The other treatments presented negative contributions, although T7 and T12 presented some stability.

Figure 3 - AMMI analysis for the characteristic crown volume before harvest (VAC): A) Biplot AMMI1, Means (x) vs PC1 (y); and B) Biplot AMMI2, PC1 (x) vs PC2 (y), with environments corresponding to years for graft/rootstock combinations in orange trees. Years are identified numerically, and combinations are identified as T, followed by the number

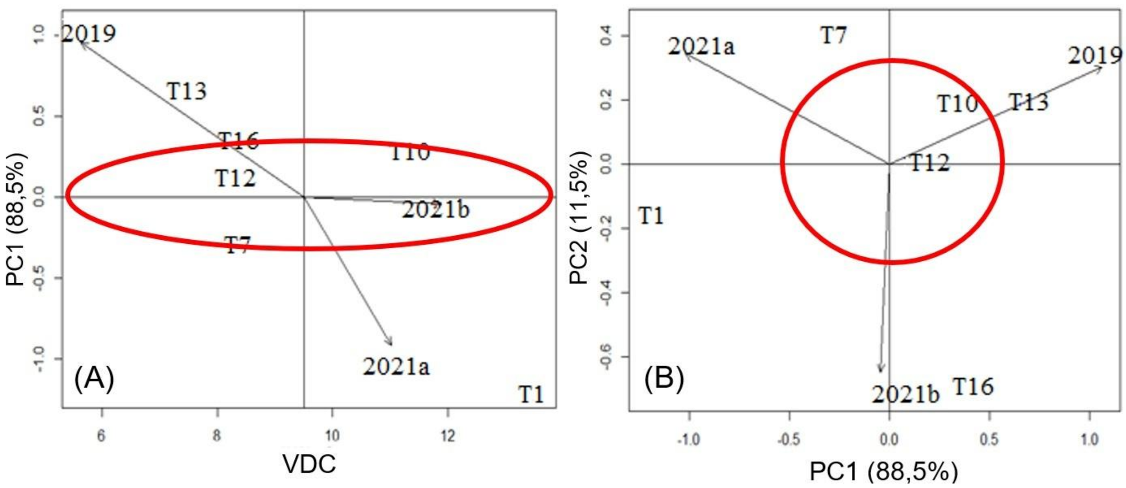


Source: research data.

By including the second axis in the AMMI2 analysis, the behaviors were ratified, demonstrating that the first axis was sufficient to capture almost all the constituent components of the observed variation in VAC characteristics. Similar to ALT, the dispersion in both the AMMI1 and AMMI2 models was consistent with that obtained by Carvalho *et al*. (2020), Huang *et al*. (2020), Ferrer *et al*. (2022), and Singh *et al*. (2023).

For VDC in the AMMI1 analysis, the T10 material was again considered promising, with apparent stability. T1 also had a positive contribution to the average but with low stability. The other treatments presented negative contributions, although T7, T12, and T16 presented some stability. Similar to that obtained for VAC, by including the second axis in the AMMI2 analysis, the performances were confirmed, demonstrating that the first axis was sufficient to capture almost all the constituent components of the observed variation in this characteristic. Therefore, among the evaluated materials, the V10 treatment had the best VAC and VDC (Figures 4A and 4B).

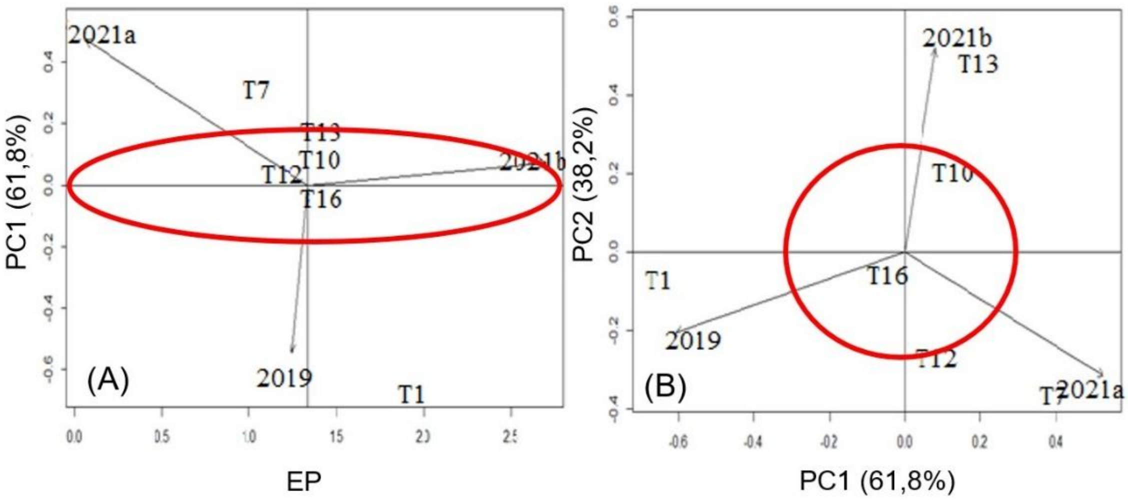
Figure 4 - AMMI analysis for the characteristic crown volume after harvest (VDC): A) Biplot AMMI1, Means (x) vs PC1 (y); and B) Biplot AMMI2, PC1 (x) vs PC2 (y), with environments corresponding to years for graft/rootstock combinations in orange trees. Years are identified numerically, and combinations are identified as T, followed by the number



Source: research data.

As shown in Figure 5A, compared to AMMI1 analysis, the best EP within the set of genetic materials was observed in T13, T10, and T16, which were close to the axis and, thus, presented stability. Although it made a positive contribution to the mean, T1 again showed low stability. Similar to the results obtained for VAC, when including the second axis in AMMI2 analysis, the behaviors were confirmed, demonstrating that the first axis was sufficient to capture almost all of the constituent components of the observed variation in this characteristic. Thus, among the evaluated materials, treatments T10 and T16 had the best EP (Figures 5A and 5B), eliminating T13. Additionally, the dispersion of the graft/rootstock combinations in the AMMI2 model was consistent with that obtained by Carvalho *et al*. (2020), Huang *et al*. (2020), Ferrer *et al*. (2022), and Singh *et al*. (2023), but the relative concentration in AMMI1 differed from those in the cited studies.

Figure 5 - AMMI analysis for the production efficiency (EP) characteristic: A) Biplot AMMI1, Means (x) vs PC1 (y); and B) Biplot AMMI2, PC1 (x) vs PC2 (y), with environments corresponding to years for graft/rootstock combinations in orange trees. Years are identified numerically, and combinations are identified as T, followed by the number

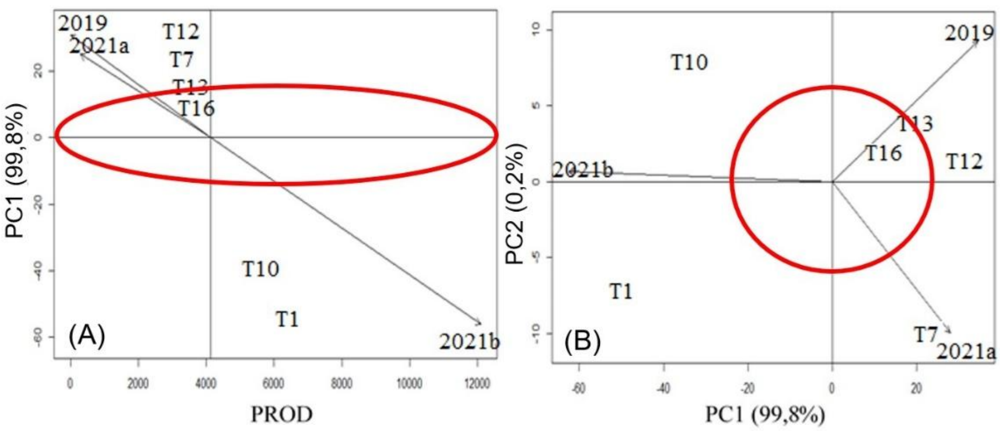


Source: research data.

Unlike the results observed by Siqueira and Salomão (2017), the best rootstocks, regardless of stability, were also those with the largest canopy volumes, i.e., plants with reduced size also had a lower EP (Figure 5). For this set of graft/rootstock combinations, densification results in EP loss. Thus, it is necessary to verify the appropriate spacing to avoid competition between plants since those with the largest VAC and VDC also had the best EP (T10).

As shown in Figure 6A, based on AMMI1 graphical analysis, the graft/rootstock combinations with a positive contribution to PRO, namely T1 and T10, did not present stability, but T13 and T16 showed stability. When using the second axis in AMMI2 analysis, the behaviors were confirmed, demonstrating that the first axis was sufficient to capture almost all the constituent components of the observed variation in this characteristic (Figures 5A and 5B). However, the complicating factor here was that the materials with the best productivity did not present stability. Additionally, the dispersion of the graft/rootstock combinations in the AMMI2 model was consistent with that obtained by Carvalho *et al*. (2020), Huang *et al*. (2020), Ferrer *et al*. (2022), and Singh *et al.* (2023); however, the relative concentration in AMMI1 differed compared to the results of these studies.

Figure 6 - AMMI analysis for the fruit production characteristic (PROD): A) Biplot AMMI1, Means (x) vs PC1 (y); and B) Biplot AMMI2, PC1 (x) vs PC2 (y), with environments corresponding to years for graft/rootstock combinations in orange trees. Years are identified numerically, and combinations are identified as T, followed by the number



Source: research data.

In orange plantations in which different graft/rootstock combinations may be available, different rootstocks are used for different environmental conditions due to their influence on the final characteristics of the plant, such as fruit quality and quantity, plant vigor and size, abiotic stress tolerance, and biotic stress resistance/tolerance (Medina *et al*., 2005; Santana *et al*., 2018). These distinct genetic compositions result in different performances considering the G×E interactions; therefore, the behavior observed in the graphs is completely coherent and allows the selection of materials that present greater stability or greater adaptability and higher productivity.

To understand and interpret the performance of genotypes under the effect of G×A interactions, Silva and Duarte (2006) recommended conducting experiments in different locations or years, enabling the evaluation of the magnitude of the interaction and its possible impact on genotype selection and recommendations. Here, the effect of the year is not the focus of the discussion, as it was only used to understand the stability, adaptability, and better performance in the average of the evaluated characteristics of the different graft/rootstock combinations.

4 Conclusions

Considering all evaluated characteristics, graft/rootstock combination T10 [Citrandarin 'San Diego' (TSK x TRENG – 314)] stood out, showing low stability in NF and PRO but stability in other characteristics (VAC, VDC, and EP). Combination T1 [Rangupur Santa Cruz (C. *limonia* Osbeck)] showed promise in terms of positive contribution to the averages; however, it did not present apparent stability.

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