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Post-harvest ssociations between the soluble solids content and the main dependant components related to the biometry of strawberry cv. Selva

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Abstract: This study investigated the direct and indirect associations between soluble solids content and key biometric traits in strawberry pseudofruits (cv. Selva) using path analysis, aiming to optimize breeding strategies for improved fruit quality. The cultivar was grown in a dystrophic Red Latosol under a tropical Aw climate (dry winter, rainy summer), with an average annual rainfall of 1,340 mm and a temperature of 26°C. A total of 110 intact fruits were harvested (one per plant), stored at 10°C for 20 days, and evaluated for length, width, thickness, fresh mass, maturity (% skin coverage), and soluble solids content (°Brix). Descriptive statistics revealed significant variability: fresh mass ranged from 4.70 to 27.40 g, length from 25.86 to 60.88 mm, and soluble solids content from 3.50 to 13.69%. Path analysis identified length as the strongest positive predictor of soluble solids content (direct effect = 0.88), followed by width, maturity, and malformation, while fresh mass exhibited a notable negative effect (-0.75), likely due to solute dilution in larger fruits. Indirect effects highlighted trade-offs; for example, fresh mass and postharvest integrity negatively influenced length but positively impacted maturity. The model explained 18.46% of the variation in BRIX (residual effect = 0.80), underscoring the complexity of these interactions. These findings emphasize the potential of morphometric traits as indirect selection criteria for enhancing sweetness in breeding programs. The study advances the integration of path analysis into strawberry improvement, offering a cost-effective tool to reconcile yield and sensory quality in tropical climates.

Keywords: horticulture; network correlations; path analysis; plant breeding; statistical analysis; Fragaria.
Abbreviation: MAS_fresh mass; LEN_length; WID_width; THC_thickness; BRI_°Brix; MAL_malformation of pseudofruit; MAT_maturation and POS_postharvest integrity.

Introduction

Strawberry production has grown significantly, with a 46% increase between 2013 and 2019 (Antunes et al., 2021; FAO, 2021). This growth reflects not only the expansion of cultivation but also changes in consumers' eating habits, as they increasingly associate their diet with disease prevention and the pursuit of a better quality of life (Zacharaki et al., 2024). When purchasing products, consumers often base their decisions on quality criteria such as color, shape, weight, odor, and freshness (Pinheiro et al., 2021). Unlike other fruits, it is often difficult to identify the commercial variety of strawberries, which can result in differences in sensory quality, including flavor, and confuse consumers when making purchasing decisions.

Strawberries stand out for their distinctive characteristics, such as their vibrant red color, heart shape, strong aroma, and sweet flavor. Furthermore, they are recognized as a functional food, rich in bioactive compounds such as vitamin C, anthocyanins, and flavonoids, which have antioxidant properties (Afrin et al., 2016; Edger et al., 2019). However, factors such as plant genetics, growing conditions, ripening stage, and post-harvest management directly influence the physical, biochemical, and sensory characteristics of the fruits (Lalk et al., 2020; Nunes et al., 2021). These aspects must be considered when evaluating the final quality of the product.

The growing demand for high-quality foods has driven genetic improvement programs for strawberries. In this context, estimating correlations between traits is essential, as it allows predicting how changes in one attribute affect others during the selection process (Silva et al., 2016). However, the most widely used strawberry cultivars globally are often poorly adapted to tropical climates, as they are developed mainly in temperate regions such as the United States, Spain, and Italy (Zeist & Resende, 2019). In South America, most seedlings are imported from Argentina and Chile, which increases production costs in countries such as Brazil, where cultivation occupies 4,300 hectares and more than 75% of seedlings are imported (FAO, 2021).

In breeding programs, the relationship between variables is extremely important for the simultaneous selection of traits, especially when the attribute of interest is complex or difficult to measure. In such cases, indirect selection, based on correlated traits with higher heritability, can speed up the process. However, some errors may occur in the selection strategies of the traits evaluated due to the quantification of the magnitude of the correlations between the variables. A strong relationship between two traits may result from the effect of a third trait or a group of traits on them (Cruz et al., 2014).

This aspect is crucial in simultaneous or indirect trait selection. Phenotypic correlation, although measurable, is limited in breeding programs because it includes genetic and environmental influences, making genetic correlation more appropriate, as it reflects only the hereditary association. In strawberries, cultivars are selected for productivity, disease resistance, and fruit quality (firmness, sweetness, acidity, and aroma) (Resende et al., 2008; Whitaker et al., 2011). The selection process, which involves classifications and multiple evaluations, is time-consuming and costly. Traditional selection, focused on a single trait through direct selection (based on the attribute of interest) or indirect selection (using a correlated trait), may not fully meet the demands of producers and consumers (Whitaker et al., 2011). Therefore, multivariate techniques, such as path analysis and selection indices, are essential to optimize the choice of genotypes that balance agronomic, biometric, and biochemical traits.

Path analysis, proposed by Wright (1921), is a useful tool for understanding the cause-and-effect relationships between traits, dividing the correlations into direct and indirect effects. This approach allows identifying key factors that influence fruit yield and quality, which are affected by agronomic practices and environmental conditions (Cockerton et al., 2021; Du et al., 2021). Multivariate techniques, such as path analysis and selection indices, are essential to optimize the choice of genotypes that combine agronomic, biometric, and biochemical traits in a balanced way.

The integrated application of these techniques to elucidate the relationships between key strawberry traits, such as soluble solids content and biometric attributes, offers an innovative approach to the genetic improvement of the crop. This methodology not only speeds up the selection process but also provides a deeper understanding of the interactions between traits, contributing to the development of cultivars that are more adapted and aligned with market demands. In this study, the objective is to apply path analysis to explore the direct and indirect associations between the soluble solids content and the main biometric components of the strawberry pseudofruit, aiming at the development of high-quality and better-adapted cultivars.

Results

Descriptive Analysis of Fruit Characteristics and Data Variability

The fruits used in this study exhibited considerable variation in their evaluated characteristics (Table 1). The fruit mass (MAS) ranged from 4.70 to 27.40 g, while the length (LEN) varied between 25.86 and 60.88 mm, width (WID) from 17.81 to 37.47 mm, and thickness (THC) from 16.39 to 33.59 mm. The soluble solids content (BRI) ranged from 3.50 to 13.69%. In contrast, postharvest conservation after 20 days varied from 1 to 10, and maturation (MAT) ranged from 18.01 to 100%.

The interquartile range (IQR), a robust measure of data dispersion unaffected by outliers, was calculated for the evaluated variables. The IQR values were 6.35 for MAS (16.57 - 10.22), 9.68 for LEN (51.35 - 41.67), 4.62 for WID (27.73 - 23.11), 3.59 for THC (23.89 - 20.30), 2.98 for BRI (9.20 – 6.22), 1.00 for postharvest integrity (POS) (10.00 - 9.00), and 19.68 for MAT (86.07 - 66.39). Notably, the MAT variable exhibited the highest variability compared to the other traits (Table 1).

All variables displayed asymmetric distributions. The density curves revealed distinct patterns, with MAS and LEN showing bimodal distributions concentrated between 10 and 20 g and 40 and 50 mm, respectively. Similarly, WID exhibited a bimodal pattern with data concentrated between 22.5 and 27.5mm, while THC showed a concentration of data between 20 and 25mm. BRI also displayed a bimodal distribution, with the highest data concentration between 7.5 and 10.5%. POS exhibited multimodality with data concentrated between 9.5 and 10%, and MAT presented a bimodal pattern with peaks between 37.7 and 87.5.

Correlation Analysis Among Evaluated Attributes

Fruit mass (MAS) exhibited strong positive correlations with the other biometric variables (Fig. 3 and 4). Specifically, the correlation coefficients between LEN and MAS, WID and MAS, THC and MAS, and THC and WID were 0.787, 0.785, 0.797, and 0.780, respectively, indicating a linear increase between the paired variables. In contrast, the remaining correlations among variables were below moderate levels ($r < 0.5$).

The correlation network illustrated in Fig. 3 highlights the strength and direction of these relationships. The thickness and color of the connecting lines represent correlation intensity, where thicker green lines indicate strong positive correlations, thinner green lines indicate weak positive correlations, and thin red lines represent weak negative correlations. Notably, negative correlations were observed between LEN and MAT, MAT and POS, and THC and BRI, indicating that increases in one variable corresponded to decreases in the other.

Fig. 1. Location of the study area, Cinturão Verde, in Três Lagoas, Mato Grosso do Sul, Brazil. The map was created using the R software's geobr p7ackage.

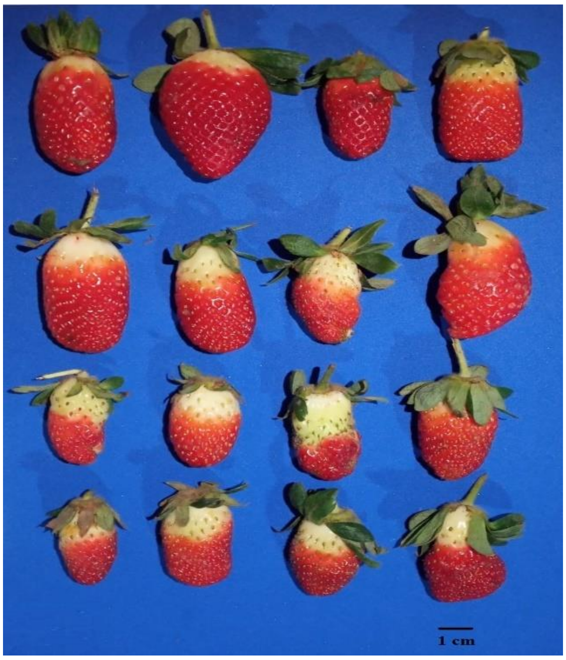

Fig. 2. The shape variations of Selva strawberries cultivated in Três Lagoas, Mato Grosso do Sul, Brazil in 2023 were analyzed.

Table 1. Descriptive statistics for characters fresh mass (MAS), length (LEN), width (WID), thickness (THC), soluble solids content, °BRIX (BRI), malformation of pseudofruit (MAL), maturation (MAT) and postharvest integrity (POS) evaluated in 110 strawberry pseudofruit harvested in Três Lagoas, Brazil, 2023.

Descriptive statistics	MAL	MAS	LEN	WID	THC	BRI	POS	MAT
Minimum	0.0	4.70	25.86	17.81	16.39	3.50	1.00	18.01
Maximum	1.0	27.40	60.88	37.47	33.59	13.69	10.00	100.00
First quartile	1.0	10.22	41.67	23.11	20.30	6.22	9.00	66.39
Median	1.0	14.05	46.51	25.41	22.18	8.05	10.00	74.35
Mean	0.8	13.72	45.69	25.86	22.48	8.08	9.33	75.97
Third quartile	1.0	16.57	51.35	27.73	23.89	9.20	10.00	86.07
Standard deviation	0.40	4.44	7.39	3.82	3.06	2.13	1.23	14.65
Coefficient of variation (%)	50.0	32.0	16.0	15.0	14.0	26.0	13.0	20.0

Path Analysis and Causal Relationships
The path analysis, based on the hypothesized causal diagram (Fig. 4), revealed both direct and indirect effects among the studied attributes. In the diagram, larger circles represent first-degree correlations and smaller circles represent second-degree correlations, with green lines depicting significant positive effects and red lines indicating significant negative effects. The analysis demonstrated that LEN, WID, MAT, and malformation (MAL) exerted positive direct effects on BRI, while MAS exhibited a negative direct effect.
Indirectly, LEN, WID, and THC had significant negative influences on MAS. Conversely, MAS, WID, THC, and POS positively influenced LEN, whereas MAT and MAL negatively affected it. The residual effect was 0.8014, and the determination coefficient was 0.1846, indicating the proportion of unexplained variation by the model.

Discussion

Significant correlations were identified between the explanatory variables and the soluble solids content (BRI) in strawberries. The variable that showed the greatest positive brightness was fruit LEN ($\rho = 0.88$), indicating that longer fruits tend to have a higher concentration of soluble solids. On the other hand, MAS showed the greatest negative demonstration ($\rho = -0.75$). This may be due to the fact that greater fruit length would increase tissue vascularization differently from mass, since a greater mass would only decrease the soluble solids content, since, in theory, the amount of soluble solids available for each fruit would be similar, regulated by genetic factors, and fruits with greater mass had a lower sugar content (Fig. 5). This manifestation can be explained by the dilution effect: fruits with greater mass tend to have a lower concentration of soluble solids, since the accumulation of carbohydrates and other metabolites is distributed in a larger volume of tissue. In larger fruits, dilution of soluble solids may occur due to a greater volume of water, while smaller fruits tend to have a higher concentration of sugars per unit mass. This effect has been observed in other studies, such as that of Bartczak et al. (2010), which found a positive improvement between plant fresh weight and total yield of strawberries. In addition to length and mass, other variables such as MAT, WID and MAL also influenced the content of soluble solids. Maturity, in particular, showed a positive gloss, indicating that fruits that ripened more quickly may accumulate higher concentrations of sugars. This is relevant for producers seeking to optimize early harvest, especially in markets where precocity is valued. Fruit quality, defined by superior standards of size and appearance, was also influenced by traits such as WID and THC, indicating that larger fruits may have a higher quality in terms of size, but may suffer dilution of soluble solids due to the greater volume of water. This trade-off between size and sugar concentration is crucial for plant selection in breeding programs, especially when the goal is to produce high-quality fruits in both size and flavor.
The path analysis revealed that, in addition to LEN, WID, MAT, and MAL had positive direct effects on soluble solids content, except that these attributes can be used as indirect selection criteria to increase sweetness in breeding programs. Al-Ashkar et al. (2021) highlighted the importance of identifying traits with a strong direct effect in selection, as they are highly correlated with the variable of interest and can generate an effective response in indirect selection. Growth modeling is an essential tool for understanding the relationship between biometrics and productivity, aiding in the development of more adapted genotypes. Therefore, selecting fruits with greater length and lower fresh mass can be an effective strategy to improve strawberry quality without compromising its yield.
According to Feldmann et al. (2020), morphometric traits such as width, height, aspect ratio, and descriptors derived from multivariate analysis (such as principal components of biomass and shape) can be highly heritable (with H^2 between 0.58 and 0.72), which increases the efficiency in selecting superior genotypes. The study also emphasizes that complex morphometric traits, even latent ones, can be transformed into useful quantitative variables for genetic analyses, increasing the potential for selection assisted by traits correlated with attributes of agronomic interest, such as °Brix. Thus, the combined use of multivariate and morphometric analyses, such as path analysis and selection based on composite indices, can significantly improve the selection of genotypes with a balance between fruit quality and productivity.
In a field experiment with seven exotic strawberry genotypes, Ara et al. (2009) observed that the number of leaves, stolons per plant, nodes per stolon, and fruits per plant had positive correlations and a direct impact on fruit production. They suggested that these traits should receive more attention during selection. Similarly, Karami and Gholami (2012), in a trial with 20 strawberry cultivars, concluded that the total number of fruits had the greatest direct impact on production, identifying the number of fruits, fruit weight, fruiting initiation data and fruiting time as the main components of yield. In another study, Emdad et al. (2013) analyzed six strawberry genotypes and observed a strong relationship between traits such as plant height and fruiting time. number of flowers per plant and fruit length, suggesting that these variables should be prioritized in selection. Diel et al. (2020) also highlighted the effectiveness of path analysis based on the total number of fruits for indirect selection of total fruit mass.
Techniques such as indirect selection, based on highly correlated and highly heritable traits, are promising for accelerating genetic gain in strawberry cultivars, especially considering the complexity of the genome and the strong genotype × environment interaction. It is recommended that genetic improvement programs to increase the soluble solids content in strawberries prioritize the selection of longer fruits with lower fresh mass, since these attributes are strongly correlated with fruit quality. In addition, monitoring ripening during harvest and storage can help maintain the balance between fruit quality and conservability. These results contribute to the understanding of the phenotypic relationships between biometric attributes and strawberry quality, providing valuable information for improving selection and postharvest management techniques.

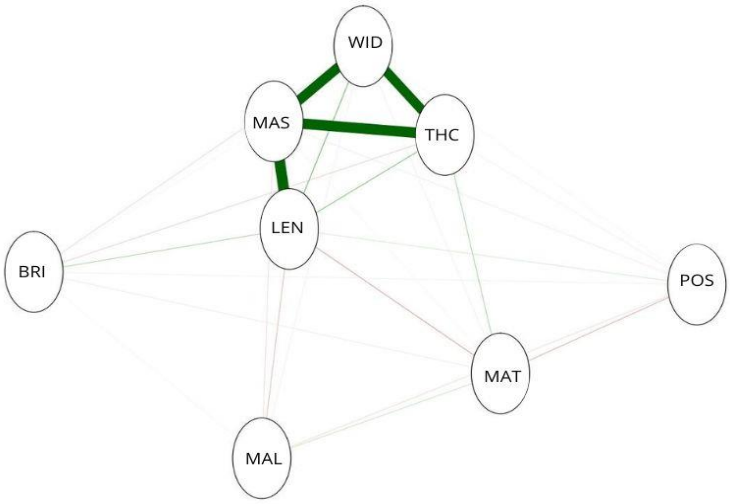

Fig. 3. Pearson's correlation network between fresh mass (MAS), length (LEN), width (WID), thickness (THC), soluble solids content °BRIX (BRI), malformation of pseudofruit (MAL), maturation (MAT) and postharvest integrity (POS) evaluated in 110 strawberry pseudofruit harvested in Três Lagoas, Brazil, 2023.

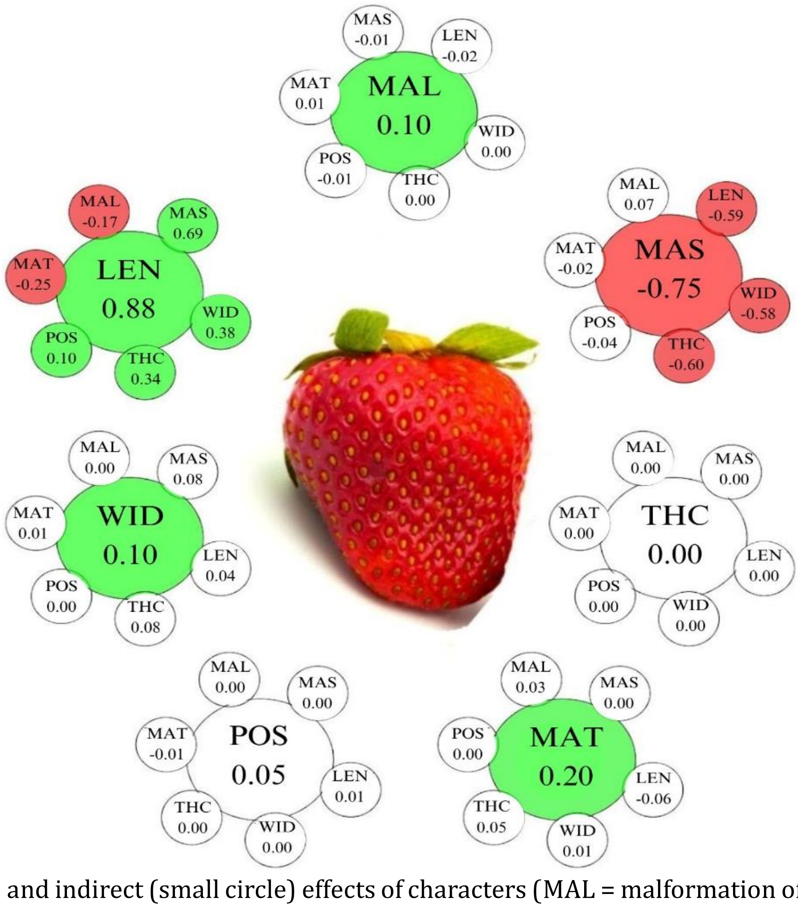

Fig. 4. Direct (larger circle) and indirect (small circle) effects of characters (MAL = malformation of pseudofruit; MAS = fresh mass; LEN = length; WID = width; THC = thickness; POS = post-harvest conservation; MAT = maturation on the quantity of soluble solids (BRIX) in 110 pseudofruit strawberry cv. Selva. Três Lagoas, Mato Grosso do Sul, Brazil, 2023

Materials and Methods

Plant Materials

The strawberry fruit (Fragaria × ananassa Duch.) cv. Selva was cultivated in Três Lagoas, Brazil (20° 45' 35'' S, 51° 41' 42'' W) (Fig. 1) and obtained through open pollination. The plants were grown in dystrophic Red Latosol (Embrapa, 2013) and received necessary cultural treatments when needed. According to the Köppen classification, the region's climate is classified as Aw, characterized as hot and humid tropical, with two well-defined seasons: a dry winter and a rainy summer. The municipality's average annual rainfall is 1340 mm and the average annual temperature is 26°C.

Sampling strategy and variables analyzed

The fruits were harvested in June. Immediately after harvest, they were stored at 10°C for 20 days to maintain post-harvest quality during transport. Subsequently, the fruits were transferred to the Plant Science Laboratory of the UNESP School of Engineering in Ilha Solteira (São Paulo, Brazil) for analysis. One hundred and ten intact fruits were randomly selected from the field (one per plant), all with standardized dimensions of 42 ± 2 mm in width (W) and length (L) (Fig. 1), a commercial size that reduces extreme defects - smaller fruits may be immature, while larger ones have higher metabolic activity (PBMH and PIMo, 2009), ensuring reliable data.

Morphometric characteristics of the fruits, including length (mm), width (mm), and thickness (mm), were measured using a digital caliper. Fresh mass (g) was determined with an analytical balance. Degree of maturation (% of skin coverage) and soluble solids content (°Brix) were assessed using a refractometer.

Statistical Analysis

A scatter plot was generated to illustrate the dispersion and correlation between the measured variables. A correlation network was constructed where the proximity of nodes (representing traits) was proportional to the total correlation value. Edge thickness was adjusted with a cut-off value of $|r_{ij}| \geq 0.70$ to highlight significant correlations. Green edges indicated positive correlations, while red edges represented negative correlations.

Path analysis was conducted to explore the relationships between the dependent variable (°Brix) and independent variables (fresh mass, length, width, thickness, pseudofruit malformation, maturation, and postharvest integrity). All statistical analyses were performed using R software version 4.3.2 (R Core Team, 2023) with the GGally (Schloerke et al., 2018), qgraph (Epskamp et al., 2012), and agricolae (Mendiburu and Mendiburu, 2019) packages.

Conclusions

Based on the results of this study, it is evident that there is a wide variety of traits observed even within a single strawberry cultivar. Such diversity can pose challenges for commercial fruit production, particularly with regard to standardizing quality and consistency of the product. Therefore, it is important for producers to be aware of these variations and work to minimize them through the adoption of careful cultivation practices and selective plant breeding.

Authors contributions: DBS, KSS, and GAF were responsible for the conceptualization of the study; BGL developed the methodology; DBS, KSS, and BGL conducted the formal analysis; DBS, KSS, KMCS, and DGC carried out the investigation; GAF provided resources and supervised the experiment; DBS, APLL, SFL, and AFAF were in charge of data visualization; DBS, KSS, and KMCS drafted the original manuscript; and DGC, APLL, SFL, and AFAF were responsible for reviewing and editing the text.

References

Afrin S, Gasparrini M, Forbes-Hernandez TY, Reboredo-Rodriguez P, Mezzetti B, Varela-López A, ... Battino M (2016) Promising health benefits of the strawberry: a focus on clinical studies. J. Agric. Food Chem. *64*(22):4435-4449. https://doi.org/10.1021/acs.jafc.6b00857

Al-Ashkar I, Ibrahim A, Ghazy A, Attia K, Al-Ghamdi AA, Al-Dosary MA (2021) Assessing the correlations and selection criteria between different traits in wheat salt-tolerant genotypes. Saudi J. Biol. Sci. 28(9):5414-5427. https://doi.org/10.1016/j.sjbs.2021.05.076

Antunes LEC, Reisser Júnior C, Bonow S (2021) Morango: produção aumenta ano a ano. *Campo Negócios 37*: 88–92. +++

Ara T, Haydar A, Hayatmahamud KK, Hossain MM (2009) Analysis of the different parameters for fruit yield and yield contributing characters in strawberry. *Int. J. Sustain. Crop Prod*. *4*(5):15-18. https://ggfjournals.com/content/papers/v4i515-18

Bartczak M, Lisiecka J, Knaflewski M (2010) Correlation between selected parameters of planting material and strawberry yield. *Folia Hort. 22*(1):9-12. https://doi.org/10.2478/fhort-2013-0144

Cockerton HM, Karlström A, Johnson AW, Li B, Stavridou E, Hopson KJ, ... Harrison RJ (2021) Genomic informed breeding strategies for strawberry yield and fruit quality traits. Front. Plant Sci. *12*:724847. https://doi.org/10.3389/fpls.2021.724847

Cruz CD, Carneiro PCS, Regazzi AJ (2014). Modelos biométricos aplicados ao melhoramento genético*. rev. e ampl*. Viçosa: Ed. da UFV, 2.

Diel MI, Lúcio AD, Schmidt D, Pinheiro MVM, Olivoto T, Sari BG, ... Lambrecht DM (2020) Linear relationships between yield, quality and phenological traits of strawberry cultivars. J. Agric. Stud. *8*(3):737-755. https://doi.org/10.5296/jas.v8i3.16807

Du Y, Du J, Liu X, Yuan Z (2021) Multiple-to-multiple path analysis model. PLoS One. *16*(3):e0247722. https://doi.org/10.1371/journal.pone.0247722

Edger PP, Poorten TJ, VanBuren R, Hardigan MA, Colle M, McKain MR, ... Knapp SJ (2019) Origin and evolution of the octoploid strawberry genome. Natur Genet. 51:541–547. https://doi.org/10.1038/s41588-019-0356-4

Embrapa - Empresa Brasileira de Pesquisa Agropecuária (2013) Sistema brasileiro de classificação de solos. 3. ed. Rio de Janeiro: Embrapa Solos.

Emdad A, Hossain MI, Kabir K, Jahan MS (2013) Correlation and path analysis in six strawberry (*Fragaria ananassa*) genotypes. The agric. *11*(2):74-78. https://doi.org/10.3329/agric.v11i2.17491
Epskamp S. (2019) Network Visualizations of Relationships in Psychometric Data and Structural Equation Models. de Mendiburu F, de Mendiburu MF. Package 'agricolae'. R package version.
FAO–Food and Agriculture Organization Corporate Statistical Database. FAO Online Database. Accessed: Jun, 26, 2024. from http://www.fao.org/faostat/es/#data/SC
Feldmann MJ, Hardigan MA, Famula RA, Lopez CM, Tabb A, Cole GS, Knapp SJ (2020) Multi-dimensional machine learning approaches for fruit shape phenotyping in strawberry. *GigaSci*. *9*(5):giaa030. https://doi.org/10.1093/gigascience/giaa030
Karami F, Gholami M (2012) Interrelationships of traits and path analysis of yield in strawberry (*Fragaria× ananassa* Duch.). In VII Inte Strawb Symp 1049 (pp. 415-421).
Lalk GT, Bi G, Zhang Q, Harkess RL, Li T (2020) High-Tunnel Production of Strawberries Using Black and Red Plastic Mulches. Hortic. 6(4):73. https://doi.org/10.3390/horticulturae6040073
Mendiburu F, Mendiburu MF (2019). Package 'agricolae'. *R Package, version*, *1*(3), 1143-49.
Nunes G, Teixeira F, Schwarz K, Camargo CK, Resende JTVD, Santos EFD, ... Novello D (2020) Influence of genetic variability on the quality of strawberry cultivars: Sensorial, physical-chemical and nutritional characterization. Acta Sci. Agron. *43*:e46862. https://doi.org/10.4025/actasciagron.v43i1.46862
Pinheiro DF, Resende JTVD, Constantino LV, Hata FT, Hata NNY, Lustosa SBC (2021) Physical, biochemical, and sensory properties of strawberries grown in high-altitude tropical climate. Ciênc e Agrotec, 45:e008221. https://doi.org/10.1590/1413-7054202145008221
PBMH & PIMo - Programa brasileiro para a modernização da horticultura & Produção integrada de morango. (2009) Normas de Classificação de Morango. São Paulo: CEAGESP (Documentos, 33).
R Core Team (2023) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. Avaliable in: <https://www.R-project.org>.
Resende JTV, Camargo LKP, Argandona EJS, Marchese A, Camargo CK (2008) Sensory analysis and chemical characterization of strawberry fruits. Hort Bras 26:371–374. https://doi.org/10.1590/S0102-05362008000300015
Schloerke B, Crowley J, Cook D, Briatte F, Marbach M, Thoen F, ... Larmarange J (2018). Package GGally: extension to 'ggplot2'.
Silva ARD, Rêgo ERD, Pessoa AMDS, Rêgo MMD (2016) Correlation network analysis between phenotypic and genotypic traits of chili pepper. Pesq Agrop Bras. 51:372-377. doi.org/10.1590/S0100-204X2016000400010
Whitaker VM, Hasing T, Chandler CK, Plotto A, Baldwin E (2011) Historical trends in strawberry fruit quality revealed by a trial of university of Florida cultivars and advanced selections. HortSci. 46(4):553–557. https://doi.org/10.21273/HORTSCI.46.4.553
Wright S. (1921) Correlation and causation.
Zacharaki AK, Monaghan JM, Bromley JR, Vickers LH (2024). Opportunities and challenges for strawberry cultivation in urban food production systems. Plants, People, Planet, *6*(3):611-621. https://doi.org/10.1002/ppp3.10475
Zeist AR, Resende, JTV (2019) Strawberry breeding in Brazil: Current momentum and perspectives. Hort Bras. 37:7–16. https://doi.org/10.1590/S0102-053620190101