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Plant protection

Evaluation of production and fruit quality of a yellow passion fruit cultivar infected with the cowpea aphid-borne mosaic virus

Francielly Rodrigues Gomes[1], Danielle Fabíola Pereira da Silva[2], Cláudia Dayane Marques Rodrigues[3], Alejandro Hurtado Salazar[4], Hildeu Ferreira Assunção[5], Simério Carlos Silva Cruz[6]

Abstract – This work aimed to characterize and evaluate the correlations between fruit and pulp characteristics of a commercial cultivar of yellow passion fruit (FB 200) infected with the cowpea aphid-borne mosaic virus (CABMV). The observation of natural infection occurred after the beginning of flowering. The parameters weight, length, and diameter, peel thickness, pulp yield, soluble solids content, titratable acidity, and the soluble solids content/titratable acidity ratio were evaluated. A completely randomized block design composed of 20 plots with five replications was adopted. The data were subject to descriptive analyses and Pearson's Correlation at 1 and 5% of significance. CABMV has decreased the quality and physical characteristics of fruits, but they still could be destined for juice processing industries. Many parameters of the fruits presented significant positive correlations.

Index Terms: *Passiflora edulis*, *Potyviridae*, *Potyvirus*, passion fruit woodiness.

Avaliação da produção e qualidade de frutos de uma cultivar de maracujazeiro-amarelo infectada com o cowpea aphid-borne mosaic virus

Resumo – Este trabalho teve como objetivo caracterizar e avaliar as correlações entre as características do fruto e da polpa de uma cultivar comercial de maracujá-amarelo (FB 200) infectada com o cowpea aphid-borne mosaic virus (CABMV). A infecção natural foi constatada após o início da floração. Os parâmetros peso, comprimento, diâmetro, espessura da casca, rendimento de polpa, teor de sólidos solúveis, acidez titulável e relação de sólidos solúveis/acidez titulável foram avaliados. Adotou-se o delineamento de blocos inteiramente casualizados composto por 20 parcelas, com cinco repetições. Os dados foram submetidos a análises descritivas à correlação de Pearson a 1 e 5% de significância. O CABMV diminuiu a qualidade e as características físicas dos frutos, mas estes ainda podem ser destinados às indústrias de processamento de sucos. Correlações positivas significativas foram observadas entre muitos parâmetros avaliados.

Termos para Indexação: *Passiflora edulis*, *Potyviridae*, *Potyvirus*, endurecimento do fruto do maracujá.

Corresponding author:
fram_rodgomes@hotmail.com

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[1]M.Sc, PhD student, Universidade Estadual Paulista/Faculdade de Ciências Agrárias e Veterinárias, Jaboticabal – SP, Brazil. E-mail: fram_rodgomes@hotmail.com (ORCID 0000-0001-7282-0719)

[2]PhD, Professor at Programa de Pós-graduação em Agronomia, Universidade Federal de Jataí, Jataí – GO, Brazil. E-mail: daniellefpsilva@ufj.edu.br (ORCID 0000-0001-7366-5650)

[3]Undergraduate student, Unidade Acadêmica Especial de Ciências Agrárias, Universidade Federal de Jataí, Jataí – GO, Brazil. E-mail: claudia-marques@ufj.edu.br (ORCID 0000-0002-8502-6810)

[4]PhD, Professor at Universidad de Pamplona, Facultad de Ciencias Agrarias, Pamplona, Colombia. E-mail: alhuza@gmail.com (ORCID 0000-0002-1251-125X)

[5]PhD, Professor at Programa de Pós-graduação em Agronomia, Universidade Federal de Jataí, Jataí – GO, Brazil. E-mail: hildeu@ufj.edu.br (ORCID 0000-0002-4203-6568)

[6]PhD, Professor at Programa de Pós-graduação em Agronomia, Universidade Federal de Jataí, Jataí – GO, Brazil. E-mail: simerio@ufj.edu.br (ORCID 0000-0002-6327-8590)

In recent decades, the cultivation of passion fruit has been gaining momentum in tropical fruit farming as an alternative for smallholder farms. This fruit crop has been attracting producers because it can generate revenue quickly and enables farmers to grow fruits virtually during the whole year (SACOMAN et al., 2018).

Brazil is the largest producer and consumer of yellow passion fruit (*Passiflora edulis* Sims) in the whole world (BOTELHO et al., 2019) and has produced 593,429 tons of fruits in an area of 41,800 hectares in 2019 (IBGE, 2020). The fruits destined for fresh consumption account for about 60% of the Brazilian production, while the remaining 40% produce is processed.

The cowpea aphid-borne mosaic virus (CABMV) can compromise fruit quality and yield. Its main symptoms consist of small plant size; induction of mosaic, blisters, and deformation in leaves; fruit woodiness resulting in poor pulp yield and a small number of seeds per unit (VIANA et al., 2014).

The CABMV from the *Potyviridae* Family and *Potyvirus* genus is a single-stranded RNA. Owing to the symptom induced in the fruits, the disease caused by the CABMV is called passion fruit woodiness (PFW). It can be transmitted naturally through several aphid species or mechanically through inoculation by a buffer extract or from purified and concentrated viral preparations, or even through non-sanitized pruning tools (FREITAS et al., 2015; MBEYAGALA et al., 2018).

Since there are no reports of efficient chemical control for this virus, some management techniques have been tested, and they showed promising results to increase passion fruit yield, e.g., the production of tall seedlings in a greenhouse covered with an anti-aphid screen, orchard elimination at the end of the productive cycle, and an annual crop cycle associated with reduced plant densities (NARITA et al., 2012). It is worth noting that late infection can lead to a decrease in the losses caused by the disease, and the use of suitable management techniques can increase orchard profitability even in the presence of the CABMV (SAMPAIO et al., 2008).

Given the importance of the passion fruit crop to the Brazilian fruit farming, there is the need to understand the occurrence of the CABMV and its impact on quality, yield, and, consequently, the profitability of orchards, which can assist future decisions. Therefore, this work aimed to characterize and evaluate the correlations between fruit and pulp characteristics of yellow passion fruit (cv. FB 200) naturally infected with an isolated cowpea aphid-borne mosaic virus.

The experiment took place in an orchard in the municipality of Jataí, State of Goiás, Brazil, located at coordinates 17°92'63''S/69 51°71'28''W, during the months of September through December. The climate is tropical wet-dry (Aw), according to the Köppen-Geiger classification, with the dry period occurring between May and September and the rainy period, between October and April. Average temperature is about 23 °C, and the annual rainfall rate is 1,541 mm.

The cultivation of the plants occurred in a two-wire trellis system spaced at 3 per 5 meters. Irrigation during the dry periods took place every day by means of a dripping system with a discharge of 2 L per hour. There were no records of occurrence of the CABMV in the area. The virus occurred naturally through aphids infected with the disease, and the first symptoms were observed after the beginning of flowering, approximately ten months after planting. Two branches were collected from the upper third of each plant, wrapped into plastic bags, and sent to the laboratory to confirm the infection. To verify the presence of the disease the Plate Trapped Antigen-Enzyme Linked Immunosorbent Assay test (PTA-ELISA) was performed with a polyclonal antiserum against the CABMV. The absorbance of the samples was measured using a wavelength at 405 nm. Were used positive and negative controls, and the test samples presented positive results to the CABMV when the reading of the average absorbance showed values equal to or higher than three times the average value of the negative test samples. The analysis has confirmed that 100% of the tested samples presented the CABMV.

The experimental arrangement was a completely randomized block design with 20 blocks composed of three plants. Five fruits were selected randomly in each block, in a total of 100 fruits. The fruits were evaluated for: fruit weight (g), determined on the basis of individual weighing; length and diameter (mm), determined by using longitudinal and transversal measurements around the fruits; peel thickness (mm), determined with the measure of the epicarp + mesocarp; pulp yield (%), measured using pulp weight and transformed to percentage; soluble solids content (°Brix), measured in a portable refractometer; titratable acidity (% of citric acid), determined by titration with a NaOH solution (AOAC, 2016) and soluble solids content/titratable acidity ratio (SSC/TA), determined on the basis of the quotient between these two characteristics.

The data of the evaluated characteristics underwent descriptive analysis, and correlation was tested through Pearson's correlation at 1% ($p < 0.01$) and 5% ($p < 0.05$) probability.

Fruits produced from CABMV-infected plants had 134.57 g in weight and 82.69 mm in length (Table 1). Celestrino et al. (2020), growing fruits of the same species under different conduction systems for secondary branches, without the occurrence of the CABMV, found values ranging from 260 to 280 g in weight. Negreiros et al. (2007) produced fruits with 166.27 g in weight and 79.93 mm in length for yellow passion fruit without CABMV occurrence. The reduced weight for the cultivar FB 200 in the present study was due to the occurrence of the virus, which causes a decrease in leaf area and interferes in photosynthetic processes, thus contributing to the formation of smaller, deformed, and hardened fruits (JUNCO et al., 2020).

Table 1. Physical and chemical characterization of yellow passion fruit (cv. FB 200) with the cowpea aphid-borne mosaic virus.

Characteristic	Average	SD[/1]	Range (Min-Max)	CV (%)[/2]
Weight (g)	134.57	21.76	85.55-175.31	16.17
Length (mm)	82.69	3.46	73.93-88.79	4.19
Diameter (mm)	70.16	5.49	62.28-83.92	7.82
Peel thickness (mm)	7.16	1.02	4.43-8.56	14.29
Pulp yield (%)	52.69	10.02	37.29-75.46	19.02
Soluble solids content (°Brix)	12.76	1.26	9.90-14.60	9.88
Titratable acidity (% of citric acid)	5.67	1.16	2.61-7.78	20.46
Soluble solids/Titratable acidity Ratio	2.35	0.57	1.61-4.04	24.59

[/1] Standard deviation; [/2] Coefficient of variation.

Fruit diameter for plants infected with the CABMV ranged from 62 to 83 mm, and it was 70.16 mm on average (Table 1). Based on the commercial classification system (COIMBRA et al., 2012), the fruits produced in the present study were classified as 2A, which indicates that the occurrence of the CABMV has affected fruit diameter, leading to a decrease in commercial value. The selection of fruits that presents higher diameters implies heavier fruits with higher pulp yield, being a quality parameter evaluated by the consumers (BOTELHO et al., 2019).

The fruits of the cultivar FB 200 infected with the CABMV presented peel thickness of 7.16 mm and 52.69% of pulp yield (Table 1). Although thinner peels may lead to lower resistance during fruit transport, they result in less waste disposal by consumers and greater pulp yield because the internal part of the fruits is larger (BRAGA et al., 2017). High pulp yield is one of the characteristics of cultivar FB 200 (BORGES et al., 2008). A pulp yield rate higher than 50% is desirable for fruit processing purposes (CAMPOS et al., 2013). Therefore, the findings in the present study indicate that the fruits produced with the occurrence of the CABMV could meet the market demand of the juice processing industry.

Regarding the chemical characteristics of the pulp, there was 5.67% of titratable acidity and 12.76 °Brix in soluble solids content for fruits of the commercial cultivar FB 200 (Table 1); therefore, these fruits are suitable for processing. The juice processing industry demands a minimum standard of 2.5% of citric acid and 11 °Brix at the temperature of 20 °C, which requires less sugar and reduced addition of acidifiers when preparing beverages (SILVA et al., 2015).

The SSC/TA ratio was 2.35, on average, the fruits of the cultivar FB 200 (Table 1). For fresh consumption, the fruits must have ratio values higher than three since it implies fruits with better quality because sweeter and less acid fruits with a high ratio are preferred in this industry; however, lower ratio values are acceptable for juice processing (MEDEIROS et al., 2014; SANTOS et al., 2017). Therefore, the SSC/TA ratio for fruits with the CABMV indicates that these fruits could meet the standards required by the juice processing industry.

Fruit weight of the commercial cultivar FB 200 presented a significant correlation with fruit diameter (r = 0.592) and pulp yield (r = -0.514) (Table 2). Although these correlations are related to the internal content of the fruit, and are an indication of higher pulp yield (NEGREIROS et al., 2007), Oliveira et al. (2011), when evaluating the characteristics of yellow passion fruit with different sizes, found that there is no influence of fruit size on juice yield. Santos et al. (2009), evaluating different passion fruit progenies without the occurrence of the CABMV, found a positive correlation between fruit weight and diameter (r = 0.904) but they have not found a correlation between diameter and pulp yield.

Peel thickness presented a positive correlation with fruit length (r = 0.527) (Table 2), indicating that the increase in peel thickness is proportional to that of fruit length. These two characteristics may have presented a correlation because of the occurrence of the CABMV, since the virus causes peel hardening and increases peel thickness, thus increasing fruit length (FISCHER et al., 2005; SANTOS et al., 2009).

Titratable acidity presented a positive correlation with soluble solids content (r = 0.564) and the soluble solids content/titratable acidity ratio (r = -0.908) (Table 2), indicating that the soluble solids content increases along with titratable acidity, and if the ratio increases, titratable acidity decreases.

Table 2. Pearson's coefficient correlation between physical and chemical characteristics of yellow passion fruit (cv. FB 200) with the cowpea aphid-borne mosaic virus.

	FW	FL	FD	PT	PY	SSC	TA
FL	0.235^{NS}	--	--	--	--	--	--
FD	0.592**	0.333^{NS}	--	--	--	--	--
PT	0.363^{NS}	0.52^{7}*	0.35^{4N}S	--	--	--	--
PY	-0.514*	0.074^{NS}	-0.270^{NS}	-0.12^{4N}S	--	--	--
SSC	0.264^{NS}	0.0004^{NS}	0.203^{NS}	-0.464*	-0.235^{NS}	--	--
TA	0.399^{NS}	-0.104^{NS}	0.349^{NS}	-0.056^{NS}	-0.346^{NS}	0.564**	--
SSC/TA	-0.269^{NS}	-0.269^{NS}	-0.266^{NS}	-0.076^{NS}	0.347^{NS}	-0.267^{NS}	-0.908**

NS – non-significant; ** and * significant at 5% ($p < 0.05$) and 1% ($p < 0.01$) of probability, respectively. FW: Fruit weight (g); FL: Fruit length (mm); FD: Fruit diameter (mm); PT: Peel thickness (mm); PY: Pulp yield (%); SSC: Soluble solids content (°Brix); TA: Titratable acidity (% of citric acid); SSC/TA: Soluble solids content/titratable acidity ratio.

The balance between acidity and soluble solids influences fruit flavor, which implies better fruit quality. Moreover, the acidity content allows flexibility in sugar addition for juice preparation (MORGADO et al., 2010). The SSC/TA ratio is an essential tool to assay fruit flavor and is favored by reduction in acidity as the soluble solids content increases (GILES et al., 2016).

Although the pulp characteristics for the cultivar FB 200 were not affected in the present study, it is worth mentioning that the occurrence of the CABMV in passion fruit crops decreases its commercial value, reducing its production cycle and yield (ANJOS et al., 2001). Crop management is recommended to avoid the disease in the orchard. The spread of the CABMV does not occur by seeds but by vector insects (NARITA et al., 2011), and in some other crops, such as cowpea (*Vigna unguiculata*), some techniques such as Integrated Pest Management are used (SILVA et al., 2014). Since the spread of the disease in passion fruit crop occurs during probing, there is no effective chemical control, and the use of seedlings produced under protected conditions, cleaning of pruning tools, increase in the population of plants, and establishment of the orchard in isolated areas are some management techniques recommended for passion fruit with a view to reducing losses (SAMPAIO et al., 2008).

The CABMV decreased the quality of yellow passion fruit cv. FB 200 by negatively affecting its physical characteristics. However, under the conditions of the experiment for this cultivar, the chemical characteristics of the pulp and juice production were not affected; thus, the requirements of the juice processing industry were satisfied. Despite the occurrence of the virus, many of the fruits' features presented a significant positive correlation.

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