Evaluation of intraspecific hybrids of yellow passion fruit in organic farming

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The objective of this work was to evaluate 14 hybrids intraspecific of yellow passion fruit aiming to select those with higher performance in an organic production system in Lençóis, Bahia, Brazil. The following variables were evaluated: Plant growth rate index, segregation for peel color, accumulated productivity, fruit physical-chemical attributes, severity of virus disease in plants and fruits, scabs in fruits and overall state of health of plants. Hybrids HFOP-05, BRS Sol do Cerrado and BRS Gigante Amarelo presented highest plant vigor with no direct relation to the percentage of flowering and fruitification of plants. Some hybrids presented yellow, light purple and dark purple peel color. Fruits with dark purple peel presented interesting chemical characteristics, such as lower acidity and greater ratio, providing sweeter flavor of the fruits. There was no differentiated response of the hybrids as to severity of the diseases evaluated. Leaf analysis showed relatively low concentration only for N, P and K. The hybrids selected, BRS Gigante Amarelo, BRS Sol do Cerrado, HFOP-08, HFOP-09, HFOP-11 and HFOP-12 are highlighted for productivity, physical characteristics of fruits and preference of the consumer market being considered an alternative for passion fruit producers that opt for a more environmental friendly production with greater market value.

Key words: Breeding, fruit quality, Passiflora edulis f. flavicarpa, sustainable cultivation, productivity.

INTRODUCTION

In 2014, crop of yellow passion fruit (Passiflora edulis f. flavicarpa O. Deg.) in Brazil was 823,000 tons in 57,000 ha (14.48 t ha⁻¹), and 71% of the production was obtained in the Northeast region (IBGE, 2015). Brazil is the largest producer and consumer of passion fruit in the world, with 95% of the national production of passion fruit being represented by the yellow variety, also known as yellow passion fruit vine (Janzantti and Monteiro, 2014). The culture of yellow passion fruit has shown strong expansion, awakening interest of fruit growers because of the possibility of growing in almost all regions of Brazil, quick start of production, and its excellent acceptance...
in the fresh market and industry (Rocha et al., 2001; Malacrida and Jorge, 2012). Other tropical regions have been increasing the production of this fruit crop, such as Colombia, Kenya and Ecuador, alongside traditional producers such as Australia and South Africa, because of the increasing international demand (FIBL and IFOAM, 2014).

In Brazil, the State of Bahia has 42% of the production, the regions of Sertão Produtivo and Chapada Diamantina being among the main passion fruit production centers (IBGE, 2015). These regions have similar characteristics, such as tropical semi-arid climate, compulsory irrigation, high incidence of diseases of shoot and root system, and nomadic farming conducted mainly in family farming system. The yellow passion fruit production system is predominantly based on conventional techniques, with mineral fertilization of soil and applications of pesticide to ensure high yields of culture, thus potentially causing major impacts to the environment and to human health (Calle et al., 2010; Wyckhuys et al., 2011).

In recent years, numerous studies have been directed to meeting the consumers’ growing demand for food that is healthier and has minimum environmental impact, seeking preservation of the ecosystem, biological conservation of soil, water and air quality, as well as obtaining reduced production cost (Conti et al., 2014; Siegmeyer et al., 2015; Henneron et al., 2015; Reganold and Wachter, 2016). Although being a good alternative, aimed at differentiated markets (Motta et al., 2008), organic agriculture is usually labeled as a system of low-productivity, high-risk production, and high-cost certification (Acs et al., 2009; Nelson et al. 2004; Meier et al., 2015; Ponisio et al., 2015), in addition to being unable to produce enough food to feed the World’s population (Seufert et al., 2012; Ponti et al., 2012).

On the other hand, the global market for organic products has increased considerably in recent years. In 2013, turnover was USD 72 billion, growth over 11% compared to 2012 (FIBL and IFOAM, 2014). In Brazil, this market is growing every year, being considered the largest market for organic products in Latin America. One of the contributing factors is the position occupied by the country in terms of organically managed area, with over 706,000 ha, second only to Argentina and Uruguay. Regarding the number of organic producers in this activity, Brazil has about 13,000 producers, with 90% of them being small farmers using family labor. Organic farming is an option to increase the incomes of family farmers, enabling increases in the prices of the products sold, since the cost and benefit relation is easily understood by the consumer (Ponti et al., 2012).

The vast majority of commercial plantations of passion fruit in Brazil and abroad is based on the conventional production system (Medeiros et al., 2009; Calle et al., 2010; Wyckhuys et al., 2011). Although there is some research on the cultivation of passion fruit in organic system (Motta et al., 2008; Macoris et al., 2011; Janzantti et al., 2012; Costa et al., 2013; Janzantti and Monteiro, 2014), most studies focus on economic analysis of production and nutritional and biochemical attributes of the fruits produced, with scarce reports on the agronomic performance of the varieties (Amaro and Monteiro, 2001; Fischer et al., 2007). Nevertheless, the use of genetic materials that are more adapted to organic farming is a decisive factor for their viability, because they have attributes such as pest tolerance, production stability, and more efficient use of resources such as water and nutrients (Ponti et al., 2012; Forster et al., 2013; Seufert et al., 2012).

Thus, the objective of this study was to select intraspecific hybrids of yellow passion fruit for organic production system, based on agronomic performance and quality of fruits from hybrids with different peel colorings aiming at industrial processing and fresh market for new market niches.

**MATERIALS AND METHODS**

**Experiment location and cultural practices**

The study was conducted in a commercial production area in the municipality of Lençóis, State of Bahia, Brazil (12º17’37’’ S, 42º39’27’’ W, 700 m). According to the Köppen classification, the climate in Lençóis is classified as mesothermal type of Cwb . The soil is classified as Red oxisol, dystrophic, alic with clayey texture (Embrapa, 1999). Correction of soil acidity was performed by the use of dolomitic limestone, following cultivation of soil enhancing plant cocktail consisting of pearl millet (*Pennisetum americanum* L.), sorghum (*Sorghum bicolor* L.), jack bean (*Canavalia ensiformis* L.) and estil plants (*Stylosanthes macrocephala* M. B. Ferr. et S.). Thereafter, mowing was performed for the deposition of plant biomass on the ground. The soil of the experimental area had the following chemical attributes in the 0 to 20 cm layer before installation and by the end of the study, respectively: pH (H2O) 6.50 and 6.90; P 18 and 126 (mg dm-3); K 0.15 and 0.41; Ca 4.30 and 7.27; Mg 2.30 and 3.85; Al 0.0 and 0.0; H + Al 3.08 and 1.10; CTC 9.91 and 13.01 (cmol, dm-3); V 69 and 92 (%); M.O. 47.6 and 54.0 g kg-1 soil.

Seedlings were grown in a screened nursery in plastic bags of 2 L, containing decomposed pine bark mixed with organic compound consisting of 20 g of Bokashi per liter of pine bark. Ninety days after sowing, transplanting to the field was conducted in December 2012, and the work was conducted until February 2014. Plant spacing was 2.5 m between rows and 4.0 m between plants (1000 plant ha-1) and the plant conduction system was espalier or fence trellis with a single stand of flat galvanized wire with 2.77 mm of gauge. Upright wood posts were set at 6.0 m intervals in the row to support the wire, which was set at 2 m above soil. Pollination was natural by carpenter bees (*Xylocopa spp.*) and the irrigation system was dripping, with two emitters of 4 L h-1 per plant.

During the experiment, cultivation with adaptations to the organic production system was carried out according to the recommendations for the yellow passion fruit in Brazil and to the federal laws of organic agriculture (Borges et al., 2001, 2003; Brasil, 2011, 2014). Thirty days before planting, the pits (0.4 x 0.4 x 0.4 m) were opened and fertilized with 10 L of tanned cattle manure, 1 kg of rock dust (ground calcisilic nat pyroxenite), 500 g of agricultural gypsum, 300 g of dolomite limestone, and 1 kg of Bokashi organic fertilizer produced at the farm (300 g of wood soil of the 0 to 0.05 m layer + 200 kg of cattle manure + 200 kg of rock
dust + 250 kg of castor bean cake + 25 kg of micronutrients “fried” BR 12 + 10 kg of magnesium oxide + 20 L of molasses, mixed daily for 10 days, slightly moistened).

After planting, fertilizations were carried out every 90 days in coverage, consisting of the application of 10 L of cattle manure and 1 kg of the fertilizer Bokashi around the plant (circle of approximately 0.6 m radius away 0.15 m from the passion fruit vine stem). A layer of approximately 0.1 m of dry mass of S. macrocephala and Styllosantes capitata was added under each fertilization, forming a laminar microcomposting around the stem.

Control of spontaneous vegetation was carried out by means of mechanized weeding between rows and hoeing in rows when needed.

There was no previous cultivation of passion fruit in the experimental area and in its vicinity, and no measures of pest and disease control were carried out during the evaluation period.

Plant material

14 intraspecific hybrids of yellow passion fruit P. edulis Sims were evaluated with 12 hybrids of the HFOP-01–12 series, derived from crosses between parental individuals selected by Embrapa Cassava and Tropical Fruits, due to the higher productivity and desirable fruit physicochemical attributes (Neves et al., 2013), and two commercial hybrids released by Embrapa, BR Sol do Cerrado and BRs Gigante Amarelo. Seeds were collected in matrices of Embrapa Cassava and Fruits and immediately sown for the formation of seedlings.

Plant growth evaluation

Plant growth was evaluated weekly between 88 and 159 days after planting (DAP), calculating the percentage of plants with tertiary branches (branches that arise from the secondary branches and form the productive branches or “production curtain”) and of plants with the presence of flowers and fruits. The plant growth speed index (GSib) was calculated as given by Maguire (1962), by GSib = D1/N1 + D2/N2 + ... + Dn/Nn, where D1, D2, and Dn are the percentage of plants with tertiary branches in the first, second, and last dates of evaluation after planting, and N1, N2, and Nn are the number of days after the first, the second, and the last dates of evaluation after planting. The same rationale was performed to calculate the flowering speed index (GSIfr), computing the percentage of plants with flowers in each date, and for the fruiting speed index (GSIfr), computing the percentage of plants with fruits in each date. Thus, higher values for general GSI correspond to greater plant growth speed in terms of formation of curtain, flowering, and fructifying of plants. The climatic conditions in the evaluation period ranging from maximum temperature 28 to 32°C, minimum 16 to 20°C, relative humidity 59 to 77% and rainfall of 0.31 to 7.37 mm (INMET, 2015).

Production, physicochemical quality of fruits and evaluation of diseases

The evaluations of production and physicochemical quality of fruits were held throughout the production cycle. Variables evaluated were total accumulated production (t ha⁻¹) in the three harvests, that is, at 184, 334, and 441 DAP, percentage of production for each harvest in relation to total production, fruit mass (FM), fruit length (FL), and fruit diameter (FD), the fruit length/diameter ratio (LDR), peel thickness (PT), peel mass (PeM), seedless pulp mass (PuM), juice yield (JY) given by PuM divided by FM in percentage terms, total soluble solids content (SS), total titratable acidity (TTA) and ratio given by SS/TTA. For each harvest, five fruits were analyzed per plot, proceeding to the analysis on the mean of the three harvests.

Evaluation of the phenotypic stability of the hybrids was also carried out concerning the coloring of the fruit peel. The plants were classified as yellow fruits (without anthocyanin pigment), light purple (light or moderate anthocyanin pigmentation), and dark purple (strong anthocyanin pigmentation). Result was shown with the percentage of plants with fruits with a particular peel color in relation to the total of experimental plants of the respective hybrid. To verify the capability of the progenies with the aforementioned peel colorations, 10 fruits of each color were selected. Analysis consisted in verifying, on average, the differences between the three fruit peel color classes depending on the chemical characteristics SS, TA, and ratio.

For evaluation of diseases scab and passion fruit woodiness virus five fruits per plot were evaluated at 474 DAP (Junqueira et al., 2003). Fruits were collected randomly in the plot at the beginning of the maturation process and evaluated by grading scale (Junqueira et al., 2003; Oliveira et al., 2013). To evaluate viral disease in plants, assessments were performed considering the onset of symptoms on plants per plot using grading scale (Oliveira et al., 2013).

Evaluation of the plants’ nutritional status

At 300 DAP, 20 leaves were collected randomly per plot, removing the fifth leaf from the apex, ten leaves from each side of the espalier. Samples were stored and analyzed for macro and micronutrients, in accordance with Malavolta et al. (1997) and Jackson (1958), respectively. As the standard for interpreting the results of foliar nutrient concentrations, the concentration range proposed in other studies (Haag et al., 1973; Robinson, 1986; Malavolta et al., 1989; Menzel et al., 1993) were used.

Data statistical analysis

Experimental design comprised of randomized blocks, with 14 treatments, five replicates, and 12 plants in the unit. Results were submitted to analysis of variance and the means were grouped by the Scott-Knott test (p ≤ 0.05). Tukey test was used for variables concerning to the three classes of fruit peel color. When necessary, transformation type of the angular arc sine of square root of x/100 was carried out to meet standardization and homogeneity of variances.

RESULTS

Plant growth

Overall, there was no difference for the presence of tertiary branches among hybrids, except for HFOP-01 which was less vigorous with GSib of 3.31 (Table 1). It was expected that the increase in the tertiary branches were also accompanied by the presence of flowers and fruits. The last hybrid with the presence of flowers was the HFOP-01, with GSIfr of 2.56, thus being related to the slower formation of curtain in that genotype, followed by the hybrids HFOP-05, BR Sol do Cerrado and BRs Gigante Amarelo (Table 1). Similar behavior was observed for the presence of fruit. On the other hand, for these three hybrids, the greatest vegetative vigor, expressed by the percentage of plants with tertiary
Table 1. Plant growth speed indices (GSI) for percentage of formation of tertiary branches (GS Ib), of flowering (GS If), and of fructifying (GS Ifr) up to 159 days after planting (DAP), cumulative percentage of yield per harvest and cumulative yield at 441 DAP of 14 hybrids of yellow passion fruit grown under organic production system.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Growth speed indices (GSI)</th>
<th>Cumulative percentage of yield per harvest (%)</th>
<th>Cumulative yield (t ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GS Ib</td>
<td>GS If</td>
<td>GS Ifr</td>
</tr>
<tr>
<td>BRS-GA</td>
<td>5.97a</td>
<td>4.41b</td>
<td>3.16b</td>
</tr>
<tr>
<td>BRS-SC</td>
<td>6.53a</td>
<td>4.47b</td>
<td>2.95b</td>
</tr>
<tr>
<td>HFOP-01</td>
<td>3.31b</td>
<td>2.56c</td>
<td>1.76b</td>
</tr>
<tr>
<td>HFOP-02</td>
<td>5.64a</td>
<td>5.17a</td>
<td>3.60a</td>
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<td>6.37a</td>
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</tr>
<tr>
<td>HFOP-04</td>
<td>6.90a</td>
<td>5.79a</td>
<td>4.29a</td>
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<tr>
<td>HFOP-05</td>
<td>5.19a</td>
<td>3.76b</td>
<td>2.51b</td>
</tr>
<tr>
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<td>7.27a</td>
<td>5.74a</td>
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<td>6.72a</td>
<td>5.58a</td>
<td>4.14a</td>
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<td>5.97a</td>
<td>6.19a</td>
<td>4.65a</td>
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<td>5.80a</td>
<td>5.52a</td>
<td>3.73a</td>
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<td>HFOP-10</td>
<td>6.90a</td>
<td>6.69a</td>
<td>4.97a</td>
</tr>
<tr>
<td>HFOP-11</td>
<td>6.48a</td>
<td>6.15a</td>
<td>4.78a</td>
</tr>
<tr>
<td>HFOP-12</td>
<td>6.03a</td>
<td>5.06a</td>
<td>3.76a</td>
</tr>
<tr>
<td>CV (%)</td>
<td>22.0</td>
<td>23.39</td>
<td>26.05</td>
</tr>
<tr>
<td>F value</td>
<td>2.67**</td>
<td>4.07**</td>
<td>4.33**</td>
</tr>
</tbody>
</table>

Mean yield of passion fruit in the region of this study in 2014 (IBGE, 2015): 12.43 t ha⁻¹

¹Means followed by the same letter in the column do not differ by the Scott–Knott (p ≤ 0.05). ¹BRS SC: BRS Sol do Cerrado e BRS GA: BRS Gigante Amarelo. DAP = Days after planting

Production, physicochemical quality of fruits, and evaluation of diseases

It was observed that the production of the hybrids in the first cycle, at 184 DAP, was low, ranging from 7.8 to 11.4% of total cumulative production, and the second crop was greater, at 334 DAP, ranging from 13.3 to 21.4% (Table 1). In the third harvest, at 441 DAP, the highest average relative yield was obtained, and the commercial hybrids BRS Gigante Amarelo and HFOP-01 were late bearing, with 76.6 and 74.8% of their cumulative percentage of yield per harvest recorded in the third cycle, respectively. These two hybrids were also the later in the production of flowers and fruits (Table 1).

Cumulative production ranged from 24.5 to 36.9 t ha⁻¹ in 18 months of production, with average production of 29.4 t ha⁻¹ for all genotypes (Table 1). Hybrids HFOP-01, HFOP-11, HFOP-12, and HFOP-03 and BRS Sol do Cerrado had the highest cumulative production (32.20 to 36.98 t ha⁻¹).

For most physicochemical characteristics evaluated, except for soluble solids (SS), there were differences (p ≤ 0.05) among the hybrids of yellow passion fruit (Table 2). Considering fruit mass (FM), it was observed that the group consisting of hybrids BRS Gigante Amarelo, BRS Sol do Cerrado, HFOP-09, and HFOP-12 had the highest fruit masses averaging 207.2 g. In contrast, the lowest values for this variable were recorded for HFOP-07, HFOP-02, and HFOP-06 (142.6 g on average). For the characteristic fruit length (FL), hybrid BRS Gigante Amarelo stood out with 9.9 cm, while hybrids HFOP-02 and HFOP-06 had the lowest length values with 7.5 cm for both (Table 2). Concerning the variable fruit diameter (FD), it was observed that BRS Gigante Amarelo had greater diameter with 8.2 cm, while hybrids HFOP-06 and HFOP-07 had the lowest values with 7.0 cm for both (Table 2).

In assessing peel thickness, four hybrids of yellow passion fruit had fruits averaging less than 5.9 mm, with a range of variation from 5.2 mm (HFOP-01) to 7.6 mm (HFOP-09) (Table 2). Length to diameter ratio (FL/FD) is used to evaluate fruit shape, with oval fruits being preferred by consumers. Based on this premise, the following hybrids stood out: BRS Gigante Amarelo, HFOP-11, HFOP-12, HFOP-08, and HFOP-09. Juice yield was significantly different only for HFOP-01 with 33.5% with the others hybrids in a second group, in which means ranged from 26.2 to 29.9% (Table 2).

Concentration of soluble solids was similar among all hybrids studied, with range of variation from 13.2 to 14.1
Table 2. Peel color (PC), fruit mass (FM), fruit length (FL), fruit diameter (FD), fruit length to diameter ratio (FL/FD), peel thickness (PT), peel mass (PeM), pulp mass (PuM), juice yield (JY), soluble solids (SS), total titratable acidity (TTA), and ratio (SS/TA) of 14 hybrids of yellow passion fruit grown under organic production system, in mean values of three harvests carried out up to 441 days after transplanting.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>PC</th>
<th>FM (g)</th>
<th>FL (cm)</th>
<th>FD (cm)</th>
<th>FL/FD</th>
<th>PT (mm)</th>
<th>PeM (g)</th>
<th>PuM (g)</th>
<th>JY (%)</th>
<th>SS (°Brix)</th>
<th>TTA (%)</th>
<th>Ratio (SS/TTA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRSGA</td>
<td>1.48</td>
<td>215.5a</td>
<td>9.9</td>
<td>8.2</td>
<td>1.3a</td>
<td>6.6b</td>
<td>118.8a</td>
<td>59.7a</td>
<td>27.0b</td>
<td>13.8b</td>
<td>3.55b</td>
<td>3.9a</td>
</tr>
<tr>
<td>BRS-SC</td>
<td>1.27</td>
<td>198.2a</td>
<td>8.9</td>
<td>7.9</td>
<td>1.1c</td>
<td>5.9c</td>
<td>102.5a</td>
<td>58.0a</td>
<td>27.4c</td>
<td>13.6a</td>
<td>3.34a</td>
<td>4.1a</td>
</tr>
<tr>
<td>HFOP-01</td>
<td>2.88</td>
<td>168.5a</td>
<td>7.9</td>
<td>7.5</td>
<td>1.1c</td>
<td>5.2c</td>
<td>74.8d</td>
<td>57.8a</td>
<td>33.5a</td>
<td>13.6b</td>
<td>3.66b</td>
<td>3.7b</td>
</tr>
<tr>
<td>HFOP-02</td>
<td>3.07a</td>
<td>143.5d</td>
<td>7.5e</td>
<td>7.3c</td>
<td>1.1c</td>
<td>5.9c</td>
<td>73.7d</td>
<td>42.6b</td>
<td>28.8b</td>
<td>13.8b</td>
<td>3.22c</td>
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<td>HFOP-03</td>
<td>2.72a</td>
<td>157.2c</td>
<td>7.4</td>
<td>7.1</td>
<td>1.1c</td>
<td>6.4b</td>
<td>80.6c</td>
<td>44.6b</td>
<td>27.4b</td>
<td>14.1c</td>
<td>3.73b</td>
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<td>HFOP-04</td>
<td>2.85a</td>
<td>164.8a</td>
<td>8.3</td>
<td>7.5</td>
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<td>7.0a</td>
<td>85.5c</td>
<td>47.8b</td>
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<td>170.0a</td>
<td>8.3</td>
<td>7.7b</td>
<td>1.1c</td>
<td>6.6b</td>
<td>85.7c</td>
<td>51.7a</td>
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<td>3.52a</td>
<td>137.9d</td>
<td>7.5e</td>
<td>7.0d</td>
<td>1.1c</td>
<td>6.1b</td>
<td>71.6d</td>
<td>37.6b</td>
<td>26.8b</td>
<td>13.8b</td>
<td>3.69b</td>
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<tr>
<td>HFOP-07</td>
<td>2.52a</td>
<td>146.5a</td>
<td>7.9d</td>
<td>7.0d</td>
<td>1.1c</td>
<td>6.5b</td>
<td>74.9d</td>
<td>40.4b</td>
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<td>176.8b</td>
<td>8.8</td>
<td>7.6</td>
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<td>HFOP-09</td>
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<td>9.3b</td>
<td>7.9</td>
<td>1.2c</td>
<td>7.6a</td>
<td>115.5a</td>
<td>56.2b</td>
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<td>3.7b</td>
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<td>HFOP-10</td>
<td>2.43a</td>
<td>185.1b</td>
<td>8.5</td>
<td>7.8</td>
<td>1.1c</td>
<td>7.3a</td>
<td>97.5b</td>
<td>53.7a</td>
<td>28.8c</td>
<td>13.9b</td>
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<td>HFOP-11</td>
<td>1.21a</td>
<td>180.0a</td>
<td>8.9</td>
<td>7.6</td>
<td>1.2c</td>
<td>5.8b</td>
<td>90.2c</td>
<td>53.0a</td>
<td>28.7b</td>
<td>13.5b</td>
<td>3.83b</td>
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<td>195.1a</td>
<td>9.0</td>
<td>7.7</td>
<td>1.2c</td>
<td>6.2a</td>
<td>101.8a</td>
<td>52.3a</td>
<td>26.2b</td>
<td>13.4b</td>
<td>3.36b</td>
<td>4.0a</td>
</tr>
<tr>
<td>Cq (%)</td>
<td>21.4</td>
<td>8.8</td>
<td>4.2</td>
<td>3.2</td>
<td>7.8b</td>
<td>3.8c</td>
<td>9.40</td>
<td>11.9b</td>
<td>7.90</td>
<td>4.35</td>
<td>6.73</td>
<td>7.25</td>
</tr>
<tr>
<td>F value</td>
<td>12.41</td>
<td>12.03a</td>
<td>19.52</td>
<td>9.43</td>
<td>16.57a</td>
<td>7.52a</td>
<td>16.12a</td>
<td>6.56a</td>
<td>3.66ns</td>
<td>0.86ns</td>
<td>2.54*</td>
<td>3.07*</td>
</tr>
</tbody>
</table>

*aMeans followed by the same letter in the column do not differ by the Scott–Knott (p < 0.05). ns = not significant; * significant (p < 0.05). ^BRS SC: BRS Sol do Cerrado e BRS GA: BRS Gigante Amarelo.

*Brix (Table 2). For total titratable acidity, it was found that 71% of the hybrids showed acidity, ranging from 3.53 to 3.83%, with hybrids BRS Sol do Cerrado, HFOP-02, HFOP-04, and HFOP-12 showing lower acidity, mean of 3.34% (Table 2). For the SS/TA ratio, we observed that most genotypes (64%) studied showed similar behavior, with ratio from 3.5 to 3.8, with the exception of hybrids BRS Gigante Amarelo, BRS Sol do Cerrado, HFOP-02, HFOP-04, and HFOP-12, which had higher ratio (Table 2).

As for the evaluation of virus and scab, at 474 DAP no statistically significant difference (p < 0.05) was detected among the hybrids for severity on plant and fruit (Figure 1). Mean severity was 33.3, 29.5, and 21.1%, respectively, for virus on plant, scab on fruits and virus on fruits.

Identification and capabilities of plants with purple-colored fruits

Fruits with peel color ranging from yellow to dark purple were observed in the majority of the hybrids tested (Figure 2a). BRS Sol do Cerrado, BRS Gigante Amarelo, HFOP-08, and HFOP-09 showed 100% of plants with all fruits with yellow peel, meanwhile hybrids HFOP-05 and 06 presented predominance of plants with fruits with purplish peel.

In general, it was observed that the dark purple fruits had soluble solids (SS) concentration equivalent to the yellow and light purple fruits, on average 13.78 °Brix (Figure 2b). Yellow and light purple fruits did not differ for titratable acidity, on average 3.55%, which in turn was higher than the acidity of dark purple fruits, 3.27% (Figure 2c). Consequently, the dark purple fruits were observed to have higher mean value for ratio (Figure 2d).

Plants nutritional status

Foliar concentrations of N, P, and K were relatively low for all hybrids of yellow passion fruit at 300 DAP (Table 3). For N, B, Mn, Fe, and Cu there was no difference between the hybrids evaluated, while for P, K, Ca, Mg, S, and Zn, two groups were formed, with superior hybrids depending on the nutrient evaluated (Table 3).

DISCUSSION

Cumulative production for the organic production system observed in this study is within that observed for the conventional farming of yellow passion fruit (from 20.83 to 34.53 t ha⁻¹) when evaluating three levels of potassium fertilization (Fortaleza et al., 2005). Neves et al. (2013), evaluating the productivity of 30 hybrids and 11 parental passion fruit trees, found mean values of 24.03 to 43.75 t ha⁻¹. Importantly, productivity range observed in this experiment, conducted in organic agriculture, was higher than the mean yield for Brazil (14.48 t ha⁻¹) and for the state of Bahia (12.43 t ha⁻¹) (IBGE, 2015). Productivity is an effective attribute for selecting varieties for organic agriculture.
Figure 1. Mean severity of the passion fruit woodiness virus in plant (VIFP) and fruit (VIRF) and scab on fruit (SCFR) of 14 hybrids of yellow passion fruit.

Figure 2. Percentage of plants with yellow, light purple, and dark purple peel color for 14 hybrids of yellow passion fruit grown in organic production system (A); soluble solids concentration (B), total titratable acidity (C) and ratio (D) of juice for each fruit peel color category (yellow, light purple, and dark purple). Means followed by the same letter in the column do not differ by the Tukey Test (p ≤ 0.05).
Table 3. Foliar nutrient concentrations of 14 hybrids of yellow passion fruit grown in organic production system 300 days after transplanting.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>S</th>
<th>B</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRS-GA</td>
<td>40.2a</td>
<td>1.3b</td>
<td>10.4a</td>
<td>13.8b</td>
<td>4.4</td>
<td>2.9b</td>
<td>65.3a</td>
<td>3.6a</td>
<td>90.3a</td>
<td>60.3a</td>
<td>24.6b</td>
</tr>
<tr>
<td>BRS-SC</td>
<td>33.0a</td>
<td>1.0b</td>
<td>8.5b</td>
<td>17.2b</td>
<td>5.5</td>
<td>2.6b</td>
<td>57.6a</td>
<td>4.0</td>
<td>86.6a</td>
<td>73.6a</td>
<td>22.6b</td>
</tr>
<tr>
<td>HFOP-01</td>
<td>39.4a</td>
<td>2.0a</td>
<td>10.0a</td>
<td>12.9b</td>
<td>4.3</td>
<td>2.9b</td>
<td>77.0a</td>
<td>4.0</td>
<td>103.0a</td>
<td>66.3a</td>
<td>29.0a</td>
</tr>
<tr>
<td>HFOP-02</td>
<td>37.0a</td>
<td>1.3b</td>
<td>9.6</td>
<td>16.2b</td>
<td>5.1</td>
<td>3.0b</td>
<td>69.3a</td>
<td>4.0</td>
<td>121.0a</td>
<td>74.0a</td>
<td>30.0a</td>
</tr>
<tr>
<td>HFOP-03</td>
<td>41.8a</td>
<td>2.0a</td>
<td>12.1a</td>
<td>15.7a</td>
<td>4.6</td>
<td>2.8b</td>
<td>72.3a</td>
<td>4.6</td>
<td>99.3a</td>
<td>67.0a</td>
<td>27.6a</td>
</tr>
<tr>
<td>HFOP-04</td>
<td>36.6a</td>
<td>1.3b</td>
<td>9.4</td>
<td>19.7a</td>
<td>5.0</td>
<td>2.9b</td>
<td>96.6a</td>
<td>4.0</td>
<td>97.6a</td>
<td>77.6a</td>
<td>28.3a</td>
</tr>
<tr>
<td>HFOP-05</td>
<td>37.6a</td>
<td>1.3b</td>
<td>9.0</td>
<td>14.6b</td>
<td>4.5</td>
<td>2.9b</td>
<td>74.0a</td>
<td>4.0</td>
<td>91.3a</td>
<td>62.6a</td>
<td>24.6b</td>
</tr>
<tr>
<td>HFOP-06</td>
<td>36.6a</td>
<td>1.0g</td>
<td>7.9b</td>
<td>15.3b</td>
<td>4.5</td>
<td>2.9b</td>
<td>73.0a</td>
<td>4.0</td>
<td>89.6a</td>
<td>68.0a</td>
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</tr>
<tr>
<td>HFOP-07</td>
<td>39.0a</td>
<td>1.0b</td>
<td>7.7b</td>
<td>19.6a</td>
<td>5.6</td>
<td>3.1b</td>
<td>69.3a</td>
<td>4.0</td>
<td>91.6a</td>
<td>91.3a</td>
<td>22.6b</td>
</tr>
<tr>
<td>HFOP-08</td>
<td>32.2a</td>
<td>1.0b</td>
<td>6.7b</td>
<td>24.9a</td>
<td>6.6a</td>
<td>3.3a</td>
<td>73.6a</td>
<td>4.0</td>
<td>91.0a</td>
<td>75.6a</td>
<td>27.6a</td>
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<tr>
<td>HFOP-09</td>
<td>37.2a</td>
<td>1.0b</td>
<td>6.3b</td>
<td>22.9a</td>
<td>6.3a</td>
<td>3.3a</td>
<td>65.0a</td>
<td>3.6</td>
<td>93.0a</td>
<td>80.0a</td>
<td>26.0a</td>
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<td>HFOP-10</td>
<td>35.4a</td>
<td>1.3b</td>
<td>6.8</td>
<td>24.5b</td>
<td>5.9</td>
<td>3.2a</td>
<td>85.3a</td>
<td>3.6</td>
<td>87.3a</td>
<td>76.3a</td>
<td>23.6a</td>
</tr>
<tr>
<td>HFOP-11</td>
<td>37.0a</td>
<td>1.3b</td>
<td>8.5b</td>
<td>22.6a</td>
<td>6.3a</td>
<td>3.4a</td>
<td>72.0a</td>
<td>4.3</td>
<td>101.0a</td>
<td>85.0a</td>
<td>30.0a</td>
</tr>
<tr>
<td>HFOP-12</td>
<td>38.8a</td>
<td>1.3b</td>
<td>7.6b</td>
<td>22.9a</td>
<td>7.2a</td>
<td>3.3a</td>
<td>97.0a</td>
<td>6.3a</td>
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<td>83.3a</td>
<td>31.0a</td>
</tr>
<tr>
<td>F value</td>
<td>0.67ns</td>
<td>2.29*</td>
<td>3.88**</td>
<td>5.75**</td>
<td>3.27**</td>
<td>3.47**</td>
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<td>1.08ns</td>
<td>1.17ns</td>
<td>1.60ns</td>
<td>3.18**</td>
</tr>
</tbody>
</table>

1 Means followed by the same letter in the column do not differ by the Scott–Knott (p ≤ 0.05). ns = not significant; * significant (p ≤ 0.05); ** highly significant (p ≤ 0.01). 2 BRS SC: BRS Sol do Cerrado e BRS GA: BRS Gigante Amarelo.

agriculture, and varieties previously selected due to this attribute in the conventional farming can be indicated after validation under organic conditions, as conducted in this study (Kokare et al., 2014).

Fruit size is a characteristic much appreciated by consumers at the time of purchase of the yellow passion fruit (Negreiros et al., 2008), who generally prefer larger fruit weighing more than 170 g (Cavichioli et al., 2008) and with attractive appearance when intended for the fresh market. For producers, these fruits have higher classification and better prices (Neves et al., 2013). Taking this as a criterion, half of the evaluated hybrids showed fruit weight within the marketing standards, even with values above the means found in the literature for conventional cultivation of passion fruit (Negreiros et al., 2008; Flores et al., 2011).

In this study, peel thickness was very close to that obtained by Neves et al. (2013), where thickness ranged from 3.73 to 7.61 mm, and Zaccheo et al. (2012) observed passion fruit peel thickness ranging from 3.3 to 7.6 mm. Both for the fresh fruit market and for processing, peel thickness is an important factor to be observed for fruit classification, being inversely related to the juice yield (Ferreira et al., 2010). On the other hand, thicker fruits have greater resistance to transport over long distances (Fischer et al., 2007). Thus, greater peel thickness can be interesting in the selection of promising hybrids in organic farming, provided there is a balance in relation to total weight of fruit and of juice content, as it happened with HFOP-09 and HFOP-12.

Results in the literature are contradictory as to the performance of passion fruit in organic and conventional farming. For the conventional system, Amaro and Monteiro (2001) observed higher fruit length (8.20 the 8.50 cm), while for diameter, which ranged from 6.6 to 7.3 mm, no difference was observed between the two systems. On the other hand, Fischer et al. (2007), evaluating yellow passion fruit, observed that fruits produced in organic system showed greater length (9.18 cm), diameter (7.63 cm), and peel thickness (8.60 mm) compared to conventional ones. The observed values corroborate those of the present work. This variation can be related to the plant material, localization and cultural practices. Juice yields observed in this study were lower than those of Amaro and Monteiro (2001) when evaluating passion fruit produced in organic system, with values from 29.7 to 43.4%. The low juice yield may be related to the genetic material used and to environmental conditions that strongly influence the pulp yield expression (Neves et al., 2013).

Acidity, soluble solids, and ratio are essential to the quality of flavor and acceptability of fruits (Mattheis and Fellman, 1999; Goldenberg et al., 2012). For the fresh fruits market, high soluble solids content is very desirable and is also directly related to greater advantage for the industry (Nascimento et al., 2003). The variation range from 13.2 to 14.1 °Brix is close to the range of 10.8 °Brix to 15.2 °Brix, observed for conventional farming (Zaccheo et al., 2012) and close to the values for organic and conventional farming, which ranged from 13.3 to 14.80 °Brix, respectively (Macoris et al., 2011). However, values observed in this study are above the minimum 11
Acidity gives greater difficulty of spoilage by microorganisms and allows for greater flexibility in the addition of sugar to beverages, thus being important for processing (Dell'Orto Morgado et al., 2010) as it decreases as the addition of acidifying substances and provides nutritional improvement, food safety, and organoleptic quality. In this study, it was found that the values observed for the hybrids satisfactorily meet the minimum total acidity required by law (2.5%) (Brasil, 2003). Fischer et al. (2007) observed similarity in the titratable acidity of yellow passion fruits grown under organic and under conventional conditions. Macoris et al. (2011), in a similar study, found higher acidity in fruits conventionally grown. The highest ratios were observed for hybrids HFOP-02, HFOP-12, HFOP-04, BRS Gigante Amarelo, and BRS Sol do Cerrado, being very close to those observed by Zaccheo et al. (2012), when investigating progenies of yellow passion fruit in conventional farming. Fischer et al. (2007) found no differences among organic and conventional fruits.

Some hybrids exhibit uniformity as to peel color and other hybrids showed segregation for yellow and purple colors. Traditionally, yellow peel fruits are preferred by the Brazilian fresh market, either due to ignorance concerning the qualities of purple fruits or even because of consumer tradition. In Colombia, a kind of purple passion fruit called “Gulupa” (P. edulis Sims) is cultivated with interesting organoleptic and nutritional characteristics, which is exported to many countries in Europe (Franco et al., 2014). In this study, dark purple fruits showed interesting characteristics to be explored, with lower acidity and high ratio, giving the sweeter flavor of these fruits. Other authors reported sweeter and more perfumed flavor of purple passion fruit in relation to the yellow one (Pinzón et al., 2007). In purple passion fruit, degradation of acids in the juice is faster in the summer due to increased temperature and, therefore, ratio increases hence, the flavor of the fruit is sweeter (Goldenberg et al., 2012). This fact may also have contributed to the values observed in this study, since the average local temperature was high most of the year. The data presented here reinforce the importance of intensifying the studies with purple peel passion fruit, since it has interesting organoleptic characteristics, especially for the organic market niche, in which fruit appearance is a less important attribute than flavor or nutritional quality.

Identification of genetic material resistant to the passion fruit woodiness virus is an elementary activity in breeding programs, as it is considered a widespread disease in the main producing regions of Brazil (Oliveira et al., 2013). Evaluation of virus in plant, and of scab and virus on fruits, showed a low severity in this work (33.3, 29.5, and 21.1%, respectively), which may be related to some factors such as the location, still little exploited for passion fruit cultivation, or climate conditions of the region with low relative humidity of the air, high incidence of light and high temperature, which are unfavorable to these diseases.

In the present study, intervention was not required to control these diseases, probably because it was a new cultivation area and located in the surroundings of a permanent reserve park at Chapada Diamantina. Therefore, it was not possible to select the most tolerant genotypes based on their direct reaction to these diseases in the locality. However, the weather conditions were very favorable to the growth of passion fruit plants, which reflected in high productivity and longevity of the orchard (Table 1).

On the other hand, cultivation of passion fruit plants in new areas, without the presence of virus inoculum sources, such as old plants and alternative hosts, is one of the best practices recommended for preventing viruses, in the absence of resistant genotypes or as preventive measures (Cerqueira-Silva et al., 2014). Results obtained in this study under organic agriculture corroborate this recommendation.

Foliar concentrations of N, P and K were relatively low in all hybrids of yellow passion fruit at 300 DAP (Table 3), while for the other nutrients the concentrations observed are in the range considered adequate for the culture (Carvalho et al., 2001, 2011; Menzel et al., 1993). The low concentrations in leaves, particularly of N, P and K, were expected, since this was the first crop in a deforested area with a soil with naturally low fertility and with no application of soluble and concentrated fertilizers. However, the highest yield values obtained by the superior genotypes in this study (Table 1) are equivalent to the results obtained by Carvalho et al. (2001) for a population of high productivity that was used as a standard for the preparation of nutrient sufficiency ranges of passion fruit under conventional cultivation. Therefore, in the evaluation period, the organic fertilization provided and the nutritional levels shown by the hybrids in general did not result in apparent limitation to cumulative productivity. Moreover, the lowest values of concentration of N, P, and K in foliar tissue obtained in organic cultivation may evidence a higher efficiency of use of these nutrients in this system when compared to the values of the ranges considered appropriate in conventional farming, obtained for the same phenological stage of cultivation and with similar yields, approximately 36 t ha⁻¹. Nutrients absorption efficiency is one of the critical factors for selection of plant genotypes aimed at adaptation to organic farming (Wolfe et al., 2008).

Importantly, the lower foliar concentrations of some nutrients observed in this study (Table 3), when compared to the appropriate ranges (Carvalho et al., 2001), did not cause visual symptoms of deficiency in plants and did not limit their production nor the quality of fruits (Tables 1 and 2). Although there was no mineral supplementation in the form of potassium sulfate for the
culture in this study – only through organic fertilizers, there are indications that the practices of green cover and organic fertilization adopted contributed to correct the deficiency of this element in the soil, according to the chemical analysis of the soil carried out at the beginning and at the end of the cultivation. On the other hand, the higher foliar concentration of some elements may be indication of greater capacity for absorption and assimilation of a particular nutrient by the genotype (Table 3), or of less precocious production, due to collection of leaves being conducted at 300 DAP, and even of its better adaptation to the organic agriculture, characterized by lower availability of nutrients in the soil solution. However, the highest foliar nutrient concentrations were not directly related to higher yields and fruit quality indices observed for the evaluated hybrids (Tables 1 and 2).

Overall, results obtained in this study allowed selecting intraspecific hybrids of yellow passion fruit with high horticultural performance in organic farming. Fruit yield and physicochemical attributes were adequate traits for selection of genotypes for organic farming, and hybrids with purple peel fruits showed high potential for this niche market. Cultivation of intraspecific hybrids of yellow passion fruit led to high fruit yields under organic farming, in spite of the low N, P, and K foliar concentrations under conventional system (Tables 1 and 2), or of less precocious production, due to collection of leaves being conducted at 300 DAP, and even of its better adaptation to the organic agriculture, characterized by lower availability of nutrients in the soil solution. However, the highest foliar nutrient concentrations were not directly related to higher yields and fruit quality indices observed for the evaluated hybrids (Tables 1 and 2).

Conclusion

The intraspecific hybrids of yellow passion fruit BRS Gigante Amarelo, BRS Sol do Cerrado, HFOP-08, HFOP-09, HFOP-11, and HFOP-12 were selected for cultivation under organic farming because they combine high yield, lack of nutritional deficiencies, and fruit quality attributes valued by the market.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

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