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Yield and physicochemical characteristics of west indian cherry genotypes grown in the semi-arid region

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***Abstract*—** *This study aimed to evaluate the yield and physicochemical characteristics of three West Indian Cherry genotypes cultivated in the semi-arid region of the state of Piauí, Brazil. The experiment was conducted in a randomized block design (RBD) with three replications and three treatments, corresponding to the West Indian Cherry genotypes 'Clone 14', 'BRS 366 Jaburu', and 'Junko' cultivated in a 4 x 3 m spacing. Combined genotype analysis revealed the following mean variations: yield from 22.96 to 47.53 t ha -1; fruit mass from 4.18 to 5.52 g; longitudinal diameter from 20.28 to 22.80 mm; transverse diameter from 17.32 to 18.42 mm, pulp yield from 27.58 % to 34.54%; red Hue° varying from 19.00° to 26.00°; soluble solids from 7.2 to 8.1 °Brix; titratable acidity from 0.82 to 1.34; ratio of total soluble solids to titratable acidity from 5.00 to 10.37; pH from 3.52 to 3.74; total anthocyanins from 2.56 to 12.11 mg.100 g-1 of pulp; flavonoids from 4.30 to 7.44 mg.100 g-1 of pulp; lycopene from 0.30 to 4.71 mg.100 g-1 of pulp; β-carotene from 14.00 to 32.51 mg 100 g-1 of pulp; mean ascorbic acid content of 2.676 mg.100 g-1 of pulp. Under the present experimental conditions, "BRS 366 Jaburu" was the most promising among the studied genotypes.*

I. INTRODUCTION

The physicochemical characteristics of West Indian Cherry grown in different regions have been extensively studied, especially with regard to its high nutritional potential. These fruits are rich in ascorbic acid (Cruz et al., 2019), carotenoids, flavonoids, and anthocyanins (Prakash & Baskaran et al., 2018), which has encouraged the expansion of West Indian Cherry cultivation in Brazil in recent years.

The ascorbic acid content, a basic parameter used to select West Indian Cherry fruits, as well as titratable acidity (TTA), total soluble solids (TSS), and pH are influenced by the geographic location of the growing region (Neto et al., 2014), the fruit maturation stage (Nasser et al., 2014; Estevam et al., 2018), harvest season (Nasser et al., 2018), crop management practices, and genetic factors (Souza et al., 2020). Therefore, studies on the characterization of new genotypes deserve more attention as West Indian Cherry production is directly influenced by the environmental conditions of the location where the orchard stands.

Due to its rusticity, West Indian Cherry adapts well to tropical and subtropical climate regions. The optimum temperature for its cultivation ranges between 15 °C and 32 °C, with halted growth and development at temperatures from 10° to 14 °C (Prakash & Baskaran et al., 2018). The optimum cumulative rainfall range for appropriate fruit development varies from 1,200 to 2,000 mm year-1. Cultivation should be complemented by irrigation in regions with less than 1,200 mm year-1 (Dias et al., 2020).

From this perspective, the semi-arid region of Piauí shows appropriate conditions to establish fruit orchards, with favorable edaphoclimatic conditions for West Indian Cherry cultivation, such as a mean annual temperature of 27 °C, mean rainfall from 1,000 to 1,200 mm year-1, and mineral, homogenous, well-drained, deep soils with a low slope, favoring the position of the area with regard to the incidence of solar radiation.

Therefore, this study aimed to characterize and select West Indian Cherry genotypes with promising agronomic characteristics for cultivation in the semi-arid region of Piauí, Brazil.

II. MATERIALS AND METHODS

The study was conducted from September to October 2019 at the experimental orchard of the Fruit Growing Study Group of the Federal University of Piauí, Campus Professora Cinobelina Elvas (UFPI/CPCE), in the city of Alvorada do Gurguéia, Piauí, Brazil, at the coordinates 08° 22'24.89 S and 43° 51'11.89" W, and 231 meters above sea level. The climate of the region is classified as Aw (tropical megathermal), with dry winters (Alvares et al., 2014). The meteorological data of the study area were obtained daily throughout the experimental period by the National Institute of Meteorology (INMET, 2019) through an automatic weather station in the city of Bom Jesus, Piauí (A336).

The study was conducted in a randomized block design (RBD) with three replications and three treatments, corresponding to the West Indian Cherry genotypes 'Clone 14', 'BRS 366 (Jaburu)', and 'Junko', with the experimental unit consisting of three plants of each genotype.

The study was developed with one-year-old West Indian Cherry genotypes in a 4 x 3 m spacing (833 plants ha-¹), planted on February 27, 2018, in a Yellow Latosol with clay loam texture (Santos et al., 2013). Irrigation was supplied daily with a micro-sprinkler system at a flow rate of 40 L/h. The physical and chemical characteristics of the soil before the experiment was established are shown in Table 1.

Table 1: Physical and chemical characteristics of the soil at a depth of 0-20 cm in the West Indian Cherry cultivation area, February 2018, in Alvorada Gurgueia, Piauí.

H^+	H^+Al^{3+}	Al^{3+}	Ca^{2+}	Mg^{2+}	K^+	T	P	K^+
H_2O	----------mg.dm^{-3}----------						mg.dm^{-3}	
5.7	1.71	0	1.28	0.17	0.15	3.3	3.68	57.1
Cu^{2+}	Fe^{2+}	B^+	Mn^{2+}	Zn^{2+}	V	M.O	Clay	Silt	Sand
----------mg.dm^{-3}---------					%	%	g/kg	g/kg	g/kg
2.37	53.28	0.59	37.23	1.7	48.1	6.5	64	29	907

P, K, Cu, Fe, Mn and Zn - Mehlich Extractor 1; Ca, Mg and Al - KCl Extractor - 1 mol/L; H + Al - Calcium Acetate Extractor at pH 7.0; Organic Matter (OM) - Walkley-Black method.

In July 2018, the apex of the main stem was pruned at 50 cm from the soil to promote sprouting and form new structural branches. Subsequently, three branches were selected to shape the plant architecture throughout the vegetative period by pruning them at 40 cm from their insertion in the main stem. The branches were brushed with 1% copper acetate solution for preventive disease control in both periods after pruning. Moreover, 5L of bovine manure was added to each plant to improve the physical and chemical characteristics of the soil.

Production fertilization was performed 30 days after pruning based on soil analysis (Table 1) and the fertilization recommendations for the crop, being superficially incorporated over a 40 cm strip corresponding to the plant canopy projection. Micronutrient fertilization was performed by foliar application every 30 days, with the first at the beginning of sprouting, using 200 mL 100L-1 of the commercial micronutrient Ativax®, composed of 2% S, 1% Mg, 1% Zn, 0.50% Mn, 0.50% Fe, 0.50% B, 0.30% Cu, and 0.10% Mo, totaling four applications.

Weed control was performed mechanically during the crop cycle. Phytosanitary treatments were performed whenever necessary according to the need of the plants. The evaluations were performed after the flowering from September to October 2019, when the plants achieved the first production.

The ripe fruits were harvested early in the morning and transported in isothermal boxes to the Plant Propagation Laboratory of the Federal University of Piauí, *Campus* Professora Cinobelina Elvas (UFPI/CPCE). Subsequently,

the fruits were evaluated with regard to yield (t ha-¹) and the following characteristics:

Physical characteristics: fruit mass (g), longitudinal (mm) and transverse diameters (mm), measured with the aid of a digital caliper; pulp yield (%), obtained by the difference between fruit weight and residue weight; and color appearance (Lightness (L*) Chroma (C*) and Hue Angle (°h)) (Mcguire, 1992);

Chemical characteristics: TSS, total soluble solids (°Brix), TTA, total titratable acidity (g malic acid.100-¹), TSS/TTA ratio, ascorbic acid (mg.100 g-¹), determined by titration using 2,6 dichlorophenol indophenol; pH, according to the methodology described by AOAC (1997); anthocyanins, flavonoids, lycopene, and β-carotene, determined according to the method proposed by Lees & Francis (1972).

The data were subjected to analysis of variance (ANOVA). When significant, the data were compared by Tukey's test at 5% probability using the software R, version 3.2.5, with the statistical package ExpDes.pt (R core team, 2020).

III. RESULTS AND DISCUSSION

With regard to the quality of West Indian Cherry fruits, Table 2 shows that there was no difference by Tukey's test at $p<0.05$ of significance in the mean fruit mass, longitudinal and transverse fruit diameters, and pulp yield, varying from 5.52 ± 4.18 g, 22.80 ± 20.28 mm, 18.42 ± 17.32 mm, and 34.64 ± 27.58 %, respectively.

Table 2: Physical analysis in fruits of three West Indian Cherry genotypes cultivated from September to October 2019 in Alvorada Gurguéia, Piauí.(FM) fruit mass, (LD) longitudinal diameter, (TD) transverse diameter (PY) pulp yield.

Genotypes	FM (g)	LD (mm)	TD (mm)	PY (%)	Yield (t ha-¹)
JUNKO	4.18a	20.28a	17.32a	34.64a	22.96c
BRS 366	5.52a	22.80a	18.42a	31.62a	37.92b
CLONE 14	4.61a	21.31a	18.15a	27.58a	47.53a
FV (%)	18.68	6.45	7.50	12.84	5.7

Note: Means followed by the same letter in the column do not differ by Tukey Test at $p>0.05$ probability.

The mean diameter values found for the studied genotypes were similar to those reported by Lima et al. (2014) when studying six West Indian Cherry genotypes, observing a variation from 0.84 to 0.92 mm, highlighting that West Indian Cherry is a subglobose drupe fruit.

Despite these results, a higher fruit yield was observed for genotype 'Clone 14', with 47.53 t ha $^{-1}$, followed by genotypes 'BRS 366 Jaburu' and 'Junko', with 37.92 and 22.96 t ha $^{-1}$, respectively, in the first year of cultivation. According to the Company for the Development of the São Francisco and Parnaíba Valleys (Codevasf, 2016), West Indian Cherry production in regions with a semi-arid climate only stabilizes after the third year of cultivation, with a mean yield of 24.97 t ha^{-1}. This demonstrates the potential for cultivation of the southeast region of Piauí as the first year already provided results above the expected average.

Fruit color varied significantly between the studied genotypes, ranging from intense red to bright red (Table 3). According to the Hue° angle, genotype 'BRS 366 Jaburu' showed higher values of lightness (38.16 ± 31.07*), saturation (47.67 ± 28.32*) and red color (26.00 ± 19.00°). Similar values were found by Lima et al. (2014) when evaluating West Indian Cherry fruits in the municipality of Muzambinho-MG, reporting lightness values varying from 42.25 to 35.77 and saturation from 48.23 to 39.88.

Table 3: Fruit color means of three West Indian Cherry genotypes cultivated from September to October 2019 in Alvorada Gurguéia, Piauí.

Genotypes	Lightness (L*)	Chroma (C*)	HUE angle (h°)
JUNKO	32.68ab	31.50b	19.00b
BRS 366	38.16a	47.67a	26.00a
CLONE 14	31.07b	28.32b	21.00ab
FV (%)	5.73	6.87	8.30

Note: Means followed by the same letter in the column do not differ by Tukey Test at $p>0.05$ probability.

The presence of these colored compounds in fruits is conditioned by pigments such as carotenoids, which normally range from yellow to orange, and lycopene, evidencing the red color (Neto *et al*., 2014). Color is one of the most attractive quality attributes for the consumer as the visual impact caused by this variable may determine its preference (Lima *et al*., 2014).

The soluble solids content differed statistically, showing higher values for genotypes 'Clone 14' and 'BRS 366 Jaburu', with 8.13 ° Brix and 7.83 ° Brix, respectively. In turn, genotype 'Junko' showed 6.43 ° Brix (Table 4). According to Martins *et al*. (2016), soluble solids values in West Indian Cherry cultivated in Piauí, as a function of

climatic conditions, vary from 5 to a maximum of 12 ° Brix, with a mean value around 7.0 or 8.0 ° Brix. Therefore, the studied genotypes were within the expected parameter.

With regard to titratable acidity, genotypes 'Clone 14' and 'Junko' showed the highest values, with 1.37 and 1.33 g malic acid.100-¹ of fruits, respectively. In turn, 'BRS 366 Jaburu' showed 0.82 g malic acid.100-¹ of fruits (Table 4). This is due to the accumulation of organic acids during fruit ripening (Corrêa *et al.,* 2017), verified by the TSS/TTA ratio of West Indian Cherry fruits (Table 4), according to which the studied genotypes showed contrary results to those observed in titratable acidity.

Table 4: Chemical analysis, total soluble solids (TSS), total titratable acidity (TTA), ascorbic acid (AA), and potential of hydrogen (pH) in fruits of three West Indian Cherry genotypes cultivated from September to October 2019 in Alvorada Gurguéia, Piauí.

Genotypes	JUNKO	BRS 366	CLONE 14	FV (%)
TSS (° Brix)	6.43b	7.83a	8.13a	3.54
TTA (g malic acid.100-¹)	1.33a	0.81b	1.37a	5.74
TSS/TTA	4.84b	9.59a	5.95b	6.88
Ph	4.25a	3.74b	3.52b	2.54
AA (mg.100 g-¹)	2164.00b	2675.67a	1693.33c	6.76

Note: Means followed by the same letter in the line do not differ by Tukey Test at $p>0.05$ probability.

The ratio of total soluble solids to titratable acidity (TSS/TTA) determines fruit flavor, that is, the sweetness and free acid content of fruits. Thus, the higher this ratio, the sweeter the fruits tend to be (Estevam *et al.,* 2018). According to Repolho *et al*. (2019), the TSS/TTA ratio is the most important post-harvest parameter as it indicates the balance between the sugar content and the acid content in the pulp, corroborating the pH results obtained.

Genotypes 'Clone 14' and 'BRS 366 Jaburu' showed lower acidity, with pH values of 3.52 and 3.74, respectively, while 'Junko' showed 4.25 (Table 4), corroborating the fact that West Indian Cherry is considered a slightly acid fruit, with a low and little-variable pH that decreases with fruit ripening (Repolho *et al*., 2019). These characteristics are interesting for industrial fruit processing.

According to Normative Instruction No. 1, of January 7, 2000, West Indian Cherry fruits meant for industrial processing should have a minimum pH of 2.8, 80% pinkish or reddish skin color, measure more than 15 mm in diameter, minimum weight of 4 g / fruit, good firmness, and absence of mechanical damage (Lima *et al*., 2014).

Genotype 'BRS 366 Jaburu' showed the highest ascorbic acid content (vitamin C), with 2,675.75 mg.100 g-¹ of pulp, differing statistically from 'Junko' and 'Clone 14', with 2,164 and1,693.33 mg.100 g-¹ of pulp, respectively (Table 4). According to Neto *et al*. (2014), more acidic West Indian Cherry genotypes show higher vitamin C contents, corroborating the results observed in this study and in study conducted by Carvalho et al. (2018), when evaluating the vitamin C content of fruits produced organically in Petrolina PE, quantifying 2,307.57 mg.100 g-¹ of pulp in this same genotype ('BRS 366 Jaburu').

The vitamin C content in West Indian Cherry genotypes is highly variable, ranging from 779.0 to 3,094.43 mg.100 g^{-1} of pulp. Variations within the same species are due to factors such as the cultivar, type of soil, climatic conditions, and crop management practices (Carvalho *et al.,* 2018). According to the Brazilian Fruit Institute (1995), the minimum value demanded by industries with regard to the ascorbic acid content for import is 1,200 mg 100 g^{-1} of pulp, while export to Europe and Japan requires a minimum of 1,000 mg of ascorbic acid per 100 g of pulp.

In addition to being rich in ascorbic acid, West Indian Cherry is also a significant source of anthocyanins, flavonoids, lycopene, β-carotene, and other carotenoids, which, in addition to the activity of provitamin A, participate as antioxidants in the biological system, decreasing the risk of degenerative diseases such as cancer, cardiovascular diseases, cataract, muscle atrophy, and strengthening the immune system (Silva *et al*., 2013).

With regard to fruit color, all evaluated pigments showed a statistical difference by Tukey's test at $p < 0.05$ of significance (Table 5). However, genotype 'Clone 14' did not stand out with regard to any of the evaluated pigments (Table 5). The content of anthocyanins and β-carotene was higher in genotype 'Junko', with 14.44 and 32.50 mg.100 g-¹ of pulp, respectively (Table 5). Genotype 'BRS 366 Jaburu' showed the highest content of flavonoids and lycopene, with 7.44 and 4.71 mg.100 g-¹ of pulp, respectively (Table 5). According to Cruz *et al.* (2019) and Marques *et al.* (2017), these values are within the expected range from 3.68 to 13.74 mg.100 g-1 of pulp.

*Table 5: Mean pigmentation levels in fruits of three West Indian Cherry genotypes cultivated from September to October 2019 in Alvorada Gurgueia, Piauí.(A) anthocyanins, (F) flavonoids, (L) lycopene, (*β) β-carotene

Genotypes	A	F	L	β
	- - - - - - - mg.100 g-1- - - - - - -			
JUNKO	14.44a	5.71b	0.30c	32.50a
BRS 366	2.57c	7.44a	4.71a	14.99b
CLONE 14	6.57b	4.60c	1.60b	17.14b
FV (%)	8.45%	5.52%	19.44	21.08

Note: Means followed by the same letter in the column do not differ by Tukey Test at $p>0.05$ probability.

The quantification of pigments such as anthocyanins, flavonoids, lycopene, and β-carotene is extremely important as these data, especially in fruits, are insufficient even at a world level (Dala-Paula *et al*., 2019). Anthocyanins and flavonoids encompass the classes of natural pigments found often in plants. The contents of anthocyanins and flavonoids in fruits are genetically determined and influenced by factors such as the season, soil composition, and maturation stage, becoming highly unstable at high temperatures (Estevam *et al.*, 2018).

In turn, lycopene and β-carotene are carotenoids with antioxidant action found in larger quantities in the fruit skin, providing the color from yellow to red, which increases considerably with ripening. According to Silva *et al*. (2013), warmer regions, such as the one of the present study, result in higher carotenoid contents in fruits.

IV. CONCLUSION

Given the edaphoclimatic conditions of the southeast region of Piauí, the studied genotypes showed promising features for cultivation. The genotype "BRS 366 Jaburu" stood out with regard to the studied agronomic parameters, with bright and intense red fruit color, good TSS/TTA ratio, higher content of total soluble solids, flavonoids, lycopene, and ascorbic acid, resulting in a high potential for economic exploration in the Gurgueia Valley region, Piauí.

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