Productivity and quality of Formosa and Solo papaya over two harvest seasons

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Abstract – The objective of this work was to evaluate the productivity and quality of papaya fruits (*Carica papaya*) of the Solo (12 genotypes) and Formosa (9 genotypes) heterotic groups over two harvest seasons. The experiment was conducted under field conditions in the municipality of Pinheiros, in the state of Espírito Santo, Brazil, in a randomized complete block design. Ten morpho-agronomic and physicochemical variables of the fruits were measured in winter (210–300 days after planting) and summer (450–540 days after planting). The data were subjected to the combined analysis of variance, to the breakdown of the genotype x environment interactions, and to the grouping of means by the Scott-Knott test. Although harvest season affected the evaluated characteristics, it did not alter the classification of the genotype. In the Solo group, the H 36-45 and UC 15 hybrids stand out due to their greater productivity, fruit weight, and soluble solids contents. In the Formosa group, the Rubi Incaper 511 cultivar shows greater productivity, higher number of commercial fruits, and lower number of deformed fruits over both evaluated harvest seasons.

Index terms: *Carica papaya*, agronomic performance, environmental effect, genotype evaluation.

Produtividade e qualidade de frutos de mamão Formosa e Solo em duas épocas de colheita

Resumo – O objetivo deste trabalho foi avaliar a produtividade e a qualidade de frutos de mamoeiro (*Carica papaya*) dos grupos heteróticos Solo (12 genótipos) e Formosa (9 genótipos), em duas épocas de colheita. O experimento foi conduzido em condições de campo em Pinheiros, ES, em delineamento de blocos ao acaso. Dez variáveis morfoagronômicas e físico-químicas dos frutos foram avaliadas no inverno (210 a 300 dias após o plantio) e no verão (450 a 540 dias após o plantio). Os dados foram submetidos à análise de variância conjunta, à decomposição da interação genótipo x ambiente e ao agrupamento das médias pelo teste de Scott-Knott. Embora a colheita em diferentes épocas tenha influenciado as características avaliadas, não alterou a classificação dos genótipos. No grupo Solo, destacam-se os híbridos H 36-45 e UC 15, por suas maiores produção e massa do fruto e por seu alto teor de sólidos solúveis. No grupo Formosa, a cultivar Rubi Incaper 511 apresenta maior produção, maior número de frutos comerciais e menor número de frutos deformados nas duas épocas de colheita avaliadas.

Termos para indexação: *Carica papaya*, desempenho agronômico, efeito ambiental, avaliação de genótipos.

Introduction

The demand for Brazilian papaya (*Carica papaya* L.) continues to increase in the international and domestic markets. However, the reduced number of available cultivars, the incidence of diseases, and the effect of climatic conditions on fruit development compromise the continuous growth in productivity (Moretti et al., 2010; Pinto et al., 2013b).

The main papaya cultivars grown in Brazil are Golden and Sunrise Solo, of the Solo heterotic group, and Tainung 1 and Calimosa, of the Formosa heterotic group. However, it is necessary to find new genotypes to increase the variety of materials that are available to producers (Luz et al., 2015). The fruits of the cultivars of the Solo group are small (500–700 g), have reddish pulp, and are preferred for export, whereas those of the Formosa group are medium-sized (1,000–1,500 g) and have reddish-orange pulp (Oliveira et al., 2012). The hybrids of the Formosa group have been gaining ground in the domestic and foreign markets, with

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growth in exports to Europe, Canada, and the United States (Reis et al., 2015).

Papaya blooms and produces fruits continuously for up to two years after reaching reproductive maturity (Martelleto et al., 2013). Despite this, floral behavior, which is highly sensitive to environmental factors, may negatively affect fruit production, leading to sexual reversion, carpelloidy, and pentandry (Damasceno Júnior et al., 2008). Furthermore, factors such as cultivar, water regime, temperature, incidence of pests and diseases, light exposure, and fruit maturity at harvest markedly affect fruit quality (Moretti et al., 2010). When comparing different cultivars, Reis et al. (2015) observed variations in the morphological and physicochemical characteristics of the fruits, which allowed identifying the best papaya genotypes of the Solo and Formosa groups. However, these authors did not consider the variation of these characteristics within each heterotic group and throughout the production cycle.

The objective of this work was to evaluate the productivity and quality of papaya fruits of the Solo (12 genotypes) and Formosa (9 genotypes) heterotic groups over two harvest seasons.

Materials and Methods

The experiment was carried out in a commercial papaya crop in the municipality of Pinheiros (18°30'59"S, 40°17'38"W), in the state of Espírito Santo, Brazil. According to Köppen's classification, the climate is a tropical monsoon (Am), with an annual mean air temperature of 23.6°C and an annual mean rainfall of 1,308 mm (Alvares et al., 2013).

The chemical characterization of the soil at 0–20 cm-depth showed (Silva, 2009): pH (H_2O) 5.4 (ratio 1:2.5); 85 mg dm^{-3} P; 45 mg dm^{-3} K; 0.3 $cmol_c$ dm^{-3} Mg; 0.3 $cmol_c$ dm^{-3} Al; 2.5 $cmol_c$ dm^{-3} H+Al; sum of bases of 1.4 $cmol_c$ dm^{-3}; effective cation exchange capacity of 1.7 $cmol_c$ dm^{-3}; base saturation of 36.1%; and 1.5 dag dm^{-3} organic matter. The Mehlich-1 method was used to extract P and K, and 1 mol L^{-1} KCl to obtain Mg and Al. Planting and topdressing fertilization were carried out according to Prezotti et al. (2007).

The seedlings were grown in the Bioplant Plus commercial substrate (Bioplant Agrícola Ltda., Nova Ponte, MG, Brazil), composed of coconut fiber and powder, pine bark, vermiculite, rice husks, and nutrients. At 30 days after sowing, on 11/15/2012, the seedlings were transplanted – three per hole – to a previously prepared area. Sexing was performed after the emergence of floral buds, and one hermaphrodite plant was kept per hole. The used spacing was 3.50x1.80 m, and the plants were irrigated using a central pivot according to the crop's needs. The planting area was monitored in order to eliminate plants with symptoms of viral pathogens. The other crop treatments were carried out following the recommendations in the literature (Martins & Costa, 2003).

Twenty-one papaya genotypes were evaluated: 12 of the Solo heterotic group and 9 of the Formosa heterotic group (Table 1). The experimental design was a randomized complete block, with five replicates and six plants per plot. For evaluation, the period of fruit production was subdivided into two seasons: winter, in which the fruits were harvested between June and August 2013 (210–300 days after planting); and summer, in which the fruits were harvested from January to March 2014 (450–540 days after planting). A mark was made in the fruiting region of each plant to distinguish the fruits developed in each season. In winter, the mean air temperature was 21.9°C, with a minimum of 13.4°C; the mean air humidity was 78%; and the cumulative rainfall was 55.2 mm. In summer, the mean air temperature was 24.9°C, with a maximum of 34.2°C; the mean air humidity was 78.9%; and the cumulative rainfall was 301.4 mm (Incaper, 2015).

The following characteristics were evaluated in both harvest seasons: number of commercial fruits (NCF); number of deformed fruits (NDF); production of fruits per plant (PP), in kilograms; fruit weight (FW), in grams per fruit; fruit length (FL), in centimeters; fruit diameter (FD), also in centimeters; pulp thickness (PT), in centimeters; soluble solids (SS) contents, measured in °Brix; titratable acidity (TA), expressed in grams of citric acid per 100 g of juice; and the SS/TA ratio.

Three plants were sampled per plot to determine the NCF and the NDF. For the other variables, five fruits per plot – harvested at stage 2 of maturation, when 25% of the surface was yellow – were assessed, according to the systems approach (Martins & Costa, 2003). The fruits were kept under the counter at 20±1°C prior to the physicochemical analyzes.

The data were subjected to the combined analysis of variance, in which each phenotypic observation can be described by the statistical model: $Y_{ijk} = \mu + G_i + A_j + GA_{ij} + B/A_{jk} + e_{ijk}$, in which μ is the general mean; G_i is the effect of the i-th genotype; A_j is the effect of the j-th environment; GA_{ij} is the effect of the interaction of the i-th genotype with the j-th environment; B/A_{jk} is the effect of the k-th block within the j-th environment; and e_{ijk} is the random error. The genotype was considered as fixed, and the other effects of the model as random.

After the combined analysis of variance, the genotype x environment interactions were broken down, and the genotypic determination coefficient (H^2) and the coefficient of variation (CV) were estimated. In each harvest season, the means were grouped by the Scott-Knott test, at 5% probability. The differences between the means of each genotype for both harvest seasons were evaluated by the t-test, also at 5% probability. The Genes software (Cruz, 2013) was used for the data analysis.

Table 1. Evaluated genetic papaya (*Carica papaya*) materials, type of cultivar, and supplier institution.

Genetic material	Type of cultivar	Supplier institution[1]
Solo group		
H 10-60	Solo x Solo hybrid	CNPMF
H 26-60	Solo x Solo hybrid	CNPMF
H 36-45	Hybrid	CNPMF
L 06-08	Line	CNPMF
L 47-P8	Line	CNPMF
L 54-08	Line	CNPMF
L 78-08	Line	CNPMF
UC 13	Solo x Solo hybrid	Uenf/Caliman
UC 14	Solo x Solo hybrid	Uenf/Caliman
UC 15	Solo x Solo hybrid	Uenf/Caliman
UC 16	Solo x Solo hybrid	Uenf/Caliman
Golden	Line	Caliman
Formosa group		
L 10-08	Line	CNPMF
UC 03	Formosa x Solo hybrid	Uenf/Caliman
UC 10	Formosa x Formosa hybrid	Uenf/Caliman
UC 11	Formosa x Solo hybrid	Uenf/Caliman
UC 12	Formosa x Solo x Formosa hybrid	Uenf/Caliman
Rubi Incaper 511	Line	Incaper
EW Sinja	Hybrid	East-West Seed
EW 2747	Hybrid	East-West Seed
Tainung 1	Hybrid	Takii do Brasil Ltda.

[1]CNPMF, Embrapa Mandioca e Fruticultura; Uenf/Caliman, Universidade Estadual do Norte Fluminense Darcy Ribeiro/Caliman Agrícola S/A; Incaper, Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural; and East-West Seed, East-West Seed International Ltda.

Results and Discussion

An interaction was observed between genotype and harvest season for PT, SS contents, TA, and the SS/TA ratio in the Solo heterotic group, as well as for NCF, NDF, and SS contents in the Formosa heterotic group. Between harvest seasons, differences were found for NCF, production per plant, FW, and PT, in Formosa group (Table 2).

Most variables differed according to harvest seasons and not to the harvest season x genotypes interactions. This shows that, although the environmental variations affected the studied characteristics, they did not change the classification of the genotypes, i.e., the interaction was simple. This type of interaction facilitates the work of the breeder, because it allows the recommendation of a single genetic material for different harvest seasons (Cruz et al., 2012). Luz et al. (2015) reported a strong interaction between genotype and harvest season for SS contents, NDF, NCF, FW, and PP, which can be explained by the combined evaluation of Solo and Formosa hybrids and by the greater number of harvests.

The genotypes of the Solo group were more sensitive to environmental variations than those of the Formosa group. This may be associated with the nature of the genotypes in each group: the Formosa group showed greater genetic uniformity, since there were only two lines and the other cultivars were all hybrids (Table 1).

No differences were observed for production and physicochemical characteristics (SS contents, TA, and the SS/TA ratio) between the genotypes of the Solo group, nor for NDF, PP, FD, SS contents, and the SS/TA ratio between the genotypes of the Formosa group. However, for the other characteristics of commercial interest, such as NCF, FW, and PT, it was possible to identify materials that would meet the demands of the consumer (Table 2).

For the genotypes of the Solo group, the mean NCF was 27.50, with each fruit weighing 591.75 g, which represented a production per plant of 16.50 kg. The mean value of SS contents was 13.66 °Brix, TA was 0.098% citric acid, and the SS/TA ratio was 145.99 (Table 2). These values agree with those obtained by Pinto et al. (2013a) and Reis et al. (2015), except for fruit weight, which was lower in the present study, but compatible with that of traditional Solo cultivars (Oliveira & Vitória, 2011; Costa et al., 2013).

For the genotypes of the Formosa group, the mean number of fruits was 16.12, each weighing 1,298.82 g, and plant production per plant was of 20.37 kg. The mean values of SS contents (13.01 °Brix) and of the SS/TA ratio (135.85) were lower than those of the Solo genotypes (Table 2). These values are very close to those found for the same physical and physicochemical characteristics of fruits from the Tainung 1 and Sekati cultivars, respectively, produced in the west of the state of Bahia, Brazil (Yamanishi et al., 2006). It is important to highlight that, since, in the present work, the means for number of fruits and production were obtained for each harvest season, they do not represent the total productivity of the genotypes.

The CV values ranged from 5.46% for SS contents to 61.19% for PP in the Solo group, and from 6.05% for SS contents to 51.94% for NDF in the Formosa group (Table 2). These values were higher than those reported by Oliveira et al. (2010) and Reis et al. (2015). However, when considering characteristics of great phenotypic variation, the CV values were acceptable for papaya (Pinto et al., 2013a, 2013b) and allowed identifying differences between treatments.

H^2 was greater than 70% for six variables analyzed in the Solo group and five in the Formosa group. The H^2 values obtained for PP (50.49%) and TA (37.95%) in the Solo group, and for FD (16.81%) and the SS/TA ratio (35.45%) in the Formosa group were considered low. Silva et al. (2008) observed heritability values between 28 and 86% for PP, whereas Pinto et al. (2013a) reported values of 2% for FD and 0% for SS contents. Both heritability and H^2, although not identical parameters, express how much of the variation observed is inheritable. Low heritability estimates can be attributed to the narrow genetic base of the population, which reduces the available genetic variability (Pinto et al., 2013a), as well as the effects of climate and of the nutritional conditions of the crop on fruit development (Moretti et al., 2010).

The analysis of the means of the genetic material of the Solo group showed that the NCF was higher for the summer harvest, except for 'L 47-P', which did not differ between seasons. There was an increase of 160, 151, and 136% in the NCF for the 'UC 16', 'H 26-60', and 'UC 14' from one season to the other (Table 3). For the NDF, only cultivars H 10-60, H 36-45, L 78-08, and Golden showed differences between harvest seasons, with lower values in winter.

Table 2. Combined analysis of variance, mean, coefficient of variation (CV), and genotypic determination coefficient (H^2) of ten characteristics of papaya (*Carica papaya*) fruits from 12 genotypes of the Solo group and 9 genotypes of the Formosa group evaluated in field conditions in the municipality of Pinheiros, in the state of Espírito Santo, Brazil(1).

Source of variation	DF	Mean square									
		NCF	NDF	PP	FW	FL	FD	PT	SS	TA	SS/TA ratio
		Solo group									
Block	8	157.93	71.14	77.39	13,633.48	1.14	0.60	0.01	3.74	0.0005	641.60
Genotype (G)	11	338.16*	99.83*	172.87	189,090.51*	39.86*	3.73*	0.25*	2.86	0.0004	351.79
Harvest season (S)	1	11,027.35*	710.44*	6,049.91*	315,832.55*	45.68*	4.86*	0.21	21.99*	0.0020	230.71
G x S interaction	11	96.85	32.92	85.58	21,304.49	3.57	0.59	0.29*	1.20*	0.0003*	692.80*
Residue	49	113.78	20.57	102.03	17,201.17	2.39	0.43	0.03	0.56	0.0001	274.64
Mean		27.50	9.56	16.50	591.75	15.66	8.73	2.35	13.66	0.098	145.99
CV (%)		38.80	47.43	61.19	22.16	9.86	7.52	7.93	5.46	12.07	11.35
H^2 (%)		71.36	67.02	50.49	88.73	91.05	84.05	78.78	58.02	37.95	96.93
		Formosa group									
Block	8	79.17	24.03	155.60	181,921.81	13.93	21.76	0.15	0.36	0.0001	484.07
Genotype	8	383.14*	88.75	363.82	808,098.69*	26.62*	37.01	0.60*	7.65	0.0010*	960.21
Season	1	2,700.43*	108.86	6,751.68*	2,737,644.01*	72.09	49.82	2.12*	0.01	0.0001	76.58
G x S interaction	8	92.49*	37.64*	132.28	151,829.26	5.23	30.79	0.07	3.08*	0.0002	619.86
Residue	64	28.77	7.30	81.84	111,816.88	7.73	21.57	0.06	0.62	0.0002	305.73
Mean		16.12	5.20	20.37	1,298.82	22.26	11.40	2.88	13.01	0.10	135.85
CV (%)		33.27	5.20	44.42	25.75	12.50	40.73	8.60	6.05	12.18	12.87
H^2 (%)		75.86	57.58	63.64	81.21	80.36	16.81	88.13	59.69	80.43	35.45

(1)DF, degrees of freedom; NCF, number of commercial fruits; NDF, number of deformed fruits; PP, production of fruits per plant (kg); FW, fruit weight (g); FL, fruit length (cm); FD, fruit diameter (cm); PT, pulp thickness (cm); SS, soluble solids contents (°Brix); and TA, titratable acidity (grams of citric acid per 100 g). *Significant by the F-test, at 5% probability.

The summer harvest provided a higher NCF and NDF (Table 3), as observed by Silva et al. (2007). Martelleto et al. (2011) evaluated the floral behavior of papaya in four cropping systems, and reported that the environmental and phenological conditions favorable to the production of normal fruits and carpeloids were the same, which confirms that there is a positive correlation between these variables.

Summer harvest provided greater production per plant, except for 'L 47-P8', 'L 54-08', 'UC 15', and 'Golden', which showed the same behavior in both harvests. The Golden cultivar was grouped with the genotypes with lower PP and FW in the two harvest seasons. This reinforces the results obtained by Pinto et al. (2013a, 2013b), who observed the degeneration of the Golden cultivar due to the indiscriminate production of seeds, which causes the loss of its original characteristics.

PT was slightly affected by harvest season, except for the L 06-08 line, which showed the highest mean in summer, and for the UC 14 hybrid, which had the highest mean in winter, justifying the significance of the interaction (Table 3). In the winter harvest, PT varied greatly among genotypes, as reported by Luz et al. (2015). In summer, 'L 54-08', 'UC 14', and 'Golden' had the lowest means, differing from the other genotypes, which is in alignment with Reis et al. (2015), who found low variability for this characteristic among the evaluated genotypes. PT is an important quality attribute because it indicates higher yield (Luz et al., 2015); moreover, fruits with a lower PT, have a larger internal cavity, being more susceptible to losses during transport and storage (Oliveira et al., 2010). Therefore, the greater the PT, the better the acceptance of the fruits by the market and industry.

Table 3. Grouping of the means of ten characteristics of papaya (*Carica papaya*) fruits from 12 genotypes of the Solo group evaluated over two harvest seasons in the municipality of Pinheiros, in the state of Espírito de Santo, Brazil(1).

Genotype	NCF		NDF		PP		FW		FL	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
H 10-60	15.80Bb	33.33Ab	7.40Bb	18.87Aa	6.16Bc	23.93Aa	389.74Bc	654.54Aa	12.64Bc	15.96Ab
H 26-60	15.53Bb	38.93Aa	6.00Ab	11.33Ab	8.59Bc	27.88Aa	576.21Ab	694.02Aa	14.88Ab	16.44Ab
H 36-45	17.40Bb	31.87Ab	7.79Bb	14.27Aa	12.06Ba	24.26Aa	708.62Aa	772.86Aa	18.57Aa	17.67Aa
L 06-08	17.80Bb	40.40Aa	7.80Ab	11.60Ab	9.77Bb	28.99Aa	556.78Bb	728.58Aa	15.99Bb	18.41Aa
L 47-P8	13.20Ab	22.67Ab	4.87Ab	10.13Ab	6.61Ac	15.20Ab	512.54Ab	661.81Aa	15.80Ab	17.65Aa
L 54-08	12.60Bb	26.73Ab	13.73Aa	19.20Aa	5.17Ac	13.87Ab	425.88Ac	521.64Ab	12.41Ac	14.08Ac
L 78-08	23.80Ba	53.47Aa	7.40Bb	16.13Aa	9.46Bb	29.31Aa	396.70Ac	548.44Ab	13.53Ac	15.45Ab
UC 13	18.07Bb	40.67Aa	6.47Ab	7.47Ab	10.52Bb	27.39Aa	576.54Ab	684.08Aa	15.42Ab	16.40Ab
UC 14	19.00Bb	44.80Aa	4.20Ab	9.73Ab	12.54Ba	24.72Aa	646.44Aa	557.56Ab	15.32Ab	15.44Ab
UC 15	20.47Ba	32.07Ab	7.27Ab	5.40Ab	14.59Aa	22.41Aa	713.73Aa	730.30Aa	17.87Aa	17.81Aa
UC 16	14.53Bb	37.73Aa	5.67Ab	6.27Ab	10.08Bb	33.06Aa	701.10Ba	868.58Aa	16.62Ab	18.34Aa
Golden	26.73Ba	42.33Aa	6.93Bb	13.53Aa	7.31Ac	12.24Ab	281.06Ac	294.20Ac	11.50Ac	11.63Ad
	FD		PT		SS		TA		SS/TA ratio	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
H 10-60	8.12Bb	9.06Aa	2.14Ac	2.34Aa	13.73Aa	13.64Ab	0.094Aa	0.108Aa	154.17Aa	137.20Ab
H 26-60	8.85Aa	9.45Aa	2.33Ab	2.44Aa	12.10Ba	13.06Ab	0.084Aa	0.096Ab	149.92Aa	138.83Ab
H 36-45	8.92Aa	9.44Aa	2.64Aa	2.54Aa	13.02Aa	13.87Ab	0.092Aa	0.102Aa	146.98Aa	139.04Ab
L 06-08	8.44Ba	8.98Aa	2.44Bb	2.69Aa	12.96Aa	13.18Ab	0.092 Aa	0.090Ab	152.39Aa	151.77Aa
L 47-P8	8.20Ab	9.06Aa	2.27Ac	2.47Aa	13.06Ba	15.05Aa	0.106 Aa	0.094Ab	129.03Bb	165.45Aa
L 54-08	8.48Aa	8.61Ab	2.01Ad	2.04Ab	13.80Aa	14.36Aa	0.098Aa	0.096Ab	145.15Aa	159.61Aa
L 78-08	7.82Ab	8.58Ab	2.24Ac	2.46Aa	13.10Aa	13.18Ab	0.084Aa	0.088Ab	159.22Aa	153.93Aa
UC 13	8.78Aa	9.17Aa	2.39Ab	2.48Aa	13.56Ba	14.63Aa	0.092Ba	0.110Aa	150.72Aa	135.87Ab
UC 14	9.22Aa	8.40Ab	2.58Aa	2.18Bb	13.02Ba	14.40Aa	0.086Ba	0.110Aa	156.01Aa	132.87Bb
UC 15	9.19Aa	9.26Aa	2.33Ab	2.46Aa	14.42Aa	14.56Aa	0.100Ba	0.116Aa	146.54Aa	131.49Ab
UC 16	9.20Aa	9.98Aa	2.45Ab	2.56Aa	13.00Ba	14.30Aa	0.088Aa	0.102Aa	148.73Aa	148.53Aa
Golden	7.16Ac	7.24Ac	1.98Ad	1.84Ab	13.07Ba	14.89Aa	0.106Aa	0.108Aa	129.62Ab	140.59Ab

(1)Means followed by equal letters, uppercase in the lines and lowercase in the columns, do not differ by the t and Scott-Knott tests, respectively, at 5% probability. NCF, number of commercial fruits; NDF, number of deformed fruits; PP, production of fruits per plant (kg); FW, fruit weight (g); FL, fruit length (cm); FD, fruit diameter (cm); PT, pulp thickness (cm); SS, soluble solids contents (°Brix); TA, titratable acidity (grams of citric acid per 100 g); winter, 210–300 days after planting; and summer, 450–540 days after planting.

There were interactions between genotype and harvest season for SS contents, TA, and the SS/TA ratio, confirming that the chemical characteristics of the fruits are among the most affected by climatic conditions (Moretti et al., 2010). No differences were found in SS contents between the genotypes in winter. In summer, the hybrids developed by Universidade Estadual do Norte Fluminense Darcy Ribeiro in partnership with Caliman Agrícola S/A (Uenf/Caliman), as well as the 'L 47-P8', 'L 54-08', and 'Golden', stood out because they had °Brix values between 14.30 ('UC 16') and 15.05 ('L 47-P8'). These values were high compared with those obtained by Pinto et al. (2013b) – between 9.3 and 11 °Brix, above the acceptable value by the fruit market for the Solo group, of approximately 11.5 °Brix (Fagundes & Yamanishi, 2001).

With regard to SS contents and TA, no differences were observed between the genetic materials in winter. In summer, the highest TA values were obtained by the Uenf/Caliman hybrids and by 'Golden', 'H 36-45', and 'H 10-60'. For the SS/TA ratio, the lowest values were found for the Golden and L 47-P8 cultivars in winter, whereas, in summer, the lines from Embrapa Mandioca e Fruticultura and the UC 16 hybrid had the best means. It should be noted that the sweetest papaya fruits have low acidity and high SS values (Luz et al., 2015); and nitrogen and boron fertilizations are recommended for maximum SS contents (Brito Neto et al., 2011).

Regarding the cultivars of the Formosa group, the mean NCF was higher in summer, except for 'EW Sinja' and 'EW 2747', which did not differ between harvest seasons. However, no differences were observed between harvest seasons for the NDF, except for 'L 10-08', which had the highest mean in summer (Table 4). According to Damasceno Júnior et al. (2008), the number of hermaphrodite flowers in papaya hybrids that produce commercial fruit significantly affect the environment, especially in summer; however, this was not the case in the present study. Intrapopulation variability, which confers greater rusticity and adaptive capacity, may have affected the results obtained for the evaluated genotypes.

When considering the general mean of all genotypes and harvest seasons, the ratio between the NDF and NCF was greater than 25% (Table 4), which would cause great losses to the producer. This reinforces the need to search for more efficient genotypes. Therefore, the UC 03 and Tainung 1 hybrids should be avoided in winter, and 'L 10-08' in summer because they have a higher NDF.

The PP values were higher in summer, except for the UC 03 and EW 2747 cultivars. However, 'Rubi Incaper 511' had higher yields in both harvests: in summer, it was superior to the other genotypes by more than 10 kg per plant, and in winter it was similar to UC 11, UC 12, and Tainung 1 (Table 4). It should be highlighted that 'Rubi Incaper 511' is an open-pollination cultivar; therefore, it is possible to reuse its seeds and, consequently, to reduce production costs, increasing profits (Rubi Incaper 511, 2010).

Except for the UC 11, EW Sinja, and EW 2747 cultivars, FW was the same in both harvest seasons, and genotype clustering varied little in each environment (Table 4). The 'UC 10', 'EW Sinja', and 'EW 2747' also had the highest means in the two harvest seasons; however, they produced fruits weighing more than the commercial standard of 800 to 1,100 g (Costa et al., 2013).

For PT, although the harvest seasons affected the evaluated genotypes, the materials with the highest means were the same in both seasons, namely: 'Rubi Incaper 511', 'EW Sinja', and 'EW 2747' (Table 4). Along with 'UC 10', these same cultivars had the highest fruit weights in winter, which confirms the high positive correlation between these variables, as reported by Oliveira et al. (2010) and Reis et al. (2015).

There was no difference between harvest seasons regarding SS contents, except for the L 10-08 and Rubi Incaper 511 lines, which had the lowest means among the genotypes analyzed in winter (Table 4). This result reinforces the need to continue the papaya breeding program developed by Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural (Incaper), which seeks to improve the SS contents of 'Rubi Incaper 511'. However, in summer, the UC 03 hybrid stood out with a higher mean than that obtained by Luz et al. (2015), possibly because these authors assessed the SS contents at stage 1 of fruit ripening.

For TA and the SS/TA ratio, only 'EW 2747' differed between harvest seasons, with higher TA in summer and higher SS/TA ratio in winter (Table 4). With the exception of 'UC 10', in summer, the genotypes with the highest TA had the lowest SS/TA ratio or the inverse, due to the calculation of the SS/TA ratio and

Table 4. Grouping of the means of ten characteristics of papaya (*Carica papaya*) fruits from nine genotypes of the Formosa group evaluated over two harvest seasons in the municipality of Pinheiros, in the state of Espírito Santo, Brazil[(1)].

Genotype	NCF		NDF		PP		FW		FL	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
L 10-08	16.87Ba	31.80Aa	5.27Bb	17.33Aa	14.16Bb	28.24Ab	824.93Ab	1,037.18Ab	19.31Ab	21.15Ab
UC 03	8.07Bc	21.20Ab	7.80Aa	10.27Ab	8.62Ab	20.00Ab	1,053.06Ab	945.22Ab	20.74Ab	19.41Ab
UC 10	5.53Bc	16.53Ac	1.73Ab	3.40Ac	7.61Bb	27.82Ab	1,284.82Aa	1,696.34Aa	23.18Aa	23.98Aa
UC 11	7.73Bc	21.00Ab	3.33Ab	2.93Ac	8.93Bb	34.09Aa	1,107.38Bb	1,545.92Aa	22.64Aa	25.68Aa
UC 12	11.93Bb	27.00Aa	3.53Ab	4.53Ac	11.76Bb	31.56Aa	986.24Ab	1,202.82Ab	20.02Ab	21.66Ab
Rubi Incaper 511	20.40Ba	29.27Aa	3.80Ab	5.26Ac	24.33Ba	41.94Aa	1,185.08Aa	1,456.06Ab	22.91Aa	25.37Aa
EW Sinja	5.66Ac	11.27Ac	3.13Ab	5.53Ac	7.70Bb	24.01Ab	1,484.44Ba	2,120.80Aa	20.72Ab	22.34Ab
EW 2747	9.73Ab	7.93Ac	3.00Ab	2.80Ac	11.88Ab	15.41Ab	1,200.21Ba	1,923.64Aa	20.76Bb	24.49Aa
Tainung 1	9.87Bb	28.40Aa	5.33Aa	4.67Ac	10.35Bb	38.16Aa	993.58Ab	1,331.10Ab	21.96Aa	24.29Aa
	FD		PT		SS		TA		SS/TA ratio	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Winter
L 10-08	9.31Aa	9.47Aa	2.46Ab	2.65Ac	11.19Bc	12.64Ab	0.090Ac	0.098Ab	128.90Ab	139.37Aa
UC 03	13.86Aa	10.07Aa	2.61Ab	2.62Ac	14.18Aa	14.62Aa	0.102Ab	0.114Aa	140.72Aa	133.05Ab
UC 10	10.15Aa	12.07Aa	2.68Bb	3.02Ab	13.08Ab	12.27Ab	0.106Ab	0.096Ab	134.38Ab	131.55Ab
UC 11	9.85Aa	11.07Aa	2.62Bb	2.99Ab	14.80Aa	12.76Ab	0.124Aa	0.116Aa	120.60Ab	114.99Ab
UC 12	9.92Aa	10.42Aa	2.55Bb	2.92Ab	13.34Ab	13.43Ab	0.108Ab	0.110Aa	127.37Ab	127.97Ab
Rubi Incaper 511	10.20Aa	10.64Aa	2.84Ba	3.21Aa	10.90Bc	12.42Ab	0.086Ac	0.086Ab	129.74Ab	151.62Aa
EW Sinja	12.03Aa	14.23Aa	3.10Aa	3.34Aa	12.93Ab	12.53Ab	0.096Ac	0.092Ab	141.39Aa	143.22Aa
EW 2747	10.81Ba	20.42Aa	2.94Ba	3.57Aa	13.72Ab	13.30Ab	0.094Bc	0.114Aa	155.38Aa	119.01Bb
Tainung 1	9.82Aa	10.95Aa	2.75Ab	3.00Ab	12.90Ab	13.20Ab	0.088Ac	0.090Ab	152.52Aa	153.60Aa

[(1)]Means followed by equal letters, uppercase in the lines and lowercase in the columns, do not differ by the t and Scott-Knott tests, respectively, at 5% probability. NCF, number of commercial fruits; NDF, number of deformed fruits; PP, production of fruits per plant (kg); FW, fruit weight (g); FL, fruit length (cm); FD, fruit diameter (cm); PT, pulp thickness (cm); SS, soluble solids contents (°Brix); TA, titratable acidity (grams of citric acid per 100 g); winter, 210–300 days after planting; and summer, 450–540 days after planting.

to the higher correlation with TA, when compared with SS contents (Reis et al., 2015).

Conclusions

1. In the Solo group of papaya (*Carica papaya*), the H 36-45 and UC 15 hybrids show greater production and fruit weight in the two harvest seasons (winter and summer) evaluated, and have high soluble solids contents.

2. In the Formosa group, 'Rubi Incaper 511' stands out due to its greater productivity, higher number of commercial fruits, and lower number of deformed fruits in the two harvest seasons assessed.

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