

Yield and fruit quality of papaya cultivars grown at two locations in Puerto Rico^{1,2}

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ABSTRACT

We evaluated five hybrids and an open-pollinated papaya cultivar grown on an Oxisol and Ultisol under intensive management at Isabela and Corozal, PR. At Isabela, hybrid Tainung 3 produced a significantly greater number of marketable fruits, whereas at Corozal the three Tainung hybrids did not show significant differences for this trait. There were no significant differences in weight of marketable fruit per hectare among hybrids Red Lady, Known You 1, Tainung 1 and Tainung 2 at either location. The average marketable fruit weight for these hybrids was 134,585 kg/ha at Isabela and 75,256 kg/ha at Corozal. Cultivar PR 6-65 produced significantly longer fruits at both locations, whereas hybrid Tainung 3 produced the shortest fruits. Significantly higher brix values were obtained from fruits of hybrid Tainung 3 at both locations, whereas lower values were obtained from those of PR 6-65.

Keywords: Papaya, evaluation, yield, fruit quality, Oxisol, Ultisol

RESUMEN

Rendimiento y calidad de fruta en cultivares de papaya en dos localidades en Puerto Rico

Cinco híbridos y un cultivar de polinización abierta de papaya se evaluaron en dos localidades en un suelo Oxisol (Isabela) y Ultisol (Corozal) bajo manejo intensivo. En Isabela, el híbrido Tainung 3 produjo el mayor número de frutas comerciales, mientras que en Corozal los tres híbridos Tainung no mostraron diferencias significativas para esta variable. En ambas localidades los híbridos Red Lady, Known You 1, Tainung 1 y Tainung 2 no mostraron diferencias significativas en el peso de frutas comerciales. El peso medio de frutas comerciales en estos híbridos fue 134,585 kg/ha en Isabela y 75,256 kg/ha en Corozal. El cultivar PR 6-65 produjo frutas significativamente más grandes en ambas localidades, mientras que el híbrido Tainung 3 produjo las frutas de menor tamaño. En ambas localidades los valores de

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brix fueron significativamente más altos en frutas del híbrido Tainung 3 y más bajos en las frutas de PR 6-65.

INTRODUCTION

Papaya (*Carica papaya* L.) is native to tropical America but its cultivation has been extended as far as latitudes 32° North and South, making it the fourth most important fruit worldwide (IPGRI, 2000). In 1999, worldwide production of papaya was 5,384,605 metric tons harvested in an area of 304,637 hectares. Mean worldwide yield of papaya in 1999 was 11,676 kg/ha with Brazil and Guatemala topping all countries at 48,571 kg/ha and 40,000 kg/ha, respectively (FAO, 2001).

The increase in ethnic diversity in the United States as well as changes in diet habits of the public for health considerations has opened a large market for tropical and subtropical fruits, including papaya. Nutritionally, papaya fruits are a good source of calcium and potassium as well as an excellent source of provitamin A and ascorbic acid (Nakasone and Paull, 1998).

Little is known about the performance of newly available commercial hybrids of papaya grown in diverse agroenvironments in the tropics and subtropics. Depending on soil type and rainfall, root rot caused by *Phytophthora* and seedling damping off caused by a complex of organisms may induce mortality rates as high as 40% (Nakasone and Paull, 1998). Fruit anthracnose, papaya ring spot virus and bunchy-top disease are often limiting factors for commercial production in many areas (Davis et al., 1996). Another shortcoming in papaya production is the wide plant variability encountered in fields. Plantings are usually very heterogeneous because seeds used by growers are often obtained from open pollinated fruits.

Depending on the cultivar used, marketable yield in Hawaii ranges from 17.2 to 39.1 kg/tree (Yee, 1970). In Puerto Rico, Acosta et al. (1994) reported yields of 44,026 kg/ha when plants of cultivar PR 7-65 received 112 grams of nitrogen per month. Brunner (1994) obtained yields of 103,715 kg/ha when cv Villalba was grown with drip irrigation in a Vertisol.

The objective of this study was to evaluate yield and fruit quality traits of commercial hybrids of papaya grown under intensive management at two locations.

MATERIALS AND METHODS

The study was conducted in Puerto Rico at the USDA-ARS Research Farm in Isabela (Coto clay, clayey, kaolinitic isohyperthermic Typic Hapludox) and at the Corozal Agricultural Experiment Substa-

tion of the University of Puerto Rico (Corozal clay, clayey, mixed, isohyperthermic Aquic Haplohumults). Relevant soil chemical properties and weather data for both locations are presented in Table 1 and Table 2, respectively. Elevation at Isabela and Corozal is 126 and 195 m, respectively.

Seed of five hybrids of papaya obtained from Known You Seed Co., Taiwan (Tainung No. 1, Tainung No. 2, Tainung No. 3, Known You 1, Red Lady) and an open-pollinated cultivar from Puerto Rico (PR 6-65) were germinated in styrofoam seedling trays with open bottom cells containing Pro-Mix BX.⁶ Tray cells were 38 mm deep and 13 mm on each side. About 50 days after germination, seedlings with four to six leaves were transplanted to the field 26 January 1999 (Isabela) and 4 February 1999 (Corozal) and arranged in a randomized complete block design with six replications at each location. Within a replication, plots for each cultivar consisted of two rows of 12 plants spaced 1.8 × 2.4 m apart, the inner eight of which were harvested for determination of yield and other fruit traits. The experiment was surrounded by two rows of guard plants.

At transplanting, each plant received 3.5 g phosphorous provided as triple superphosphate. Plots were drip irrigated when the soil water tension, measured with tensiometers at a depth of 15 cm, exceeded 20

TABLE 1.—Average preplant soil characteristics at two test sites in Puerto Rico, measured to a depth of 30.5 cm.

Soil characteristic (Order)	Location	
	Isabela (Oxisol)	Corozal (Ultisol)
pH (H ₂ O)	6.62	* 4.75
pH (CaCl ₂)	6.06	4.11
NH ₄ -N (mg/kg)	11.05	23.01
NO ₃ -N (mg/kg)	6.60	9.17
Organic C (%)	1.20	1.19
Phosphorous (mg/kg)	15.79	5.88
Potassium (mg/kg)	469.80	253.67
Calcium (mg/kg)	1654.20	1550.66
Magnesium (mg/kg)	67.80	62.00

⁶Trade names in this publication are used only to provide specific information. Mention of a trade name or manufacturer does not constitute a warranty of materials by the USDA-ARS or the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other materials.

TABLE 2.—Average monthly maximum and minimum air temperature, rainfall, and class A pan evaporation for January through November 1999 at the test sites.

Month	Temperature °C		Rainfall (mm)	Pan evaporation (mm)
	Max.	Min.		
Isabela				
January	27.8	19.3	128.5	120.9
February	27.2	18.4	50.3	121.7
March	28.5	19.3	178.0	144.5
April	29.2	19.8	65.3	169.2
May	30.8	21.3	201.9	139.7
June	30.4	21.9	216.9	136.4
July	30.5	22.8	110.5	144.0
August	31.6	22.5	147.3	148.6
September	31.2	22.9	133.8	143.0
October	30.3	22.2	236.0	110.7
November	28.8	21.3	235.7	85.5
Average	29.6	21.1	154.9	133.1
Corozal				
February	27.0	16.0	38.1	94.0
March	29.2	17.4	99.3	141.0
April	29.9	18.2	86.6	139.9
May	32.2	20.6	274.6	152.6
June	31.3	21.3	229.1	116.3
July	30.8	21.5	289.6	130.8
August	30.3	20.0	117.0	133.8
September	31.6	19.6	227.1	112.0
October	30.8	19.8	298.7	112.5
November	29.1	20.7	354.9	92.7
Average	30.2	19.5	201.5	122.6

kPa. Throughout the 10-month experimental period, fertilizer was provided weekly through the drip system at the rate of 6.9 and 7.8 kg/ha of nitrogen and potassium, respectively, with a mixture of potassium nitrate and urea as the nutrient sources. Insects and weeds were controlled by following recommended cultural practices (Toro, 1993).

The first harvest of fruits was made at about seven months after transplanting. Fruits were harvested at color break when they started to show a tinge of yellow at the apical end of the fruit. At each harvest, number and weight of marketable and non-marketable (deformed) fruits were determined. Representative fruits totaling about 25% of those harvested were used to determine fruit length and diameter. Brix

readings were also taken with a sugar refractometer when the fruits ripened, about five days after harvest. Analysis of variance was determined by using the ANOVA procedure of the SAS program package (SAS Institute, 1987). F values with $P \leq 0.05$ were considered statistically significant.

RESULTS AND DISCUSSION

Location and hybrids showed highly significant effects ($P \leq 0.01$) on most of the fruit parameters measured in the study. The location \times hybrid interaction was significant only for number of marketable fruits, total fruits and weight of non-marketable fruits (Table 3). The average number of marketable fruits at Isabela was about 40% higher than that obtained at Corozal. At both locations the number of marketable fruits constituted over 90% of the total fruits harvested (Table 3). Total average fruit weight was significantly higher at Isabela (128,164 kg/ha) than at Corozal (67,513 kg/ha). Similarly, average fruit length and diameter were significantly greater at Isabela. There was not a significant difference in average fruit brix between locations. Significantly lower marketable fruit weight at Corozal was caused by a lower number of fruits produced at this location (Table 3). This finding in turn may have been the result of much higher rainfall at Corozal throughout the experimental period (Table 2). Rainy weather is known to reduce pollination of some fruit crops (Hasan and Razak, 1992).

At Isabela, hybrid Tainung 3 produced a significantly greater number of marketable fruits per hectare. However, at Corozal the differences among the three Tainung hybrids for this trait were not statistically significant. Cultivar PR 6-65 produced the lowest number of marketable fruits at both locations, but differences between this cultivar and hybrids Red Lady and Known You 1 at Isabela and Red Lady at Corozal (Table 3) were not statistically significant. Cultivar PR 6-65 also produced a significantly higher percentage (14%) of non-marketable fruits at Isabela (data not shown).

There were no significant differences in weight of marketable fruit per hectare among hybrids Red Lady, Known You 1, Tainung 1 and Tainung 2 at either location (Table 3). The average marketable fruit weight for these hybrids was 134,585 kg/ha at Isabela and 75,256 kg/ha at Corozal. At both locations plants of cultivar PR 6-65 and hybrid Tainung 3 produced a significantly lower weight of marketable fruits per hectare, averaging 73,168 kg/ha. Cultivar PR 6-65 produced a significantly higher weight of non-marketable fruits at Isabela. However, differences among hybrid means for this trait were not significant at Corozal.

TABLE 3.—Yield and fruit quality traits of five hybrids and an open-pollinated cultivar planted at two locations in Puerto Rico.

Location	Hybrids	Marketable fruits (no./ha)	Non-marketable fruits (no./ha)	Total fruits (no./ha)	Weight marketable fruits (kg/ha)	Weight non-marketable fruits (kg/ha)	Total fruit weight (kg/ha)	Fruit length (cm)	Fruit diameter (cm)	Fruit brix (%)
Isabela	Known You 1	80186	4717	84903	129580	5522	135102	27.2	15.9	10.2
	PR 6-65	74722	12843	87565	115122	10681	125803	31.2	14.8	7.5
	Red Lady	90834	3362	94196	146403	3602	150005	24.1	16.2	10.9
	Tainung 1	152994	1961	154955	133294	961	134255	21.8	13.1	12.1
	Tainung 2	131184	3316	134500	129065	2427	131492	24.0	13.9	10.6
	Tainung 3	176531	12749	189280	86537	5793	92330	16.7	10.5	13.1
	Average	117742	6491	124233	123333	4831	128164	24.2	14.1	10.7
	LSD (0.05)	20293	5489	22155	18486	3493	18963	1.4	0.9	0.8
Corozal	Known You 1	62253	3129	65382	89130	2356	91486	24.3	13.2	10.1
	PR 6-65	36100	5698	4179	49474	3211	52685	28.4	12.5	7.7
	Red Lady	47262	3036	50298	63145	1912	65057	21.0	13.9	10.7
	Tainung 1	85744	5698	91442	72790	1857	74647	19.8	11.4	11.1
	Tainung 2	73882	3036	76918	75957	1228	77185	22.0	11.5	10.9
	Tainung 3	90787	10741	101528	41537	2480	44017	15.3	9.4	13.6
	Average	66004	5223	71227	65339	2174	67513	21.8	12.0	10.7
	LSD (0.05)	25754	4301	25050	35471	2034	36368	1.9	1.1	1.0
LSD (0.05) ¹	22473	4581	23062	27495	2629	28172	1.7	0.97	2.08	
Location (L) ²	**	NS	**	**	**	**	**	**	**	NS
Hybrid (H)	**	**	**	**	**	**	**	**	**	**
L × H	**	NS	**	NS	**	**	NS	NS	NS	NS

¹Compares different hybrid means at different location treatments or similar hybrid means at different location treatments.²NS = not significant, ** = significant at 0.01 probability level.

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Hybrid (H)	**	**	**	**	**	**	**	**	**	**
L × H	**	NS	**	NS	**	**	NS	NS	NS	NS

¹Compares different hybrid means at different location treatments or similar hybrid means at different location treatments.²NS = not significant, ** = significant at 0.01 probability level.

According to individual weight of marketable fruits, hybrids can be divided into three categories: 1) Known You 1, Red Lady and cultivar PR 6-65, all three of which produced marketable fruits weighing between 1.3 to 1.6 kg; 2) Tainung 1 and Tainung 2, both of which produced fruits that ranged in weight between 0.85 to 1.0 kg; and 3) Tainung 3, which produced fruits weighing between 0.45 to 0.49 kg (data not shown).

Cultivar PR 6-65 produced significantly longer fruits at both locations whereas hybrid Tainung 3 produced the shortest fruits. As compared to fruits of PR 6-65, those of Tainung 3 were 46% shorter (Table 3). Plants of hybrids Know You 1 and Red Lady produced fruits with significantly greater fruit diameter at both locations, whereas those of Tainung 3 produced fruits with the smallest diameter. The lower marketable fruit weight attained by plants of hybrid Tainung 3 at both locations resulted from the production of significantly smaller fruits rather than by a decline in the number of fruits. For example, averaged over both locations, plants of hybrid Tainung 3 produced 29% more fruits than those of Tainung 2, but fruit marketable weight of the latter was 39% greater (Table 3). Significantly higher brix values were obtained from fruits of hybrid Tainung 3 at both locations, whereas the lowest brix values were obtained from PR 6-65 (Table 3).

In this study, five hybrids from Taiwan and one cultivar from Puerto Rico were evaluated at two locations and their fruit quality traits and yield response were reported for the first time. Cultivar PR 6-65 and all of the hybrids used in this study produced significantly higher number and weight of marketable fruits per hectare at Isabela than at Corozal (Table 3). These results suggest that papaya production is more suited to the Isabela region. Total rainfall at Corozal during the experimental period was 30% greater than at Isabela. This rainfall may have resulted in nutrient runoff at Corozal due to the clayey nature and steepness of the soil at this site and hence a reduction in yield.

Red Lady, a hybrid that is becoming popular in Puerto Rico, was a good yielder and produced oblong deep reddish-orange fruits. However, yields of other hybrids were higher, particularly at Corozal. Plants of hybrid Tainung 3 produced small round fruits with yellowish flesh and very sweet flavor. Plants of hybrid Tainung 1 produced pear-shaped fruits with a reddish-orange flesh similar to that of Tainung 2. Hybrids Known You 1 and cultivar PR 6-65 produced elongated fruits with yellow flesh. Individual marketable fruit weight was higher in Red Lady, Known You 1 and PR 6-65 and lower in Tainung 3. It is recommended that growers acquire certified seed from research institutions or commercial seed companies in order to avoid off-type materials that may yield fruits of lower quality.

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