

CROSSING SUCCESS AND PERFORMANCE OF F₁ HYBRIDS IN GUAVA (*Psidium guajava* L.)

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ABSTRACT

A hybridization programme was initiated at the Fruit Crops Research and Development Centre, Horana in 2002 to develop high yielding guava varieties with good fruit quality characteristics. Nine crosses made using six parents adapted to local conditions and having different fruit and growth characteristics were evaluated over 4 years. Controlled cross pollination among varieties was easy and all the crosses made were successful with 100% fruit set and good seed set. All the F₁ hybrid progenies came into flowering in 4-12 months after planting (MAP) and had fruits in 7-15 MAP. Progeny means of the canopy height, days to 1st flowering, days to 1st harvest, number of fruits per plant, fruit yield per plant and fruit characteristics such as fruit weight, fruit size (length, width), flesh thickness total soluble solids (TSS) and seediness significantly varied among and within progenies.

Twenty eight promising individual F₁ hybrids were selected and subsequently evaluated with their parents. Based on yield and quality evaluation of fruit size, colour, vitamin C, TSS, acidity and pectin content, promising six hybrids were identified to test adaptability under different agro-ecological conditions of Sri Lanka.

KEYWORDS: Crossing, F₁ hybrids, Guava progeny, Quality, Yield.

INTRODUCTION

Guava is becoming a popular fruit crop in Sri Lanka because of its high productivity, profitability and acceptability by the people. Four new introductions have been recently recommended for cultivation and currently there is a huge demand for planting materials indicating that cultivation is moving towards commercial production. However, these varieties need further improvement for better fruit quality and for increased pest and disease resistance.

Guava is reported to have 30-35% out crossing (Nakasone and Paull, 1998). In India, several attempts have been made to select superior types from seedling populations (Phadnis, 1970; Hulamani *et al.*, 1981; Iyer and Subramanyam, 1988) and to develop new hybrids through inter varietal hybridization (Mukiherjee, 1977; Subramanyam and Iyer, 1993; Rama Rao and Dayanand, 1977; Mitra and Bose, 1985).

Little effort has been made in the past in Sri Lanka to develop new varieties of guava because it is a perennial crop and takes long to achieve the expected goal. Development of guava varieties with improved fruit quality, yield and pest and disease tolerance/resistance was initiated in 2002 at

February 2003 and transplanted in the field on 2nd and 3rd May 2003. Number of seedlings per fruit representing a progeny in each cross varied from 50-320 and a large extent of land was required to establish the experiment. Hence 8 blocks were used to lay out the experiment and the first 4 blocks were planted with 12 trees of each progeny while the remaining 4 blocks had unequal number of seedlings per progeny. In each block all progenies were randomly arranged. The experiment had a total of 800 plants established in the field and the total number of plants per cross varied from 40-120. These were continually observed for 3 years and data gathered on growth, yield and pest and disease incidence. Plant height and spread were measured at 2 months interval. Canopy height and spread were measured only on randomly selected 10 plants of each cross in each block as no observable variation in height and spread was found among the trees within a progeny. Height was measured from ground level to the highest point of the plant and plant spread to the widest point of the canopy. Only data taken at 4 and 12 months after planting (MAP) were analysed using ANOVA. Days to first flower opening, first harvest, number of fruits per harvest and yield were taken for each plant of the progenies. Yield data included, number of fruits, fruit weight, fruit length, fruit diameter, flesh thickness and total soluble solids (TSS). TSS was measured using hand refractometer and seediness (seed count/fruit) of fruits was visually counted and scored qualitatively according to a scale of no seeds, few seeds (less than 10-20), low number of seeds and high number of seeds. Crispiness was determined as a qualitative character after tasting.

Evaluation of promising individual F₁ progenies

Twenty eight promising individuals selected were vegetatively propagated using air layering method and were evaluated with their parents *i.e.* Pubudu, Kanthi, Horana Red, Horana White and Bangkok Giant. The variety Saffieda was not included as the mother trees were dead by the time the experiment was established. Experiment was conducted in a randomized complete block design with 3 replications. Each treatment had 2 trees/replicate.

Flower buds that appeared in the plants were removed up to 6 MAP in order to provide proper canopy growth prior to initial fruit set. Data were recorded on fruit yield and number of fruits harvested per tree. Fruit quality characteristics were measured on fruit length, diameter to the widest point, flesh thickness, TSS, number of seeds per fruit, and crispiness. Fruit skin and flesh colour were measured using Royal Horticultural Society (RHS) colour chart. Fruits from few selected entries at the stage of colour turning point were sent to Food Research Unit of DOA for quality analysis on Vitamin C, Acidity, TSS and other organoleptic characters. Titratable acidity was determined as anhydrous citric acid per 100g of edible portion, vitamin C as

mg per 100g of flesh. Pectin content was analysed in fruits picked at 100-115 days after flowering.

RESULTS AND DISCUSSION

Crossing programme

Controlled pollination among varieties was easy and all the crosses made at anthesis were successful and had 100% fruit set showing good cross compatibility among guava clones used (Table 2). Seth (1960) reported varietal cross incompatibility when crosses were made between Behat Coconut x Lucknow 49, S1 x Behat Coconut and some other crosses. Triploidy and some other genetic factors have been reported to be responsible for female sterility and such incompatibility was not observed in cross combinations made in the present study. Flower buds which were pollinated one day before anthesis of the female flower also had 100% fruit set and good seed set (120-325 seeds/fruit). This shows that high success rate of crossing can be achieved by pollinating the female flower at anthesis and even at one day before anthesis.

Table 2. Cross combinations and their success and the number of seeds per fruit in guava.

Cross combination			No. of crosses Made*		Success rate		No. of seeds per fruit	
Female parent	x	Male parent	OBA	AA	OBA	AA	OBA	AA
HW	x	BG	3	3	3	3	230-290	140-160
BG	x	HW	3	3	3	3	140-150	150-160
HW	x	Sa	3	2	3	2	250-325	200-250
BG	x	HR	2	3	2	3	135-150	120-130
BG	x	Pu	3	2	3	2	180-190	170
BG	x	K	2	2	2	2	200-240	120-135
BG	x	Sa	2	2	2	2	150-170	145-188
Pu	x	BG	4	3	4	3	120-130	141-165
Pu	x	Sa	3	3	3	3	250-275	170-350
Pu	x	HW	3	4	3	4	150-190	185

*OBA – One day before anthesis

AA – At anthesis

High insect activity was observed during early hours of the morning. Of the different pollinators the Dammar bee (*Trigona irridipennis*) was comparatively more associated with flowering time and robbed all the pollen. Hence in crossing programmes in order to avoid contamination from stray pollen as well as to have sufficient pollen for pollination care should be taken to bag both female and male flowers.

Performance of F₁ progenies

Growth characteristics

Hybrid progenies showed healthy growth at nursery stage and after establishment in the field. Growth measurements on canopy height and its spread were taken up to 12 MAP at 2 months intervals but only data of 4 and 12 MAP are presented and discussed (Table 3). The three crosses Pu x HW, Pu x BG and BG x Pu had significantly shorter canopy height and narrow canopy spread over the other crosses. The crosses HW x Sa, BG x Sa and Pu x Sa had tallest plant stature while BG x Ka cross produced moderately tall trees.

Individuals within the progenies did not show differences with respect to plant height and spread. Also morphological variations with respect to leaf, stem and structure were not observed within the progenies.

Table 3. Canopy height and spread of nine F₁ hybrids.

Cross	4 MAP*		12 MAP	
	Height (cm)	Spread (cm)	Height (cm)	Spread (cm)
HW x BG	84 abc	86 a	211 ab	222 a
Pu x HW	71d	67 c	190 c	190 b
HW x Sa	85 ab	84 ab	222 a	211 ab
BG x Sa	85 ab	87 a	222a	203 ab
BG x Ka	83 abc	84 ab	200 bc	201 ab
BG x Pu	73 cd	75 bc	186 c	193 b
BG x HR	87 a	88 a	212 ab	221 a
Pu x BG	75 bcd	80 ab	193 c	206 ab
Pu x Sa	85 ab	83 ab	219 a	217 a
CV%	8.9	7.8	4.7	6.7

*MAP – Months after planting.

Means with the same letter are not significantly different at 5% probability levels.

Progeny means and the range, for the days to 1st flowering and 1st harvest and % bearing trees, yield, number of fruits per tree, and average fruit per tree are presented in Table 4 and 5. All these quantitative characters showed high variability among and within progenies.

Three hybrids (BG x Pu, Pu x HW and Pu x BG) flowered earlier than the other six crosses having progeny means of 185–221 days and 284–321 days respectively (Table 4). These hybrid progenies which flowered early had 89–99% of their off-spring flowering within 4–11½ MAP. Interestingly, the crosses that flowered early are the crosses that had shorter plant height and narrow canopy spread (Table 3). The progenies of the other six crosses showed extended period of flowering and of these, only 15% of the off-springs in the BG x K cross came into flower during 7–11½ MAP.

Table 4. Days to 1st flowering, 1st harvest and % bearing trees of nine F1 hybrids.

Cross	Days to 1 st flowering			Days to 1 st harvest			% bearing trees	
	Progeny mean	Progeny range	SD+	Progeny mean	Progeny range	SD	2004*	2005**
HW x BG	278	206-349	± 41.7	433	329-646	± 58.2	65.3	99.0
Pu x HW	195	118-344	± 43.1	354	311-435	± 43.4	96.4	100.0
HW x Sa	303	213-355	± 37.2	409	347-628	± 56.5	69.9	100.0
BG x Sa	301	213-355	± 46.3	395	332-468	± 42.6	70.2	100.0
BG x Ka	321	224-350	± 35.8	448	340-612	± 70.6	20.0	67.6
BG x Pu	185	118-314	± 35.4	356	229-443	± 45.6	93.4	100.0
BG x HR	284	195-349	± 44.6	393	310-505	± 41.7	90.8	98.0
Pu x BG	209	121-314	± 48.7	359	230-430	± 53.9	93.3	100.0
Pu x Sa	296	213-349	± 28.6	412	337-470	± 26.4	83.9	100.0

+ SD = Standard deviation

* 1 ½ years after planting

** 2 ½ years after planting

The progeny means for the number of days to 1st harvest in the 3 crosses (Pu x BG, BG x Pu, Pu x HW) was less than 12 MAP and for other 6 crosses it was 13-15 MAP (Table 4). Days to 1st harvest varied greatly among the off springs in a cross and the extended period of 11-21 MAP was recorded in 3 crosses namely HW x Sa, Pu x Sa, HW x BG and BG x K while the shortest period of 10-14½ MAP was recorded in Pu x HW cross and moderate period of 8-15 MAP recorded in BG x Pu and Pu x BG.

When percent bearing trees are concerned, over 90% of the trees within the progeny came into bear within 18 MAP in 4 crosses (Pu x BG, BG x Pu, BG x HR, HW x Sa) while BG x Ka had only 20% offspring bearing during this period (Table 4). In 2½ years after planting except in BG x Ka cross, all others had 98-100% bearing trees. Early flowering and early bearing and the variability present between and among progenies facilitated progressive selection and to achieve success in comparatively short period of time which is not possible in most other fruit crops.

Fruit yield and quality characteristics

The yield and number of fruits per plant greatly varied among and within progenies (Table 5). The 4 progenies namely Pu x BG, BG x HR, BG x Pu, Pu x HW gave high mean yield and the mean number of fruits per tree when compared to other progenies. BG x Ka progeny produced very low mean yield and number of fruits per tree.

Fruit weight, seediness and TSS varied among the progenies as well as among the individuals within the progeny. The crosses HW x BG, BG x HW, BG x Pu, Pu x BG and BG x HR produced larger fruits (>300g/fruit) than HW x Sa, Pu x Sa and BG x K. However, fruit size and seediness showed some variation at different harvests of the same tree. The TSS value of the fruit varied from 5-13°Brix and the crosses HW x BG had better taste

over others. However, the taste of fruits varied at different times of the year giving less TSS values during rainy period than during the normal period.

Based on between and within progeny variability of yield, number of fruits per plant, fruit weight, fruit quality characters and earliness and other growth characteristics, 28 promising individual hybrids were selected for further evaluation in yield trials.

Evaluation of promising individual F₁ progenies

The yield and fruit quality characteristics during first year of harvest of 28 selections along with their parents are presented in Table 6. The mean yield of new selections were very high (10.8-44.8kg/tree) compared to that of their parents (4.8-27.8kg/tree). Of the new selections, both No.10 and 8, from BG x HR cross gave significantly higher yields of 44kg/tree and 44.8kg/tree, respectively, over the best yielding recommended variety (Pu) which produced only 27.8kg/tree. Yield increase in these two selections over their best parent BG, was 78.4%.

Number of fruits per tree was significantly different and varied from 20 to 192 (Table 6). The highest fruit number among the hybrid selections was produced by HR while the lowest fruit number of 20 by Kanthi. Two selections namely No. 08 and 10 from BG x HR cross gave the highest number of fruits.

The mean fruit weight of the new selections and their parents were significant and varied from 125 to 310g/fruit and the highest mean fruit weight of 310g was recorded in selection No. 24 which is a selection from HW x BG cross (Table 6). The new selections from the crosses of HW x BG, Pu x HW, BG x Pu, Pu x BG produced large fruits >200g but not significantly different from the mean fruit weight of the large fruited recommended varieties Pu and BG.

One of the breeding objectives in variety improvement of guava is to produce varieties with high yield and large fruit size. Fruit yield had high positive correlation with fruit number ($r^2=+0.9134$) while yield and fruit weight had $r^2=0.0873$. The correlation between number of fruits per tree vs. weight per fruit was $r^2=0.0003$.

Table 5. Yield, Number of fruits, fruit weight, seediness and TSS in F₁ hybrid progenies.

Cross	Yield/tree/1 ½ years (kg)		Fruits/tree/1 ½ years		Fruit weight (g)		Seediness*		TSS (°Brix) progeny range
	Progeny mean	SD+ range	Progeny mean	SD range	Progeny mean	SD range	Progeny mean	SD range	
HW x BG	2.88	0.28-9.1 ± 2.0	12	1-42 ± 9.2	302	± 63.3	FS, LS, MS	6.5-11.0	
Pu x HW	6.11	0.13-14.3 ± 3.2	27	5-65 ± 13.2	300	± 55.8	LS, FS, occasionally more	5.5-10.7	
HW x Sa	4.04	1.0-15.0 ± 2.7	24	1-90 ± 16.7	257	± 61.1	MS	7.0-11.0	
BG x Sa	3.82	0.17-12.1 ± 2.2	20	1-65 ± 13.6	254	± 78.2	LS, MS	7.0-9.0	
BG x Ka	0.64	0.07-3.4 ± 0.6	4	1-25 ± 4.8	200	± 79.4	LS, MS	6.0-10.0	
BG x Pu	6.23	0.25-17.6 ± 3.5	27	1-66 ± 14.3	304	± 49.9	FS, LS	5.6-8.1	
BG x HR	6.57	0.14-25.4 ± 5.2	36	1-123 ± 24.8	298	± 49.2	FS, LS, MS	7.0-10.7	
Pu x BG	5.53	1.1-12.4 ± 2.8	26	5-56 ± 11.8	300	± 47.3	FS, LS	6.3-13.0	
Pu x Sa	4.12	0.1-14.7 ± 3.2	23	1-84 ± 17.1	278	± 53.1	LS, MS	6.8-9.5	

+ SD - Standard deviation

*FS - Few seeds

LS - Less seeds

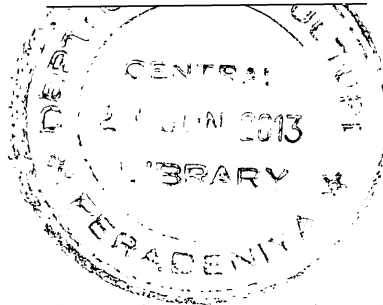
MS - More seeds

Table 6. Yield and fruit characteristics of promising F₁ hybrid selections and their parents.

Cross	Selection No.	Y/tree (kg)	Fruit No.	Seed No.	Fruit characteristics			
					Wt. (g)	Lg (cm)	Width (cm)	Flesh thickness (cm)
HW x BG	22	28.8	119	156	242	8.7	8.2	2.1
	23	20.5	117	162	252	9.2	9.2	2.2
	24	17.8	57	188	310	8.9	8.5	1.8
	25	14.6	67	180	216	7.9	8.6	2.1
Pu x HW	1	19.1	68	283	282	8.0	8.6	2.3
	2	20.7	84	172	246	7.7	8.2	2.2
	3	23.9	97	234	246	8.8	8.9	2.4
BG x Sa	26	19.8	87	176	203	8.7	8.0	1.7
	27	11.6	50	216	233	8.5	8.0	1.8
	28	28.9	131	200	221	9.6	8.6	1.9
BG x Pu	4	21.4	89	210	240	8.4	8.7	2.2
	6	23.6	93	147	255	8.6	8.8	2.4
	7	20.4	85	229	241	8.5	8.5	2.3
BG x HR	8	44.0	185	243	237	9.4	8.5	2.1
	10	44.8	182	243	246	10.2	8.8	2.1
	13	31.7	108	228	294	9.3	8.5	2.1
Pu x BG	11	26.3	115	259	229	7.8	8.1	2.1
	12	25.2	109	176	230	8.3	8.8	2.3
	14	25.3	118	162	215	8.2	8.6	2.3
	15	30.1	123	127	245	8.6	8.4	2.5
	16	28.3	127	329	224	8.8	9.3	2.5
	18	23.7	99	223	240	7.9	8.2	2.2
Pu x Sa	29	18.4	95	162	194	8.3	8.2	1.8
	30	14.1	74	346	188	8.5	7.9	1.7
HW	35	14.1	80	153	175	7.4	7.5	1.8
BG	36	25.1	96	208	260	8.5	8.6	2.1
Ka	37	4.8	20	74	250	7.5	7.5	2.0
Pu	38	27.8	109	277	257	8.1	8	2.3
HR	39	23.7	192	121	125	6.7	6	1.4
LSD (0.05)		12.5	58	147	75.0	1.19	0.93	0.4
CV %		31.2	34	43.9	17.5	8.68	6.85	12.4
Wt - Weight			Lg - Length		Y - Yield			

This shows that high yielding varieties of guava can be produced by increasing the number of fruits per plant without affecting the fruit size.

Number of seeds per fruit significantly varied among new selections and the parents. The lowest value of 74 seeds/fruit was in variety Kanthi and the next lowest seed count of 121 seeds from the variety HR. Seventeen hybrid selections gave comparatively lower number of seeds per fruit (<200) while only 2 hybrids (No. 30 and 16) had fairly large number of seeds (329 and 346).



Fruit flesh thickness significantly varied from 1.4 to 2.5cm and lowest value was recorded in HR variety. Selections from HW x Sa, BG x Sa, Pu x Sa gave lower flesh thickness of 1.5-1.9cm while others had over 2-2.5cm.

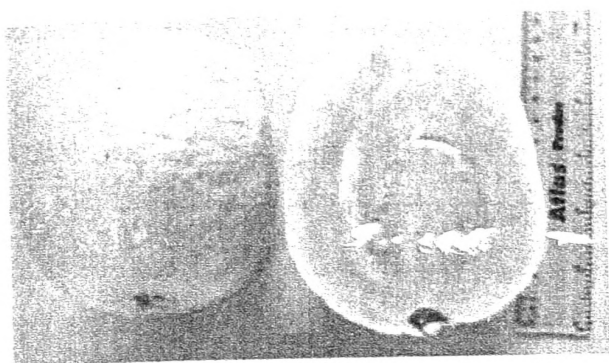
Fruit chemical quality characteristics are presented in Table 7. New selections and their parents ranged in TSS values from 6-12°Brix, acidity from 0.18-0.58%. In guava breeding programs fruit selection criteria include large fruits (200-340g) with more than 10% TSS, titratable acidity of 0.2-0.6% for dessert type and 1.25-1.5% for processing type (Nakasone and Paull, 1998). Among the selections and the parents, selection No. 15 which had high TSS value of 12 and low acidity of 0.4 with TSS/acidity ratio of 33 had very good taste as table type. Similarly, the other selections which had >10 TSS value with 0.4-0.5% acidity also had good taste. Vitamin C content varied from 30-97mg/100 edible portions while most selections had over 60mg/100g edible portion. Pectin content was analysed only for few selections/varieties due to limited resources and the tested selections and parents had 2.29-6.60% pectin. Values >3% are considered high (personnel communication, Research Officer, FRU, DOA).

Based on yield, fruit quality and general healthiness of trees, the following 6 most promising selections were identified for testing adaptability in different agro-ecological regions of Sri Lanka (Fig. 1).

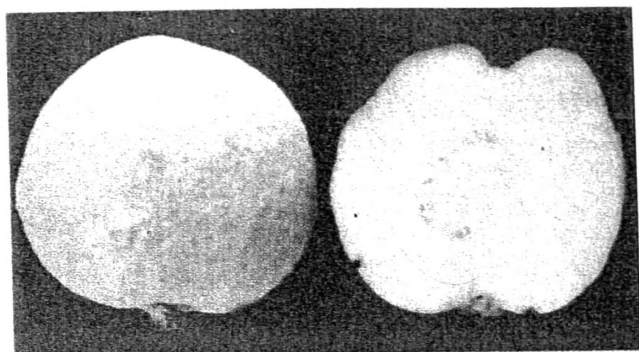
Selection No. 10 - Cross between BG x HR. Trees are moderately tall, with good spreading and loose canopy. Heavy bearing, fruits are oblong ellipsoid, large in size weighing around 240g. Skin is yellow green and flesh is red in colour at ripening.

Selection No 15 - Cross between Pu x BG. Short and loose canopy with less spreading. High yielding (30kg/tree/1st year). Fruits are round to high round, large in size (>250g) with less seeds. Yellow green skin with greenish white firm flesh, crispy and have good taste with Brix:Acidity ratio of 30 and long shelf life.

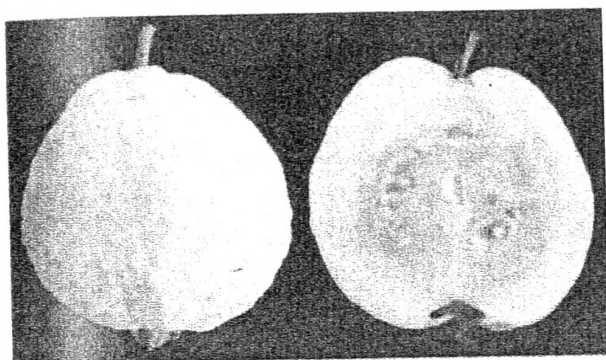
Selection No. 23 - Cross between HW x BG. Trees are moderately tall and good spreading. Fruits are oblong blocky in shape with faint vertical ribs and large (>250g), flesh is yellow green in colour, soft when ripe, less seeds, good taste and having Brix:Acidity ratio of 23.



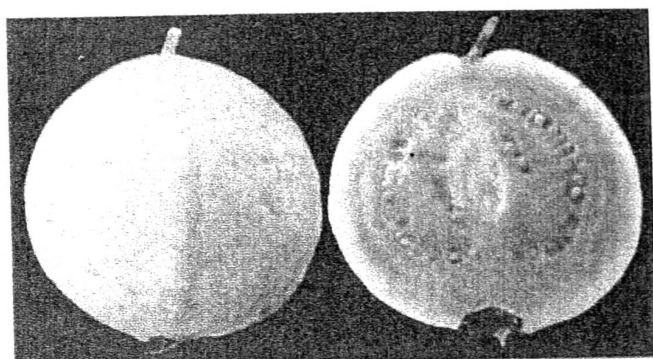
No. 10



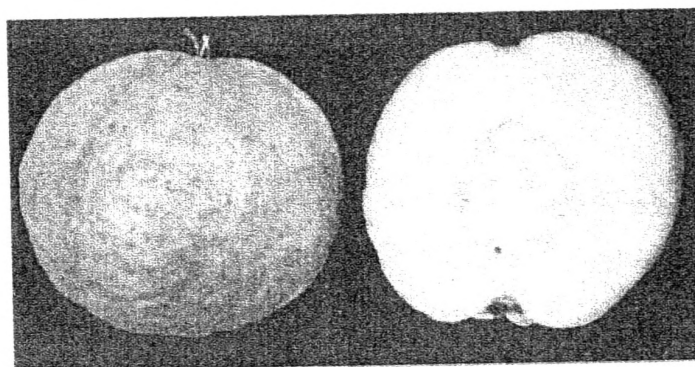
No. 15



No. 28



No. 33



No. 6

Figure 1. Some promising F₁ hybrid selections of guava identified for evaluation under different agro ecological regions in Sri Lanka.

Selection No. 28 - Cross between BG x Sa. Trees are moderately tall and moderately spreading. Fruits are pear shaped, smooth surface, skin is yellow in colour with pink flesh at ripening. Tolerance to styler end rot disease.

Table 7. Fruit quality characteristics of promising F₁ hybrid selections and their parents.

Cross	Selection No.	TSS % (Brix)	Acidity %	Brix/acid ratio	Vitamin C*	pH	% moisture	% pectin**
HW x BG	22	10.0	0.42	23.8	89.7	3.90	84.0	
	23	11.0	0.48	22.5	61.4	3.97	83.0	3.09
	24	9.1	-	-	-	-	-	
	25	11.5	0.46	25	55.8	4.01	89.0	
Pu x HW	1	7.0	0.2	35	65.0	4.06	87.0	
	2	10.0	0.46	21.6	81.7	3.94	63.0	
HW x Sa	31	10.0	0.51	19.6	27.9	3.88	82.0	
	32	10.2	0.43	23.6	19.7	3.69	81.8	
	33	11.0	0.51	21.5	76.7	3.81	87.4	2.70
	34	12.0	0.46	25.8	75.0	3.97	86.9	3.81
BG x Sa	26	10.5	0.48	21.8	36.2	3.81	87.0	
	27	9.0	0.47	19.1	73.3	3.81	88.3	
	28	8.8	0.58	15.2	60.1	3.81	-	4.93
BG x Pu	4	9.0	0.18	50.0	70.9	4.10	84.0	
	6	9.6	0.19	50.5	21.8	3.76	85.0	3.77
BG x HR	8	7.0	0.41	17.9	70.3	4.21	88.1	
	9	7.0	0.43	16.3	75.1	4.20	87.8	
	10	8.3	0.48	17.3	70.1	3.96	88.5	6.68
	13	7.0	0.48	14.6	76.7	4.40	87.1	
Pu x BG	12	6.5	0.38	17.1	97.7	3.78	86.0	
	14	6.0	0.29	20.7	81.3	3.98	92.0	
	15	12.0	0.4	30.0	46.2	3.91	81.2	3.81
	16	7.5	0.32	23.4	39.6	3.79	87.0	2.29
Pu x Sa	29	10.5	0.69	15.0	68.3	3.39	88.2	
	30	8.0	0.52	15.4	74.3	3.63	87.3	4.31
HW	35	8.0	0.43	18.6	62.1	3.88	59.0	5.85
BG	36	8.4	0.46	18.1	31.3	3.91	87.5	2.34
Ka	37	8.5	-	-	-	-	-	4.37
Pu	38	8.0	0.43	18.5	45.9	3.87	85.7	2.59
HR	39	9.0	0.38	23.4	52.4	4.04	83.9	4.77

* mg/100g of edible portion

** as calcium pectate (wet basis)

Selection No. 6 - Cross between BG x Pu. Trees are short, loose canopy fruits are round to high round, large in size >250g with less seeds, flesh is yellow green in colour, firm and crispy, very good taste with Brix:Acidity ratio of 50, and good keeping quality.

Selection No. 33 - Cross between HW x Sa. Trees are moderately tall and moderately spreading. Fruits are medium (around 200g) in size, smooth surface, yellow skin and pink flesh at ripening, good taste having Brix:Acidity ratio of 22 with tolerance to styler end rots disease.

CONCLUSIONS

Controlled pollination between guava varieties was successful. The F₁ hybrids that resulted from crossing displayed a wide variation within and between progenies in their performance and this variation was utilized to select six promising F₁ hybrids with high yield and producing big and tasty fruits.

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