

Breeding and Selection of Tomato F₁ Hybrids for Yield and Fruit Quality Characters

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ABSTRACT. *Tomato (Lycopersicon esculentum Miller) of the family Solanaceae is one of the most important vegetable crops grown in Sri Lanka. To understand the actual consumer requirements, especially in terms of fruit quality characters, an extensive survey was carried out. Results revealed that for home consumption, a majority preferred acidic, round to flat-shaped, medium-sized fruits, red in colour for curries, salads and sandwiches. The Government of Sri Lanka has also identified the production of local vegetable hybrids as a matter of high priority.*

With this information, a half diallel genetic crossing design was carried out to produce 36 F₁ hybrids using nine local and foreign varieties at the Agricultural Biotechnology Centre, University of Peradeniya. These were evaluated in the Meewatura farm of the Faculty of Agriculture, University of Peradeniya.

Yield and fruit quality characters including brix, acidity and fruit shape and colour were evaluated. General combining ability (GCA) and specific combining ability (SCA) were significant indicating the importance of both additive and dominance gene action. Out of the 36 F₁ tomato genotypes; T068 was selected as the best hybrid for the tourist industry as it showed heterobeltiosis for yield (48%) and low acidity, while T025 was selected as the best hybrid for local consumption as it too showed heterobeltiosis for yield (76%) with high acidity. Both hybrids showed that yield potentials were much higher than the currently used varieties.

INTRODUCTION

Tomato (*Lycopersicon esculentum* Miller) of the family Solanaceae is one of the most important vegetable crops grown in Sri Lanka. The yield potential of the currently available varieties is 20 to 30 mt/ha (HORDI, 2005) while the average yield of the country is 7.65 mt/ha. The world average yield is 26.56 mt/ha (FAO, 2005). Even though the demand for quality vegetables is increasing due to the increased demand by super markets and the

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tourist industry, the prices of many vegetables show a high fluctuation due to shortage of supply as well as gluts in supply (Central Bank of Sri Lanka, 2002).

The availability of quality seeds to farmers is an important factor in the production of tomatoes in order to raise their productivity and thereby increase their income (Central Bank of Sri Lanka, 2002). However, in Sri Lanka, the non availability of quality seeds and suitable varieties to meet the requirements of local households and the tourist industry are identified as the major constraints in the expansion of profitable tomato cultivation.

Tomato is used in curries, salads and sandwiches both by the local population as well as by the hotels in the tourist industry. Although variations in colour, flavour, size and shape of tomatoes exist in the present varieties, no single variety can satisfy the preferences for these characters of different target groups (Villareal, 1980; Weerasinghe *et al.*, 2004). Therefore, quality parameters have to be set for breeding fresh market tomatoes by investigating the preferences of different consumer groups.

Local hybrid seed production is also a priority area for research in Sri Lanka. Therefore, the urgent need at the moment in tomato breeding is to produce hybrid varieties with high yielding capacity combined with fruit quality traits required by the local market.

The objectives of this study were to assess the consumer preference for tomato, and to develop F_1 hybrids showing heterosis for yield and important fruit quality traits.

MATERIALS AND METHODS

(i) Survey on consumer preference

A survey on consumer preference was carried out using undergraduate students of the Faculty of Agriculture, University of Peradeniya, representing almost all the districts of Sri Lanka. A questionnaire was formatted to collect information from their homes on preferences for acidity, shape, size, pericarp thickness and colour of tomatoes for different purposes such as preparation of curries, salads, soups and sandwiches. Four hundred and twenty five filled questionnaires were statistically analyzed using Categorical Data Analysis.

(ii) Diallel genetic design to produce F_1 hybrids

A half diallel crossing programme (Haußer and Miranda, 1995; Banga and Bang, 1998; Kumar *et al.*, 2002) was carried out in the greenhouse of the Agricultural Biotechnology Centre, University of Peradeniya, using nine local and foreign tomato genotypes during Yala 2004 (Table 1). Seeds of Tomato varieties Tharindu (T002), Rashmi (T003), Thilini (T004), Rajitha (T005), T245 (T006), KWR (T007), Ravi (T008) and T146 (T009), were obtained from the Horticultural Crop Research and Development Institute, Gannoruwa, Peradeniya, Sri Lanka, and the foreign tomato variety Garden Delight (T001) was obtained from Serendib Horticulture (Pvt) Ltd. Kalagedihena, Sri Lanka.

Table 1. Half-diallel genetic design used in the study

	T001	T002	T003	T004	T005	T006	T007	T008	T009
T001	XXX	T012	T013	T014	T015	T016	T017	T018	T019
T002		XXX	T023	T024	T025	T026	T027	T028	T029
T003			XXX	T034	T035	T036	T037	T038	T039
T004				XXX	T045	T046	T047	T048	T049
T005					XXX	T056	T057	T058	T059
T006						XXX	T067	T068	T069
T007							XXX	T078	T079
T008								XXX	T089
T009									XXX

The seeds were first sown in plastic pots and 28-day old plants were transplanted into black polythene bags (15cm x 50cm) for emasculation and pollination purposes. All cultural practices and fertilizer applications were carried out according to the recommendations of the Department of Agriculture, Sri Lanka. Seeds of the F₁ hybrids were cleaned, sun dried and stored at 4°C (AVRDC, 2001; George, 2002).

Thirty six F₁ hybrids and nine parental varieties were grown in the research field of the Meewatura farm of the Faculty of Agriculture, University of Peradeniya for evaluation during *Yala* 2004. A 7x7 balanced lattice design with eight replicates and 56 blocks was used for field evaluation (Cochran and Cox, 1957).

During the field evaluation, the 36 F₁ hybrids and their parents were observed for any signs of tolerance/susceptibility to diseases, especially bacterial wilt.

Number of days to 50% flowering, fruit shape, average fruit weight, average yield per plant, brix value and acid percentage of fruit juice (Wilbur, 1983) were recorded (PGRC, 1999; 1995). Data analysis was done using SAS computer software package.

The analysis of variance was carried out according to the method of Griffing and the general combining ability (GCA) and specific combining ability (SCA) were calculated according to Hauller and Miranda (1995).

RESULTS AND DISCUSSION

The survey on consumer preference revealed that fruits with high acidity were preferred by 57% of the consumers for all household preparations, round to flat fruit shape by 45% and medium fruit size by 55% of consumers. For curries, 47% consumers preferred red-coloured fruits, while 39% preferred red fruits for sandwiches; dark red-coloured fruits were preferred by 49% consumers for salads and 32% for sandwiches respectively. Forty one per cent preferred fruits with medium pericarp thickness and 38% preferred thin pericarps (Table 2). Fruits with low acidity were preferred for salads by the tourist industry (Villareal, 1980).

Table 2. Household consumer preference for tomato

	Household Preparation	Curries %	Salads %	Sandwiches %	Soup %	Overall %
Taste	Acidic	80	53	58	36	57
	Sweet	4	27	10	33	18
Colour	Red	47	37	39		41
	Dark red	25	49	32		36
Pericarp thickness	Medium	40	45	43	36	41
	Thin	32	33	37	48	38
Size	Medium	54	56			55
	Large	22	28			25
Shape	Round	38	52			45
	Pear	16	13			15

According to the above results, the objective of the hybrid breeding programme was to select high yielding hybrids with hybrid vigour having medium sized, round to flat shaped, red-coloured, and acidic tomato types with medium pericarp thickness for home consumption and fruits with low acidity for tourist industry.

Field evaluation

Effects of GCA and SCA showed highly significant values (Table 3), indicating the importance of additive genetic variance in parental performance and the possibility of exploiting dominance gene effects in hybrids. GCA indicates the additive gene effects, while SCA indicates dominance and epistatic effects. GCA is useful for selecting parents with good combining abilities in breeding programmes, while SCA indicates the possibility of obtaining superior hybrids.

Table 3. Analysis of variance of yield

Source	DF	Type III SS	MS	F Value	Pr>F
Replicates	7	7030597.4046	1004371.0578	1.61	0.1335
Blocks (Rep)	48	41324690.0799	860931.0433	1.38	0.0633
Treatments	43	133573636.1177	3106363.6306	4.98	0.0001
GCA	8	18192176.749	2274022.094	3.65	0.0001
SCA	36	10470427.568	290845.210	0.470	0.0001
Error	225	140362208.3465	623832.0370		
Corrected Total	323	319134991.5895			

The parent T003 had high GCA for yield and average fruit weight, while the hybrid T029 had the highest SCA for the same two characters. The parent with the highest GCA for acid percentage in the fruit was T007, while T039 was the hybrid with the highest SCA value. The hybrid T023 had the lowest SCA value for fruit acidity (Table 4).

Table 4. Parents and F₁ hybrids having the highest GCA and SCA values

Character	GCA		SCA	
	Best Parents	Mean	Best Hybrid	Mean
Yield (g/plant)	T003	550.88	T029	2679.26
Av. Fruit Wt. (g)	T003	22.61	T029	69.85
Brix (High)	T001	1.16	T018	9.25
Brix (Low)	T006	-0.66	T024	0.04
Acid % (High)	T007	6.32	T039	38.75
Acid % (Low)	T001	-9.53	T023	-4.25
Days to 50% Flw	T001	-7.20	T034	5.69

Although these values will be useful for breeders as a general guideline in hybridization programmes, the parents with the highest GCA need not always produce the best hybrids (Weerasinghe *et al.*, 2004) and the hybrids with the highest SCA values may not necessarily show high heterosis.

Since analysis of variance indicated significant SCA values, the eight higher yielding hybrids and the parents were ranked as shown in Table 5. Their performances in other traits are also given. As seen very clearly, no single hybrid was superior for all the traits.

Eight hybrids gave higher yields than the best performing parent (T003) showing 'top' heterosis. The hybrids T034, T036 and T035 which produced large fruits also had high yields. T068 was the highest yielding hybrid with low brix and low acidity, while T025 ranked second in yield performance with low brix and high acidity. Table 6 shows the performance of hybrids that showed heterosis for yield.

Of the seven hybrids that showed heterobeltiosis, two hybrids T068 and T025 were the best. T068 showed 47.86% heterosis while T025 showed 76.28%. Although they were not superior for all the other traits as well, T068 was the highest yielding hybrid with low acidity and T025 was high yielding with high acidity. These two hybrids were therefore selected as new tomato hybrids for recommendation for commercial cultivars. T068 is recommended for the hotel/tourist industry while T025 for household use. Their yield and fruit quality characters are given in Table 7.

It is significant to note that the foreign variety T001 was extremely susceptible to bacterial wilt in the field. This applied to all the hybrids produced by using this variety as a parent. None of the local varieties or their hybrids showed any susceptibility to bacterial wilt in the field. The two selected hybrids showed total resistance to bacterial wilt in the field.

Table 5. Means and ranks of F₁ hybrids and parents for yield and fruit quality characters

Treatment	Average Yield/Plant		Average Fruit Weight		Brix		Acid %		Days to 50% Flower		Fruit Shape
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	
Hybrids											
T068	2669.2 ^{ab}	1	57.1	19	3.0	34	15.17	38	50	10	2
T025	2529.2 ^{abc}	2	44.5	29	2.9	39	25.41	14	50	8	2
T035	2509.1 ^{abc}	3	90.3	5	2.8	40	23.32	21	50	29	2
T036	2430.8 ^{abc}	4	98.0	3	3.1	29	22.79	22	51	23	2
T039	2377.8 ^{abcd}	5	67.4	15	2.9	38	33.44	4	51	25	3
T034	2377.1 ^{abcd}	6	98.9	2	4.0	14	19.64	29	51	33	3
T023	2352.4 ^{abcd}	7	56.7	20	2.9	36	17.52	34	52	38	2
T026	2233.4 ^{abcde}	8	58.5	18	2.6	43	29.70	6	50	6	2
Parents											
T003	2145.8 ^{abcdef}	12	100.1	1	3.3	26	24.17	20	52	35	3
T009	1846.4 ^{bcdefghi}	15	69.7	14	3.3	27	21.95	25	51	24	2
T007	1836.8 ^{cdefghi}	16	50.1	26	4.2	11	35.03	2	50	18	3
T006	1805.1 ^{cdefghi}	17	75.8	11	3.1	30	29.10	8	50	7	2
T004	1495.2 ^{defghi}	23	78.8	8	3.7	20	18.68	30	51	28	5
T005	1434.7 ^{defghi}	24	70.4	13	3.3	25	25.14	15	49	4	3
T002	1416.8 ^{defghi}	25	30.7	33	3.1	31	19.62	27	50	19	4
T008	1403.6 ^{defghi}	26	24.7	34	3.0	32	7.52	39	51	30	5

Means with same letters are not significantly different at $p=0.05$

Fruit shape: 2 = Slightly flattened, 3 = Round, 4 = High Round, 5 = Heart shap

Table 6. Yield performance of the hybrids based on heterobeltiosis

F ₁ Hybrid	Mean Yield (g/plant)	Better Parent	Mean Yield (g/plant)	Heterosis % (>BP)
T068	2669.2	T006	1805.1	47.86
T025	2529.2	T005	1434.7	76.28
T035	2509.1	T003	2145.8	16.93
T039	2377.8	T003	2145.8	10.81
T034	2377.1	T003	2145.8	10.78
T023	2352.4	T003	2145.8	9.63
T026	2233.4	T006	1805.1	20.60

Table 7. Performance of the selected hybrids

F ₁ Hybrid	Mean Yield (mt/ha)	Av. Fruit Wt.	Brix	Acid %	Days to 50% Flw	Fruit Shape	Colour
T068	69.7	57.1	3.0	15.17	50	Round to flat	Red
T025	66.1	44.5	2.9	25.41	50	Round to flat	Red
National Av. Yield	7.65						

CONCLUSIONS

The local population prefers acidic tomatoes for all preparations including curries, salads and sandwiches, whereas the hotels catering to tourists require tomatoes with low acid content. Since, GCA values need not necessarily indicate that parents with the highest GCA will produce the best hybrids, the diallel genetic design is by far the best and most popular breeding design to evaluate hybrid performance, as all possible crosses are made. As expected, the best performing hybrids were not from parents with the highest GCA values. This research also showed that the hybrid with the highest SCA did not show highest heterosis. However significant SCA indicated the possibility of producing superior hybrids. This was proven to be true.

Field testing for tolerance/resistance to bacterial wilt was shown to be very reliable. The foreign variety used and its hybrids were totally susceptible to wilt, whereas the local parents and their hybrids showed extreme tolerance/resistance. Based on consumer preference and heterosis, two superior hybrids T068 and T025 were selected for households and hotels respectively.

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