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EVALUATION OF SELECTED F_6 TOMATO LINES FOR EXTENDED SHELF LIFE

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SUMMARY

Shelf-life is an important trait in tomato, which determines marketability. *Solanum lycopersicum* alcobaca (*alc*) ripening mutant is able to prolong shelf-life. Twenty recombinant inbred lines were selected from F_5 lines. These F_5 lines were derived from intraspecific crosses involving alcobaca line L121 × Vaibhav. The objective of this study was to evaluate these recombinant inbred lines for quantitative traits such as plant height, fruit length, width, fruit yield, single fruit weight, fruit firmness, total soluble solids, fruit weight loss and fruit shelf-life in greenhouse as well as in field condition and to characterize them by SSR markers. Fruits were kept at room temperature (25 ^{0}C) and shelf-life was recorded from breaker stage to fully ripe stage. Some of the lines like 108 and 160 were outstanding for high shelf life and other quantitative traits like fruit yield and single fruit weight in greenhouse as well as in field condition. These results suggest that these lines could be grown by farmers in distant areas that have problems with storage facilities and transportation. Some of the genetic SSR polymorphic markers like TOM 184 and TOM 144 associated with the fruit shelf-life, it is identified by single marker analysis.

Key words: Shelf-life, fruit quality, ripening stages, *Solanum lycopersicum*

Key findings: Among 20 recombinant inbred lines, parents and check varieties, 108 and 160 were showing high shelf life. These lines could be tested in multi-location trials for releasing as variety.

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INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is an important vegetable crop grown world-wide. It contains 93.8 g water, 1.2 g protein, 4.8 g carbohydrate (including 0.7 g cellulose), 7 mg calcium 0.6 mg iron, 0.5 mg carotene, 0.06 mg thiamine, 0.04 mg riboflavin, 0.6 mg niacin and 23 mg vitamin C per 100 g. The energy value is 83KJ (or 20 kcal)/100 g (Nkansah *et al.*, 2003). Plant breeding applied to tomato (*Solanum lycopersicum*) has produced high-yielding varieties, though little attention has been paid to the fruit quality (Foolad, 2007). Fruit shelf-life (SL) is a ripening-associated trait influencing fresh tomato marketability (Schuelter *et al.*, 2002). It experiences great post-harvest losses by its natural perishability, precarious transportation and storage conditions. Post-harvest losses of tomato in Southeast Asia account for 13-20% of all the harvested tomatoes, In India, post-harvest losses during storage of tomato account for 30-35% of all harvested tomatoes (Kumar *et al.*, 2004). In developing countries, Kader (1992) estimated postharvest losses up to be 20-50%.

The control of fruit ripening is often achieved through early harvest, by controlling the postharvest storage atmosphere and by selection for slow or late ripening varieties. The approaches for extending Shelf- life could be done using mutants or introgression of high shelf-life genes into agronomically superior varieties. Several spontaneous ripening mutants were described in tomato, such as *rin* (*ripening inhibitor*), *nor* (*non-ripening*) and *alc* (*alcobaca*): (Giovannoni 2004). Kopeliovitch *et al.* (1979) have used several ripening gene mutants, such as *alcobaca* (*alc*), *non-ripening* (*nor*), never ripe, and *ripening inhibitor* (*rin*) to develop lines and cultivars with delayed ripening through disruption of the ethylene signaling pathway. The F_2 population developed from the best-performing F_1 hybrid (alc × 'Vaibhav') was used to map quantitative trait loci (QTLs) associated with shelf-life and fruit firmness using simple sequence repeat (SSR) markers (Yogendra and Gowda, 2013). In another study, 16 tomato RILs (which represent the F_7 generation by selfing) derived from an interspecific hybrid between Caimanta (*S. lycopersicum*) and LA722 (*S. pimpinellifolium*) by 5 cycles of antagonistic and divergent selection for fruit shelf-life and fruit weight. (Zorzoli *et al*., 2000); (Rodriguez *et al*., 2006); (Pratta *et al*., 2011) were characterized for a series of agronomic traits and molecular characterization by AFLP marker. DNA markers were used in tomato for QTL identification, diversity analysis and associations between molecular markers and many important agronomic quantitative traits. Grandillo and Tanksley (1996 a, b) using restriction fragment length polymorphism (RFLP) markers, microsatellites (simple sequence repeat, SSR) and random amplification of polymorphic DNA (RAPD), in a cross between *S. lycopersicum* and *S. pimpinellifolium*, detected significant associations between molecular markers and many important agronomic quantitative traits.

The main objective of this investigation was to evaluate 20 selected F_6 tomato lines for fruit keeping quality and other quantitative traits like fruit yield, fruit weight and to characterize them using molecular SSR markers. A mapping population of 210 F_2 individuals were developed by selfing the F_1 hybrids. The F_1 (alc × 'Vaibhav') cross was selected based on the mean performances of the hybrid and the parents. These 20 F_6 lines were derived from 210 F_2 mapping populations by repeated selfing derived by Yogendra and Gowda (2013). These 20 lines were selected from F_5 population based on the mean phenotypic performance (single plant yield, shelf-life, single fruit weight).

MATERIALS AND METHODS

Plant materials and development of F_6 lines

The material for this study consisted of F_6 tomato lines, derived from intraspecific cross between alcobac × Vaibhav, which were contrasting for shelf life. The parents of the F_6 lines were belong to same species lycopersicum but one of the parents, Alcobac carries recessive mutant allele, which is responsible for high shelf-life in tomato. The mutant *alcobaça (alc)* is one of several ripening mutant loci that inhibit normal tomato ripening; it has been studied by tomato scientists in Brazil, as well as in other countries (Leal and Mizubuti, 1975; Lobo, 1981; Lobo *et al*., 1984; Mutschler, 1984a, b; Mutschler *et al*., 1992; Vilas Boas *et al*., 1999). The F_1 was continuously selfed for 6 generations. These 20 lines are derived from 210 mapping population of Yogendra and Gowda (2013). The F_6 progenies were evaluated for different agronomic and fruit quality under both field and greenhouse conditions. Field assays conducted at the University of Agricultural Sciences, GKVK, Bangalore, which is located at an altitude of 899 m above mean sea level (MSL) and at 13° 00′ N latitude and 77° 35′ E longitude in Rabi season 2012. Seed of the 20 F_6 lines, parents and checks were germinated in seeding trays. The 30-day old seedlings were transplanted into the experimental plot with a spacing of 90 × 40 cm per standard cultural recommendations for the area in a randomized complete block design. Furthermore, these 20 lines, parents and check variety grown in 3 replications and each replication 5 plants were grown. In greenhouse, 5 plants of each genotype were grown for recording observations.

Phenotypic characterization

Traits evaluated

Phenotypic data was recorded for various quantitative and qualitative characters in F_6 progeny, parents (L121 and Vaibhav) and checks (Sankranti, pusaruby, Arka-alok, Arka-abha): plant height (cm), number of fruits per cluster, total number of fruits, fruit length (cm), fruit width (cm), single fruit weight (g), total yield per plant (g), Total soluble solids [TSS (%); was measured using a hand refractometer (Swastik Scientific Co., Mumbai, India)], fruit firmness [lbs/cm^2; measured using a fruit penetrometer (Wagner Instruments, New Delhi, India)] and fruit lycopene measured in mg/100 g (Ranganna, 1976).

Evaluation for shelf-life

Five tomato fruits at the breaker stage were harvested and stored at 25° ± 1 °C, and shelf-life in days was assessed at 10 days intervals. Shelf-life was measured as the number of days elapsed between the harvest of fruits at the breaker stage and the end of the consumption stage (first symptoms of deterioration and excessive softening).

Molecular characterization

Genomic DNA was extracted from the young leaves (30 days after transplanting) of F_6 progeny and parents using a modified cetyltrimethylammonium bromide method (Saghai-Maroof *et al.*, 1984). 30 SSR markers were used to assess the variation in F_6 progeny. These Polymorphic SSR markers were selected from earlier studies of Yogendra and Gowda (2013). These markers are linked to different traits like fruit shelf-life, fruit firmness and fruit yield. These polymorphic SSR markers were used for single-marker analysis (SMA).

Statistical analysis

The mean and variance for all the F_6 progeny RILs were computed for all the qualitative and quantitative traits mentioned above and were used for the statistical analysis. The mean values of 5 randomly selected plants were recorded for all the characters and were subjected to statistical analysis by Statistica software.

RESULTS AND DISCUSSION

Phenotypic characterization under field condition

Analysis of variance for plant growth, fruit quality and yield attributing traits in field condition

The mean sum of squares for plant growth, fruit quality and yield attributing traits is presented in the Table 3. Non-Significant differences were observed among the genotypes for all the characters except total number of fruits because all this lines were selected from F_5 performance so there is no much difference.

Mean performance of F_6 lines, tomato parental lines and check lines in field

The mean performance of tomato parental lines, F_6 lines and checks with respect to plant growth, fruit quality and yield attributing traits are presented in Table 1.

Mean performance of 20 F_6 tomato lines, Parents and commercial check varieties (Arka-Alok, Sankranti, Arka Abha and Pusa ruby) used in this study indicated that no single parental genotype was superior in respect of all the traits studied. The same lines were grown in field and greenhouse condition and observed that the mean plant height of F_6 RIL's was 75 cm in field, but in the greenhouse condition has recorded 126.3 cm. The plant height of F_6 lines in greenhouse condition is greater than field condition. In greenhouse condition the favorable condition is available for plant growth compared to field condition, so the plant length observed was greater in greenhouse condition.

The mean of fruit per cluster in field condition is (5 fruits/cluster) while, in greenhouse condition (4 fruits/cluster). The mean fruit length in field condition is (4.5 cm) while, in greenhouse condition was 3.6 cm. The mean of fruit width in field condition is (4.5 cm) while, in greenhouse condition the mean of fruit width was 3.4 cm.

Table 1. Mean values of 20 F_6 lines, parents (L121 and Vaibhav) and check under field condition.

Genotype	PH (cm)	FPC	FL (cm)	FW (cm)	FF (lbs/cm^2)	FLO	TSS (^{0}brix)	FLY (mg/100g)	FKQ (days)	FY (g)	TNF	SFW (g)
L121	114.2	3	3.3	4.9	3.12	3	3.3	3.77	37	1444	24	75
Vaibhav	99.2	5	4.8	3.9	2.61	2	2.2	0.47	21	1805	26	56
21-2	91.5	3	4.3	6.5	8.95	5	4.2	0.26	51	572	8	72
21-4	95.5	3	4.0	6.0	6.50	5	4.1	0.28	48	595	11	83
51-3	74.5	6	3.8	3.0	3.10	3	2.7	0.27	44	639	9	98
84--2	67	6	5.4	4.0	3.10	2	3.0	0.64	37	420	3	149
103-2	59.5	6	5.4	5.9	4.10	3	4.7	0.5	63	438	8	71
108-2	69	6	4.5	4.0	2.50	3	4.5	0.71	43	579	13	92
124-4	61.5	5	4.6	4.4	3.60	3	4.0	2.91	74	531	8	103
126-1	68.5	4	6.0	5.0	4.45	3	3.4	1.29	60	585	12	61
130-1	69.5	5	3.9	4.1	1.90	4	2.0	0.62	19	185	7	53
146-3	70	6	5.7	4.0	2.30	2	5.0	1.56	63	1516	29	54
151-3	77.5	6	3.3	2.8	3.00	3	4.9	0.56	50	701	15	57
160-2	66.5	4	5.0	5.5	3.75	3	5.7	0.78	66	906	14	106
160-5	67	4	5.0	5.5	5.00	4	4.5	0.40	61	960	17	105
167-2	74	6	3.7	5.2	2.35	3	4.5	0.64	63	1096	21	62
169-1	67	4	5.4	4.9	3.00	3	3.8	1.24	39	1069	23	65
169-2	60	4	5.0	5.5	3.00	3	4.0	1.20	57	1050	34	70
174-2	71.5	6	4.4	4.6	4.48	4	3.3	0.20	43	872	12	86
194-1	66	5	4.4	5.3	2.20	4	3.1	0.45	55	972	9	147
219-3	86.5	6	4.4	4.0	7.75	2	3.6	0.50	36	514	10	62
Arka alok	97.5	2	3.0	5.0	2.95	3	4.0	0.31	21	645	14	64
Sankranthi	115	6	3.0	3.0	3.00	3	3.0	0.50	38	1217	33	60
Arka abha	118	3	4.0	5.0	3.00	4	4.0	0.30	19	550	16	58
Pusa ruby	96.5	5	2.5	3.5	3.10	2	2.5	1.77	21	900	31	38

PH= Plant height (cm), FW= Fruit width (cm), FLO= Fruit locules, FPC= Fruits per cluster, SFW= Single fruit weight (g), TSS= Total soluble solids (0 brix), TNF= Total number of fruits, FY= Fruit yield (g), FLY= Fruit lycopene content (mg/100g), FL= Fruit length (cm), FF= Fruit firmness (lbs/cm^2), FKQ= Fruit keeping quality (days)

The mean of total fruit yield of F_6 lines in greenhouse condition was 1190 g while, in field condition the mean of F_6 line is 821 g.

From the above results, we can conclude that in field condition the fruit length, width, fruit per cluster and number of fruits is greater compared to greenhouse while, plant height total fruit yield and single fruit weight is more in greenhouse condition compared to field condition

We observed mean of fruit keeping quality of F_6 lines in greenhouse condition was 48 days while; in field condition it was also 48 days. It indicates in both the condition the fruit keeping quality was similar. All the F_6 lines fruit shelf life is higher compared to parent Alcobac except RILs 130-2. The Vaibhav fruit shelf life is 21 days in field condition but among the RILs the lowest fruit shelf life is 130-1 (19 days). The highest fruit shelf life recorded in 124-4 (74 days) and 160-2 (66 days). These results suggest that 124-4, 160-2 and 160-6 could be grown by farmers in even distant areas that have problems with storage facilities, transportation and bad road network since it possesses properties which can prolong its shelf life.

The mean of lycopene content in field condition was 0.887 mg/100 ml at red stages of fruits. The maximum lycopene observed in parent L121 (3.77 mg/100 ml) but in 124-1 (2.91 mg/100 ml). Total soluble solids (TSS) and dry matter are known to increase fruit quality (Loboda and Chuprikova, 1999), which fits well with consumers demand for high quality produce (El-Saeid *et al.*, 1996). The highest Total soluble solids (TSS) content was observed in RILs 160-2 (5.7^0 brix), 146-3(5.0^0 brix) and 151-3(4.9^0 brix). The parent Alcobac was observed TSS 3.37^0 brix and Vaibhav 7^0 brix.

Phenotypic characterization under greenhouse condition

Analysis of variance for plant growth, fruit quality and yield attributing traits in greenhouse condition

The mean sum of squares for plant growth, fruit quality and yield attributing traits is presented in the Table 4. Significant differences were observed among the genotypes for all the characters except Fruit firmness, fruits per cluster, Fruit keeping quality and Total soluble solids.

Mean performance of F_6 Lines and parental lines under greenhouse

The mean performance of F_6 tomato progeny, parental lines and checks with respect to plant growth, fruit quality and yield attributing traits are presented in Table 2. The fruit keeping quality of the parent Alcobac was observed to be 40 days and Vaibhav 26 days while the mean of F_6 progeny was 48 days which is more than both of the parents (Figure 1). The ripening gene mutants were significantly different from the Indian cultivars with respect to fruit quality traits. With respect to fruit shelf-life, the mean number of 44 days in *alc* was significantly higher than that in the other ripening gene mutants *rin* (38 days) and *nor* (38.5 days). Indian cultivars 'Sankranti' and 'Vaibhav' had a mean number of 19 and 18.50 days, respectively, which was higher than that of 'Pusaruby' 14.5 days (Yogendra and Gowda, 2013). However mean keeping quality of F_6 lines varied from 32 days (RILs194-1) to 83 days (RILs 160-5). This 20 F_6 lines developed from 220 F_2 Lines, obtained between Alcobac × Vaibhav. The shelf life of the fruits obtained from the selected F_2 breeding line varied from 5 to 106 days with a mean value of 53.56 days (Yogendra and Gowda, 2013). Similar study by de Vicente and Tanksley (1993), he observed that some of the F_7 lines had higher and lower shelf life compared to parental lines. According to de Vicente and Tanksley (1993), transgression could be due to heterosis, which should not be probable in this case owing to the high level of homozygosity expected in the RILs, or to the presence in both parents of alleles increasing and decreasing the trait value that recombine during the selfing and selection cycles, which appears to be more probable in this case. We have selected 20 advanced F_5 lines on the basis of high shelf-life, single fruit weight, single plant fruit yield and fruit shape because all above 4 characters is useful for market purpose so the fruit shelf-life range of this F_6 lines were 32 to 83 days.

The fruit firmness was determined at fully red stage with the help of fruit penetrometer. In the first stages the fruit firmness in parent Alcobac was (4.6 lbs/cm^2) and Vaibhav was (6.9 lbs/cm^2). The mean fruit firmness was (6.0 lbs/cm^2) which are nearer to parent Vaibhav. On the other hand, the maximum fruit firmness was observed in RILs 146-3 (10.23 lbs/cm^2). In another study related to fruit firmness, *nor* recorded high values (8.44 lbs/cm^2) compared with those of the mutant genes *rin* (7.88 lbs/cm^2) and *alc* (7.56 lbs/cm^2). However, Indian cultivars 'Sankranti' (5.0 lbs/cm^2), 'Vaibhav' (4.38 lbs/cm^2), and 'Pusaruby' (3.94 lbs/ cm^2) recorded low fruit firmness values. The range of fruit firmness is 0.55-10.65 lbs/cm^2 in the F_2 lines, which is derived from Alcobac × Vaibhav (Yogendra and Gowda, 2013).

The 2 biochemical characters studied here were total soluble solids and fruit lycopene content. The total soluble solids of parent Alcobac was 3.2%, and Vaibhav was 2.17%, while the mean of F_6 lines is 3.6% which is nearer to parent Alcobac. The maximum TSS content was in the line 151-3 (6.10%). The lycopene content was observed in parent Alcobac (1.26 mg/100 g) and Vaibhav (0.25 mg/100 g). The highest lycopene content observed in RILs 151-3 (1.44 mg/100 g).

The total yield per plant observed in the parent Alcobac (1490 g) and Vaibhav (1730 g), the mean of F_6 lines were 1190 g which is lesser than both of the parents. Among the F_6 lines, the highest fruit yield has observed in the line No.21-2 (1560 g) which is nearer to parent Alcobac and lesser than parent Vaibhav. It indicates that, none of the F_6 Lines were superior to parents in terms of total fruit yield. Pratta *et. al.* (2011); De Vicente and Tanksley (1993) observed that none of the RILs had weight similar to parent Caimanta and mean of the F_7 lines were 10.82 g, which is much lesser than Caimanta (110.23 g).

Table 2. Mean value of 20 tomato F_6 lines, parents and check varieties under greenhouse condition.

Genotype	PH (cm)	FPC	FL (cm)	FW (cm)	FF (lbs/cm^2)	FLO	TSS (^{0}brix)	FLY (mg/100g)	FKQ (days)	FY (g)	TNF	SFW (g)
L121	121.6	4	3.13	4.00	4.6	3	3.20	1.26	40	1490	34	57.0
Vaibhav	120.0	6	4.23	3.10	6.9	2	2.17	0.25	26	1730	57	51.4
21-2	165.0	4	3.33	3.36	5.6	3	2.83	0.32	60	1560	35	75.5
21-4	114.6	5	4.35	5.06	6.6	3	3.13	0.24	58	1210	25	82.0
51-3	93.3	5	4.1	3.26	6.1	3	5.0	0.79	58	1260	30	51.1
84-2	106.5	4	3.9	2.9	6.1	5	4.50	0.78	55	891	17	76.1
103-2	136.0	4	3.53	3.4	5.3	2	3.20	0.63	50	615	19	43.6
108-2	149.3	6	3.5	3.33	7.5	2	5.33	0.67	65	921	33	38.6
124-4	137.3	3	3.2	3.66	5.5	4	3.60	0.25	67	902	26	58.2
126-1	96.6	6	4.1	3.07	7.0	2	2.93	0.37	62	1062	45	35.6
130-1	132.3	3	4	3.00	8.1	2	3.67	0.34	43	601	18	47
146-3	132.6	4	4.66	2.70	10.2	2	3.33	0.19	35	1650	36	62.1
151-3	148.6	5	4.06	3.17	8.6	2	6.10	1.44	58	1249	48	48.6
160-2	115.0	4	4	3.73	6.5	5	2.97	0.39	39	1356	25	71.2
160-5	136.0	3	2.9	3.10	5.4	2	3.77	0.42	83	1350	23	81.4
167-2	118.0	5	3.53	3.13	7.0	2	2.50	0.75	46	1250	43	52.1
169-1	100.0	4	4.15	2.75	5.5	2	3.77	0.81	65	1265	31	56.6
169-2	93.66	5	4.1	3.43	6.0	2	4.07	0.71	55	884	19	55
174-2	136.0	5	3.7	3.25	6.0	2	4.0	0.51	58	846	17	58.0
194-1	165.0	5	2.53	3.67	2.8	2	4.50	0.55	32	1060	25	68.3
219-3	118.6	5	4.33	3.10	8.3	3	3.57	0.70	40	1360	33	70.3
Arka-alok	102.3	2	3	5.00	3.4	3	4.80	0.35	23	847	17	60.0
Sankranthi	148.0	6	4.33	3.33	3.7	3	3.07	0.43	42	2610	71	60.0
Arkabha	137.6	3	2.83	4.17	3.4	4	4.07	0.31	26	607	18	54.6
Pusaruby	132.0	5	2.43	4.10	3.6	2	2.33	0.80	22	1263	35	34.4

PH= Plant height (cm), FW= Fruit width (cm), FLO= Fruit locules, FPC= Fruits per cluster, SFW= Single fruit weight (g), TSS= Total soluble solids (0 brix), TNF= Total number of fruits, FY= Fruit yield (g), FLY= Fruit lycopene content (mg/100g), FL= Fruit length (cm), FF= Fruit firmness (lbs/cm2), FKQ= Fruit keeping quality (days)

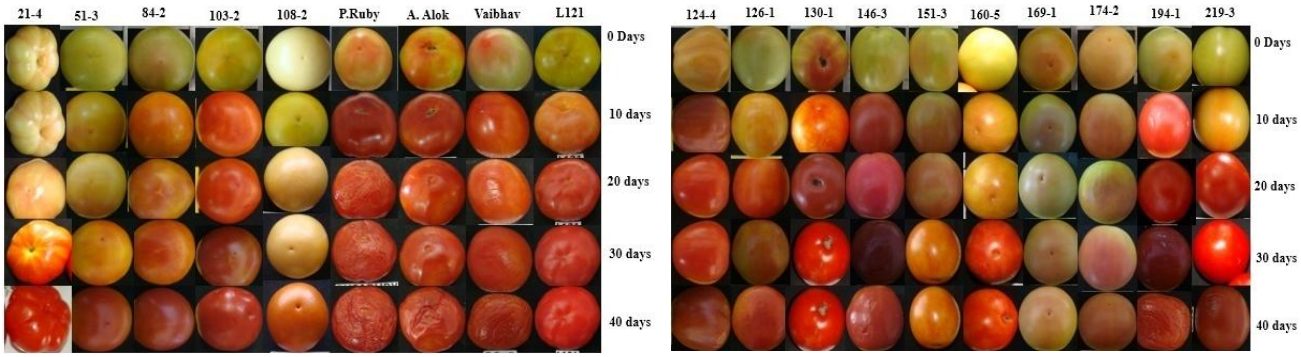

Figure 1. Photograph of selected F_6 RILs with parents L121, Vaibhav and checks for high shelf life up to 40th days.

Table 3. Analysis of variance for plant growth, fruit quality and yield attributing traits in parents and F_6 RILS under field condition.

Sl. no.	Source of variation	df	PH	FPC	FL	FW	FF	FLO	TSS	FLY	FKQ	FY	TNF	SFW
1	Replication	2	5.85	0.01	0.001	0.014	0.178	0.72	0.12	0.07	6.11	2089.7	34.79*	14.72
2	Treatments	24	982.02	5.11	2.47	2.91	8.89	2.47	2.51	2.43	807.53	438809.97	236.18	2299.70
3	Error	48	4.42	0.03	0.11	0.13	0.24	0.24	0.09	0.08	20.58	30002.90	11.05	206.69
	SEm±		1.21	0.1	0.19	0.21	0.28	0.28	0.17	0.16	2.59	100.0	1.83	8.29
	CD at 1%		4.60	0.37	0.74	0.81	1.08	1.10	0.67	0.63	9.83	379.33	6.94	31.46
	CD at 5%		3.45	0.28	0.55	0.61	0.81	0.80	0.50	0.47	7.37	284.35	5.20	23.58

Table 4. Analysis of variance for plant growth, fruit quality and yield attributing traits in parents and RILS in F_6 generation under greenhouse condition.

Sl.no.	Source of variation	df	PH	FPC	FL	FW	FF	FLO	TSS	FLY	FKQ	FY	TNF	SFW
1	Treatments	24	1284.87**	3.27	1.13**	1.09**	10.53	1.79**	2.74	1.03*	711.9	0.56**	553.04**	524.59**
2	Error	50	265.66	0.37	0.49	0.40	6.08	0.34	0.62	0.54	165.0	0.12	87.86	126.04
	SEm±		9.41	0.35	0.40	0.37	1.42	0.34	0.46	0.43	7.42	0.20	5.41	6.48
	CD at 1%		35.64	1.34	1.53	1.38	5.40	1.29	1.73	1.61	28.09	0.75	20.49	24.55
	CD at 5%		26.73	1.00	1.15	1.04	4.05	0.97	1.30	1.21	21.07	0.56	15.37	18.41

* Significant at 5% ** Significant at 1%

PH= Plant height (cm), FW= Fruit width (cm), FLO= Fruit locules, FPC= Fruits per cluster, SFW= Single fruit weight (g), TSS= Total soluble solids (0 brix), TNF= Total number of fruits, FY= Fruit yield (g), FLY= Fruit lycopene content (mg/100g), FL= Fruit length (cm), FF= Fruit firmness (lbs/cm^2), FKQ= Fruit keeping quality (days)

Comparative mean performance of fruit shelf life of tomato in greenhouse and field

In field conditions, the highest fruit shelf life was observed in the line number 124-4 (74 days). In greenhouse condition the highest fruit shelf life was observed in line number 160-5 (83 days). Most of the lines like 108-2, 124-4 and 160-5 observed high shelf life in both greenhouse as well as field condition. Some of the line like 169-1 observed fruit shelf life of 55 days in greenhouse condition compared to field condition (39 days). The fruit shelf life ranged of 20 F_6 tomato lines more or less same in both greenhouse and field condition (Figure 2).

Molecular characterization

Shelf-life is quantitatively inherited, and improving such a trait requires molecular marker-based strategies. Although the tomato is completely sequenced, its genomic resources have not been fully exploited. There are 3 methods for detecting quantitative trait loci (QTLs) are single-marker analysis, simple interval mapping and composite interval mapping (Liu 1998). The association of markers for fruit quality traits was detected using SMA. The results of single marker analysis revealed that the markers were associated with fruit keeping quality, fruit total soluble solids, plant height and fruit lycopene content traits. A total of 2 markers were associated with the fruit lycopene content and another 2 markers TOM 184 and TOM 144 were associated with fruit keeping quality. A single marker is linked to plant height and total soluble solids. The SSR marker LEat006 (0.005) is linked to fruit total soluble solids at both 1% and 5% significance level. The SSR markers used are given in Table 5 and Figure 3. Yogendra and Gowda (2013) also identified Lega 5, LEaat 3, LEga 7, LEaat 7

and SSR 45 for fruit firmness. The associated markers can be putatively used in crop improvement programs through MAS approaches. Single marker analysis determines only preliminary QTL information so further research is required for identification of true position of QTLs through simple interval mapping and composite interval mapping.

Table 5. Marker linked to plant growth, fruit quality and yield traits in 20 F_6 lines of the cross L121 × Vaibhav through single marker analysis.

Trait	Marker	P value	F calculated
Fruit keeping quality	TOM 184	0.024*	5.98
	TOM 144	0.012*	7.43
Total soluble solids	LEtat002	0.005**	9.37
Plant height	LEaat003	0.019*	6.36
Fruit lycopene content	TOM 184	0.05*	4.40
	TOM 144	0.05*	4.60

* Significant at 5%, ** Significant at 1%

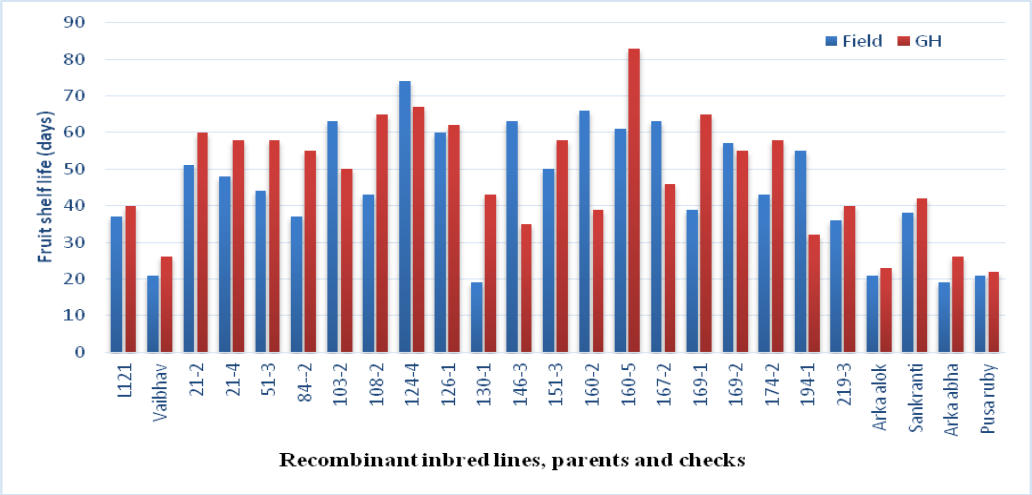

Figure 2. Comparison of fruit shelf life under greenhouse and field condition.

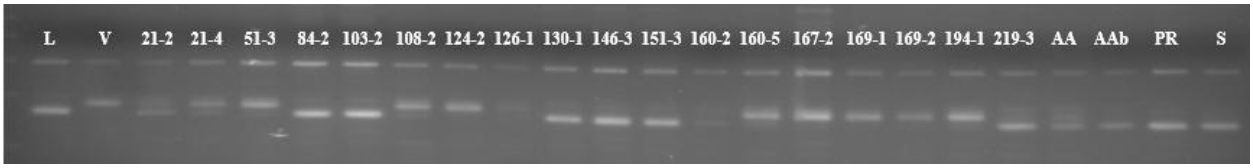

Figure 3. Agarose gel profile of SSR marker showing the amplification of parents, 20 RILs and checks.

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