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Mean performance of parents and their crosses in tomato (*Solanum lycopersicum* L.) for qualitative traits

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Abstract
The present study was carried out with twelve parents and sixty-six crosses of tomato during the *Kharif* 2021 at Vegetable Experimental Field, Sher Kashmir University of Agricultural Science and Technology-Kashmir, Shalimar, Srinagar. The experiment was conducted in Randomized Block Design with three replications. Observations were recorded on five qualitative traits viz., Lycopene content (mg/100 g), Total carotenoids (mg/100 g), TSS (°Brix), Titratable acidity (%) and Ascorbic acid (mg/100 g). Among the parents maximum lycopene content was observed in SKAU-T-914113(8.23 mg/100 g); total carotenoids SKAU-T-914113 (5.69 mg/100 g); TSS SKAU-T-01 (5.00 (°B); Titratable acidity SKAU-T-02 (1.27%) and ascorbic acid SKAU-T-02 (61.13 mg/100 g). Among crosses maximum lycopene content was observed in SKAU-T-914103 x SKAU-T-914108(9.72 mg/100 g); total carotenoids SKAU-T-620438 x SKAU-T-165690 (5.92 mg/100 g); TSS SKAU-T-165690 x SKAU-T-02 (6.33 °B); Titratable acidity SKAU-T-620438 x SKAU-T-914108 (1.57%) and ascorbic acid SKAU-T-02 x SKAU-T-914091 (64.27 mg/100 g). Overall analysis showed that parents SKAU-T-02 and SKAU-T-914103; crosses SKAU-T-914108 x SKAU-T-164334 and SKAU-T-914103 x SKAU-T-620438 showed maximum contribution towards qualitative traits. Also, positive correlation was found between total carotenoids and lycopene content.

Keywords: Correlation, mean, qualitative traits

Introduction
Tomato (*Solanum lycopersicum* L.) is one of the economically important and widely grown vegetable in *Solanaceae* family because of its high consumer preference, wider adaptability, high yielding potential and suitability for variety of uses in fresh as well as processed food industries. All species of tomato are native to Western South America. The total global area under tomato is 50,30545 hectares with the global production of 18,0766329 tonnes (Anonymous, 2020a) [3]. In India it is grown on an area of 812 thousand hectares with a production of 20,573 thousand metric tonnes (Anonymous, 2020b) [4]. In J&K, it is grown on an area of 2.28 thousand hectares with a production of 52.96 thousand metric tonnes (Anonymous, 2018) [2].

Tomatoes are an excellent source of minerals, vitamins (Akinfasoy *et al*., 2011) [1] and antioxidants viz., lycopene and beta-carotene which prevent cancer and other heart diseases (Kaur *et al*., 2013) [10]. The quality of tomato genotypes plays an important role in deciding the suitability of the genotype for processing purpose, fresh market or table purpose. The antioxidant content of tomato mostly depends on genetic and environmental factors (Martinez *et al*., 2002) [11]. The present investigation was undertaken to identify suitable parents and their crosses capable of giving higher quality performance.

Materials and Methods
The present experiment was conducted with seventy-eight tomato genotypes (twelve parents and sixty-six crosses) in randomized block design with three replications during the *Kharif* 2021 at Vegetable Experimental Field, Sher Kashmir University of Agricultural Science and Technology-Kashmir, Shalimar, Srinagar. A spacing of 60 cm × 45 cm was adopted and all the standard practices and plant protection measures were timely adopted to raise the crop successfully. Observations were recorded on five randomly selected competitive plants per replication for each entry on five qualitative traits viz., Lycopene content (mg/100 g), Total carotenoids (mg/100 g), TSS (°Brix), Titratable acidity (%) and Ascorbic acid (mg/100 g).

Lycopene content (mg/100 g) was estimated by method (Gordon and Diane (2007) [8]; Godwin *et al.* (2015) [7] and Suwanaruang (2016) [16] and total carotenoids (mg/100 g) was determined

according to the method of Harbone J.B (1973) [9]. A drop of tomato juice from each reference was put on the prism of hand refractometer and reading on per cent scale was noted for total soluble solids estimation. Titratable acidity (%) by Ranganna (1986) [14] and ascorbic acid by Thimmaiah (1999) [17]. The mean data for all observations were pooled and statistically analyzed following standard procedure as suggested by the Panse and Sukhatme (1978) [12]

Results and Discussion

The analysis of variance for qualitative traits of parents and their crosses of tomato under study are presented in Table 1 and 2. The mean sum of squares for parents and their crosses was found to be significant for all characters viz., Lycopene content (mg/100 g), Total carotenoids (mg/100 g), TSS (°Brix), Titratable acidity (%) and Ascorbic acid (mg/100 g). The trait wise mean performance of parents and their crosses is presented in Table 3 and 4.

The lycopene content in parents of tomato ranged from 1.78 mg to 8.23 mg per 100 g. SKAU-T-914113 (8.23 mg) recorded significantly superior lycopene content followed by SKAU-T-914103 (7.51 mg). Lowest lycopene content was found in SKAU-T-164334 (1.78 mg) per 100 g. The lycopene content in crosses of tomato ranged from 1.27 mg to 9.72 mg per 100 g. SKAU-T-914103 x SKAU-T-914108 (9.72 mg) recorded significantly superior lycopene content and lowest lycopene content was found in SKAU-T-914103 x SKAU-T-145057 (1.27 mg) per 100 g. These findings are in agreement with the results of Cheema *et al*., 2013 [5] and Dufera *et al*., 2013 [6].

Total carotenoids in parents ranged from 1.16 mg to 5.69 mg per 100 g. SKAU-T-914113 (5.69 mg) recorded significantly superior total carotenoids followed by SKAU-T-145057 (527 mg). Lowest total carotenoids was found in SKAU-T-914106 (1.16 mg) per 100 g. Total carotenoids in crosses ranged from 2.14 mg to 5.92 mg per 100 g. SKAU-T-620438 x SKAU-T-165690 (5.92 mg) recorded significantly superior total carotenoids and lowest total carotenoids was found in SKAU-T-914103 x SKAU-T-145057 (2.14 mg) per 100 g. These findings are in agreement with the results of Cheema *et al*., 2013 [5].

Total soluble solids content of tomato fruits is essential for processing purpose. High total soluble solids are desirable to higher yield of processed products. Among the twelve parents tested, the total soluble solids ranged from 4.27 to 5.00 °Brix. SKAU-T-01 (5.00 °Brix) and SKAU-T-620438(5.00 °Brix) recorded significantly higher amount of total soluble solids. Minimum total soluble solids was observed in SKAU-T-02 (4.27 °Brix). Among the sixty-six crosses tested, the total soluble solids ranged from 3.07 to 6.33 °Brix. SKAU-T-165690 x SKAU-T-02 (6.33 °B) recorded significantly higher amount of total soluble solids. Minimum total soluble solids was observed in SKAU-T-914106 x SKAU-T-145057 (3.07 °Brix). These findings are in support to the findings of Raju *et al*., (2014) [13].

Titratable acidity in parents ranged from 0.27% to 1.27%. SKAU-T-02 (1.27%) recorded significantly higher titratable acidity followed by SKAU-T-914106 (1.23%). Lowest titratable acidity was recorded in SKAU-T-164334 (0.27%). Titratable acidity in crosses ranged from 0.33% to 1.57%. SKAU-T-620438 x SKAU-T-914108 (1.57%) recorded significantly higher titratable acidity and lowest titratable acidity was recorded in SKAU-T-620438 x SKAU-T-164334 (0.33%).

Ascorbic acid content ranged from 37.87 mg to 61.13 mg per 100 g. Highest ascorbic acid content was found in SKAU-T-02 (61.13 mg) followed by SKAU-T-914091 (55.00 mg). Lowest ascorbic acid content was observed in SKAU-T-164334 (37.87 mg) per 100 g. Ascorbic acid content in crosses of tomato ranged from 15.80 mg to 64.27 mg per 100 g. Highest ascorbic acid content was found in SKAU-T-02 x SKAU-T-914091 (64.27 mg) and lowest ascorbic acid content was observed in SKAU-T-914113 x SKAU-T-145057 (15.80 mg) per 100 g. These findings are in agreement with the results of Cheema *et al*., 2013 [5] and Reddy *et al*., 2013 [15].

The genotypes with the highest contents of lycopene and highest antioxidant activity represents a valuable genotype not only for improving the status of dietary antioxidants in our diet but also for increasing nutritional value through germplasm enhancement programs.

Table 1: ANNOVA for five quality attributes in tomato parents.

Character	Mean sum of squares		
	Replications (df=2)	Parents (df=11)	Error (df=22)
Lycopene Content	0.200	13.352	0.020
Total Carotenoids	0.043	7.881	0.002
Total soluble solids	1.221	0.184	0.014
Titratable Acidity	0.007	0.296	0.002
Ascorbic acid	3.552	128.580	0.068

Table 2: ANNOVA for five quality attributes in tomato crosses.

Character	Mean sum of squares		
	Replications (df=2)	Crosses (df=65)	Error (df=130)
Lycopene Content	0.792	23.853	0.019
Total Carotenoids	0.175	4.593	0.000
Total soluble solids	7.017	1.336	0.017
Titratable Acidity	0.135	0.232	0.000
Ascorbic acid	22.149	427.980	0.130

Table 3: Mean performance of parents for quality traits in Tomato (*Solanum lycopersicum* L.)

Parents	Lycopene content	Total Carotenoids	TSS	Titratable acidity	Ascorbic acid
SKAU-T-01	5.31	3.11	5.00	0.87	47.27
SKAU-T-914103	7.51	4.14	4.40	0.90	51.20
SKAU-T-914113	8.23	5.69	4.93	0.87	43.87
SKAU-T-620438	3.21	3.28	5.00	0.27	38.87
SKAU-T-165690	6.29	4.87	4.67	0.93	47.47
SKAU-T-914108	7.18	5.07	4.53	1.07	45.27
SKAU-T-02	4.68	3.87	4.27	1.27	61.13
SKAU-T-914106	1.85	1.16	4.40	1.23	49.87
SKAU-T-617047	5.91	3.29	4.47	0.52	52.87
SKAU-T-914091	6.18	4.49	4.67	0.39	55.00
SKAU-T-145057	4.38	5.27	4.73	0.73	46.87
SKAU-T-164334	1.78	2.87	4.80	0.59	37.87
S.E(M)	0.082	0.022	0.068	0.028	0.150
C.V	2.731	1.497	2.527	6.052	0.540
C.D(%)	0.242	0.066	0.200	0.083	0.443

Table 4: Mean performance of crosses for quality traits in Tomato (*Solanum lycopersicum* L.)

Crosses	Lycopene content	Total Carotenoids	TSS	Titratable acidity	Ascorbic acid
SKAU-T-01 x SKAU-T-914103	5.93	2.88	4.00	0.47	36.80
SKAU-T-01 x SKAU-T-914113	4.68	2.57	4.80	0.59	35.80
SKAU-T-01 x SKAU-T-620438	4.36	3.47	4.47	0.68	51.20
SKAU-T-01 x SKAU-T-165690	6.24	4.29	4.27	0.67	43.20
SKAU-T-01 x SKAU-T-914108	5.54	3.97	5.13	0.59	40.87
SKAU-T-01 x SKAU-T-02	5.89	3.89	4.07	0.83	33.93
SKAU-T-01 x SKAU-T-914106	4.67	4.73	3.53	0.78	37.00
SKAU-T-01 x SKAU-T-617047	8.43	5.67	4.80	1.09	50.87
SKAU-T-01 x SKAU-T-914091	7.81	4.32	6.00	0.61	26.73
SKAU-T-01 x SKAU-T-145057	8.31	5.67	4.80	0.94	38.73
SKAU-T-01 x SKAU-T-164334	6.89	4.61	4.53	0.64	18.80
SKAU-T-914103 x SKAU-T-914113	1.95	2.53	5.00	0.89	45.20
SKAU-T-914103 x SKAU-T-620438	7.97	5.73	5.87	1.37	61.93
SKAU-T-914103 x SKAU-T-165690	8.92	5.85	4.73	0.61	53.27
SKAU-T-914103 x SKAU-T-914108	9.72	5.29	5.00	1.00	22.80
SKAU-T-914103 x SKAU-T-02	8.39	4.69	4.60	0.89	50.40
SKAU-T-914103 x SKAU-T-914106	7.98	5.05	4.80	1.17	45.73
SKAU-T-914103 x SKAU-T-617047	7.83	4.58	4.73	0.69	47.20
SKAU-T-914103 x SKAU-T-914091	6.59	4.69	4.53	0.89	50.80
SKAU-T-914103 x SKAU-T-145057	1.27	2.14	5.53	0.69	27.13
SKAU-T-914103 x SKAU-T-164334	6.34	4.91	4.47	1.09	60.67
SKAU-T-914113 x SKAU-T-620438	9.68	5.59	4.73	0.93	31.87
SKAU-T-914113 x SKAU-T-165690	1.34	2.27	4.73	1.29	45.40
SKAU-T-914113 x SKAU-T-914108	9.26	5.27	4.87	1.50	50.87
SKAU-T-914113 x SKAU-T-02	5.33	2.87	6.27	1.11	25.00
SKAU-T-914113 x SKAU-T-914106	2.93	3.19	5.20	0.57	29.07
SKAU-T-914113 x SKAU-T-617047	9.68	4.70	4.47	0.78	31.20
SKAU-T-914113 x SKAU-T-914091	8.69	2.23	4.80	0.99	28.93
SKAU-T-914113 x SKAU-T-145057	9.52	4.21	5.80	0.85	15.80
SKAU-T-914113 x SKAU-T-164334	1.35	2.71	5.27	0.63	52.80
SKAU-T-620438 x SKAU-T-165690	7.34	5.92	4.00	0.95	37.73
SKAU-T-620438 x SKAU-T-914108	8.21	3.32	5.43	1.57	40.13
SKAU-T-620438 x SKAU-T-02	1.84	2.58	4.87	0.91	29.27
SKAU-T-620438 x SKAU-T-914106	7.32	3.86	4.47	1.13	56.47
SKAU-T-620438 x SKAU-T-617047	6.66	2.34	5.27	1.17	41.87
SKAU-T-620438 x SKAU-T-914091	8.49	3.31	4.87	0.63	23.40
SKAU-T-620438 x SKAU-T-145057	8.22	4.69	4.67	0.79	30.87
SKAU-T-620438 x SKAU-T-164334	7.30	3.27	5.63	0.33	20.87
SKAU-T-165690 x SKAU-T-914108	9.28	4.07	5.87	1.06	40.80
SKAU-T-165690 x SKAU-T-02	2.21	2.50	6.33	1.01	62.53
SKAU-T-165690 x SKAU-T-914106	2.40	2.68	4.47	1.25	52.93
SKAU-T-165690 x SKAU-T-617047	6.85	3.29	4.27	0.67	42.87
SKAU-T-165690 x SKAU-T-914091	8.67	4.32	4.71	0.78	23.00
SKAU-T-165690 x SKAU-T-145057	9.19	3.17	4.67	1.55	52.27

SKAU-T-165690 x SKAU-T-164334	8.35	3.29	4.80	0.91	39.00
SKAU-T-914108 x SKAU-T-02	8.73	4.34	5.00	0.57	54.67
SKAU-T-914108 x SKAU-T-914106	7.51	5.10	4.53	0.94	45.80
SKAU-T-914108 x SKAU-T-617047	8.94	4.29	5.00	1.29	60.13
SKAU-T-914108 x SKAU-T-914091	9.20	5.62	5.73	1.13	63.93
SKAU-T-914108 x SKAU-T-145057	8.13	3.11	5.20	0.89	42.80
SKAU-T-914108 x SKAU-T-164334	9.12	5.61	6.07	1.30	59.20
SKAU-T-02 x SKAU-T-914106	8.19	5.29	4.67	1.13	58.73
SKAU-T-02 x SKAU-T-617047	7.64	4.27	5.20	1.00	40.87

Crosses	Lycopene content	Total Carotenoids	TSS	Titratable acidity	Ascorbic acid
SKAU-T-02 x SKAU-T-914091	7.47	3.73	5.87	1.07	64.27
SKAU-T-02 x SKAU-T-145057	8.71	4.27	4.67	0.58	31.87
SKAU-T-02 x SKAU-T-164334	8.16	3.27	5.07	0.48	28.93
SKAU-T-914106 x SKAU-T-617047	9.13	5.67	4.53	1.30	35.00
SKAU-T-914106 x SKAU-T-914091	6.27	2.34	4.93	0.69	30.07
SKAU-T-914106 x SKAU-T-145057	4.67	3.38	3.07	0.93	46.93
SKAU-T-914106 x SKAU-T-164334	1.67	2.69	4.80	1.49	40.00
SKAU-T-617047 x SKAU-T-914091	1.37	2.73	5.00	0.69	50.93
SKAU-T-617047 x SKAU-T-145057	5.24	4.94	4.87	0.91	37.13
SKAU-T-617047 x SKAU-T-164334	1.84	3.69	5.10	1.52	47.20
SKAU-T-914091 x SKAU-T-145057	1.84	2.89	5.27	0.99	41.47
SKAU-T-914091 x SKAU-T-164334	5.71	4.27	5.20	0.63	52.87
SKAU-T-145057 x SKAU-T-164334	1.75	2.28	6.00	0.91	49.27
S.E(M)	0.080	0.011	0.076	0.012	0.208
C.V	2.254	0.534	2.704	2.429	0.910
C.D(%)	0.223	0.031	0.214	0.035	0.582

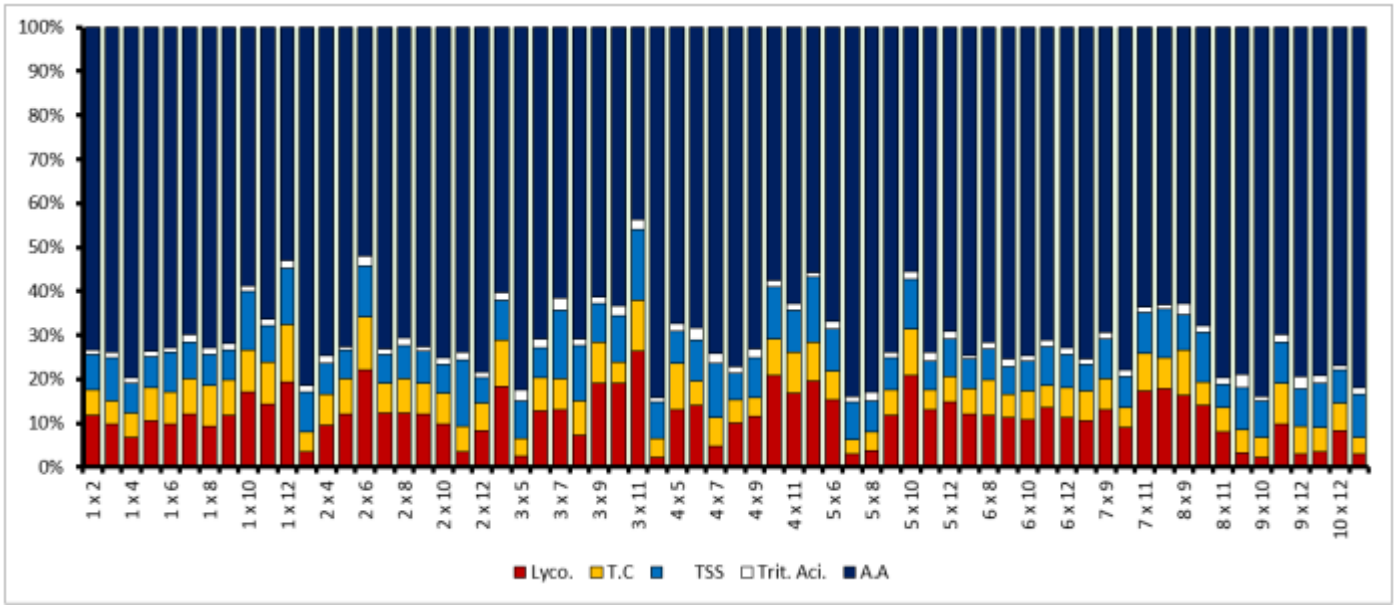

Fig 1: Percentage of five quality traits of tomato crosses.

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