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Research Article

Assessment of combining ability in tomato genotypes (*Solanum lycopersicum* L.) for quality traits

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Abstract

Combining ability effects (GCA and SCA) were estimated using seventeen parents including fourteen females and three males of tomato (*Solanum lycopersicum* L.) and their hybrids developed through line × tester method. The results indicated that the lines, HUB46 for fruit firmness and number of locules, HUB36 for fruit pH (-ve direction) and shelf life, HUB3 for equatorial diameter and TSS, HUB45 for pericarp thickness and polar diameter whereas, among testers Arka Vikas for fruit firmness, pericarp thickness, fruit pH (+ve direction), polar diameter exhibited significant gca effects and considered as good general combiners. Cross combinations HUB3×DMT-2 for fruit firmness and pericarp thickness, HUB10×DMT-2 for number of locules, HUB47× Arka Vikas for fruit pH (+ve direction), HUB14× Arka Vikas for TSS, shelf life and polar diameter, HUB4×PKM-1 for equatorial diameter exhibited significant positive sca effects and regarded as good specific combiners.

Keywords GCA, line, SCA, tester, tomato

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Introduction

Tomato (*Solanum lycopersicum* L.) is widely cultivated crop due to its adaptability, high yielding potential and enormous demand by the consumers. It is self-pollinated crop belonging to the family Solanaceae. But some extents of cross pollination do occur [1]. It has diploid chromosome number of 2n = 2x= 24. The cultivated tomato is originated from the Peru. Tomato is rich in vitamins and minerals and hence regarded as powerful antioxidant [2]. Tomato ranks second after potato but tops the list of processed vegetables in the world. It is most popular warm season and day- neutral vegetable which is globally grown either fresh market or processing and considered as a high value crop [3].

The fruit is rich in lycopene, which may have beneficial health effects and considered as the world′s most powerful natural antioxidant. Therefore, it is regarded as the most important ‘protective foods’ for its special nutritive value. Market price for the produce is driven by the quality. Quality includes both external as well as nutritional quality. As the tomato is popular and most demanding crop, awareness regarding quality is known by the consumers. Hence tomato breeding strategies not only used for increasing fruit yield but also for the quality attributes. The line × tester analysis provides information for selection of superior parents and crosses with their GCA and SCA effects respectively. The term GCA is used to designate the average performance of a line in hybrid combination, whereas, SCA is used to designate those cases in which certain combinations do selectively better or worse than would be expected on the basis of average performance of the lines involved [4].

GCA indicate the occurrence of additive gene action while SCA as non-additive type of gene action. Therefore, assessment of combining ability plays a vital role for selecting best combining parent, which on crossing would produce desirable hybrids. With this objective, the present research was done to estimate combining ability effects by utilizing line × tester mating design in tomato.

Table 1. Details of lines, tester and check used in experiment

SN.	Genotypes	Entry	Salient features
Lines			
1	AT 3	HUB 2	Semi determinate and round fruits with high pulp to juice ratio and has good firmness. Tolerant to leaf curl virus and early blight diseases.
2	Punjab chuhhara	HUB 3	Plants are determinate, Pear shaped fruits with less sour and firm.
3	Punjab Rata	HUB 4	Plants are determinate and dwarf, fruits oval round.
4	ATL 01 -19	HUB 6	Fruits are round and are medium in size.
5	Mahabaleshwar 2	HUB 7	Fruits are juicy, round and slightly acidic.
6	SL 120	HUB 9	Fruits are juicy, round and slightly acidic in nature.
7	G 10	HUB 10	Plants are determinate, Fruits are round, medium in size with good color.
8	DVRT 1	HUB 13	Fruits are spherical with 108g weight Resistance to ToLCV
9	DVRT 2	HUB 14	Determinate plant habit with large and spherical fruits.
10	Junagadh Ruby	HUB 15	Medium size fruits, flat round in shape with attractive red colour.
11	EC 686544	HUB 36	Fruits are medium in size with red color.
12	ToLCVRes 2-2016	HUB 45	Fruits are jointed with long blunt shape.
13	ToLCVRes 2-2014	HUB 46	Fruits are jointed with flat round. Early flowering with good pericarp thickness.
14	Tod var-10-2016	HUB 47	Round fruits with good pericarp thickness.
Tester			
1	PKM 1	T 1	Dark red color fruits with green shoulder, fruits are flat round in shape.
2	DMT 2	T 2	Oblate fruits, acidic with thin pericarp.
3	Arka Vikas	T 3	Oblate type with light green shoulder on fruits, suitable for both irrigated and rainfed condition.
Check			
1	Arka Rakshak	C	Square round fruits, triple disease resistance.

Methodology

The present investigations were conducted at College of Horticulture, Bagalkot. During *rabi* 2020 at department of Vegetable science. The experimental materials consist of 60 treatments comprising 42 hybrids developed by L×T design by using 14 lines and three testers (Table 1) were evaluated in randomized complete block design with two replications along with check (Arka Rakshak). Spacing followed was 90 x 75 cm and total plot size was about 1094m^2. Each genotype in each replication is comprised of a plot constituting of 15 plants per treatment.

Characters studied

Observations were noted on five randomly selected plants for eight quality traits i.e. fruit firmness, number of locules, pericarp thickness, TSS, fruit pH, shelf life, polar diameter, equatorial diameter and data was subjected for analysis.

Fruit firmness

Three fruits are selected randomly for analysis. Fruit pressure tester was used to determine firmness of the fruit. Ripe fruits at full pink stage were selected and pressure was applied with plunger and reading was recorded as N at surface area.

Number of locules

Five fruits are selected randomly from each genotype. Selected fruits were cut in horizontal manner and numbers of locules were counted.

Table 2. Analysis of variance (mean square) for combining ability, variance component and their ratios for quality parameters in tomato

SN.	Source of variation	df	Fruit firmness	No. of locules	Pericarp thickness	TSS	Fruit pH	Shelf life	Polar diameter	Equatorial diameter
1	Replications	1	389.191*	2.495**	0.481	0.085*	0.005	0.847	0.007	0.019
2	Lines	13	1106.726**	1.777**	1.997**	0.988**	0.162**	1939.901**	0.815 **	0.716 **
3	Testers	2	1401.113**	0.632	1.517**	0.499**	0.128*	18.667**	0.365 **	0.217 **
4	Lines vs. Testers	1	757.205**	7.973**	0.166	0.102*	0.004	8975.070**	1.186 **	1.277 **
6	Error	58	63.865	0.267	0.218	0.01	0.026	3.278	0.009	0.008
Variance components										
1	σ2 GCA		88.2478	0.0999	0.1246	0.137	0.0048	129.325	0.1246	0.137
2	σ2 SCA		402.462	0.121	0.2039	0.1571	-0.0005	315.042	0.2039	0.1571
3	σ2 GCA/ σ2 SCA		0.3049	0.6229	0.5501	0.6355	1.0502	0.4509	0.5501	0.6355

* - Significant at 5% and **- Significant at 1%

Table 3. Estimates of general combining ability effects for quality traits in tomato

Parents Lines	Fruit firmness	No. of locules	Pericarp thickness	TSS	Fruit pH	Shelf life	Polar diameter	Equatorial diameter
HUB2	-37.029 **	-0.391	-0.655 **	0.160 **	-0.007	-23.405 **	-0.759 **	-0.650 **
HUB3	-8.346 *	1.009 **	-0.456 *	0.489 **	0.176 *	-15.738 **	-0.02	0.497 **
HUB4	2.654	-0.408	-0.588 **	0.910 **	0.101	-25.571 **	-0.525 **	-0.428 **
HUB6	-19.271 **	0.252	-0.655 **	0.452 **	0.193 **	-28.571 **	-0.229 **	-0.01
HUB7	6.321	-0.158	0.757 **	0.117 *	-0.032	-17.238 **	-0.215 **	-0.222 **
HUB9	10.804 **	-0.025	0.542 **	0.052	0.051	-22.905 **	-0.202 **	-0.112 **
HUB10	-8.096 *	0.659 **	0.442 *	-0.105	-0.232 **	-22.905 **	-0.094 *	0.215 **
HUB13	19.054 **	1.475 **	0.630 **	-0.538 **	-0.032	-5.905 **	0.036	0.433 **
HUB14	23.313 **	-0.208	0.535 **	0.429 **	0.035	12.095 **	-0.257 **	0.05
HUB15	4.021	0.809 **	0.765 **	-0.398 **	0.076	19.929 **	0.598 **	1.023 **
HUB36	-25.154 **	-0.158	-1.251 **	-0.545 **	-0.265 **	34.095 **	-0.292 **	0.058
HUB45	-15.079 **	-1.341 **	0.827 **	-0.256 **	-0.032	33.262 **	1.998 **	-0.962 **
HUB46	25.904 **	-0.875 **	-0.3	-0.268 **	-0.140 *	22.262 **	-0.099 *	-0.103 **
HUB47	20.904 **	-0.641 **	-0.596 **	-0.500 **	0.11	40.595 **	0.058	0.210 **
S.Em. ±	3.2626	0.2111	0.1907	0.0574	0.0665	0.7392	0.0392	0.0371
C.D. @ 5%	6.5889	0.4263	0.385	0.116	0.1342	1.4929	0.0791	0.0749
C.D. @ 1%	8.8127	0.5702	0.515	0.1551	0.1795	1.9967	0.1058	0.1002
Testers								
T 1	-5.538 **	0.126	-0.076	0.383 **	-0.054	-2.071 **	-0.203 **	-0.025
T 2	0.045	-0.094	-0.200 *	-0.311 **	-0.011	4.536 **	0.047 *	0.061 **
T 3	5.493 **	-0.033	0.276 **	-0.072 **	0.065 *	-2.464 **	0.155 **	-0.037 *
S. Em. ±	1.5103	0.0977	0.088	0.0266	0.0308	0.3422	0.0181	0.0172
C.D. @ 5%	3.0501	0.1973	0.1782	0.0537	0.0621	0.6911	0.0366	0.0347
C.D. @ 1%	4.0795	0.264	0.2384	0.0718	0.0831	0.9243	0.049	0.0464

* - Significant at 5% and **- Significant at 1%, T1-PKM-1, T2- DMT-2, T3- Arka Vikas

Pericarp thickness
Five randomly selected fruits of second harvest in each genotype are selected. Pericarp thickness was measured by cutting the fruits transversely with the help of digital vernier calliper in millimetres and mean values were recorded.

Total soluble solids
Five fruits are selected randomly from each genotype. Fruit juice was extracted and a drop of juice was placed on prism of Refractometer and the reading was observed. Further, the mean values were recorded and expressed in Brix.

Fruit pH
The Fruit pH was recorded with the help of digital pH meter. The pH meter was placed in the container consisting of tomato fruit juice and pH meter reading was recorded. Tomatoes for processing purpose pH should be less than 4.4 and for culinary purpose high fruit pH is preferred. Hence fruit pH in both directions have been discussed.

Shelf life
A sample of randomly selected nine fruits per treatment were harvested at pink stage and placed on shelves in a ventilated room. Later keen observation has been done at 4 days interval. The fruits were kept until shrinkage was noticed and later number of days were counted and recorded.

Polar diameter
Polar diameter of five selected fruits was recorded with vernier calliper and average was recorded and expressed in centimetres.

Equatorial diameter
Selected five fruits were used to measure diameter with the help of vernier calliper and average was recorded and expressed in centimetres.

Results and Discussion

ANOVA of combining ability effects for different traits under study are presented in Table 2. The results illustrated that the estimated σ2sca showed higher values than those of σ2gca for most of the traits under study and hence these traits have shown non-additive gene effects predominantly. The estimates of general combining ability variances (σ2 gca), exhibited higher values than those of specific combining variances (σ2 sca) for fruit pH. Whereas for variance due to SCA (σ2 sca) was noticed high for most of the traits *viz*; fruit firmness, pericarp thickness, number of locules, shelf life, TSS, polar diameter, equatorial diameter.

From the estimation of combining abilities, the results in Table 3 and Table 4 illustrated that for fruit firmness HUB46 (25.904), HUB14 (23.313), HUB47 (20.904) and Arka Vikas (5.493) exhibited highest significant positive gca effects. Number of locules and pericarp thickness also determines the fruit firmness which is very helpful for the extended shelf life during storage as well as in transit. For number of locules negative values of gca are preferred [4]. In general, lesser the number of locules more firm fruit and for this trait parents viz., HUB45 (-1.341), HUB46 (-0.875) and HUB47 (-0.641) showed maximum negative significant gca effects. For pericarp thickness HUB45 (0.827), HUB15 (0.765), HUB7 (0.757) and tester Arka Vikas (0.276) exhibited highest gca effects. Total soluble solids (TSS) are very important trait and for these parents viz., HUB4 (0.910), HUB3 (0.489), HUB6 (0.452) and PKM-1 (0.383) showed maximum significant positive gca effects. For fruit pH both positive and negative values are considered as desirable depending on use for different purpose. High pH is desirable for culinary purpose and less pH are required for processing type of tomatoes. Hence pH values in the both directions have been studied and

Table 4. Estimates of specific combining ability effects for quality traits in Tomato

Crosses	Fruit firmness	No. of locules	Pericarp thickness	TSS	Fruit pH	Shelf life	Polar diameter	Equatorial diameter
HUB2×T1	16.929 **	-0.043	0.124	-0.635 **	-0.038	6.905 **	-0.082	-0.052
HUB2×T2	1.497	0.427	-0.327	0.629 **	-0.03	-9.202 **	-0.137 *	-0.238 **
HUB2×T3	-18.426 **	-0.384	0.203	0.006	0.068	2.298	0.220 **	0.290 **
HUB3×T1	-32.554 **	-0.593	-0.344	0.107	-0.021	-4.762 **	-0.196 **	-0.239 **
HUB3×T2	28.564 **	0.127	0.905 **	-0.659 **	0.061	2.631 *	-0.055	0.115
HUB3×T3	3.99	0.466	-0.561	0.552 **	-0.04	2.131	0.251 **	0.123
HUB4×T1	-16.104 **	-0.026	-0.052	0.15	0.054	3.071 *	0.239 **	0.456 **
HUB4×T2	0.014	0.294	0.371	0.144	0.011	-7.036 **	-0.025	-0.240 **
HUB4×T3	16.090 **	-0.267	-0.319	-0.294 **	-0.065	3.964 **	-0.214 **	-0.217 **
HUB6×T1	30.821 **	0.594	-1.121 **	0.209 *	0.038	4.071 **	0.313 **	-0.302 **
HUB6×T2	-25.461 **	-0.516	0.248	-0.088	0.02	-4.536 **	0.153 *	0.017
HUB6×T3	-5.36	-0.077	0.873 *	-0.121	-0.057	0.464	-0.465 **	0.285 **
HUB7×T1	-14.446 *	-0.026	-0.383	0.434 **	0.087	-3.262 *	0.299 **	-0.055
HUB7×T2	5.447	-0.206	-0.084	-0.308 **	-0.03	-13.369 **	-0.035	0.044
HUB7×T3	8.999	0.233	0.466	-0.126	-0.057	16.631 **	-0.264 **	0.012
HUB9×T1	2.621	0.29	0.708 *	-0.261 *	-0.121	0.405	-0.034	0.135 *
HUB9×T2	4.564	-0.24	-0.609	0.367 **	0.086	-6.202 **	0.031	-0.356 **
HUB9×T3	-7.185	-0.05	-0.099	-0.106	0.035	5.798 **	0.003	0.222 **
HUB10×T1	13.321 *	0.257	0.177	0.365 **	0.088	4.405 **	0.488 **	-0.007
HUB10×T2	-29.936 **	-0.773 *	0.231	-0.541 **	-0.18	-7.702 **	-0.147 *	-0.278 **
HUB10×T3	16.615 **	0.516	-0.409	0.176	0.093	3.298 *	-0.340 **	0.285 **
HUB13×T1	-26.729 **	0.840 *	0.614	-0.076	0.012	-18.095 **	-0.263 **	0.195 **
HUB13×T2	22.789 **	-0.59	0.218	0.072	-0.055	40.298 **	0.018	-0.096
HUB13×T3	3.94	-0.25	-0.832 *	0.004	0.043	-22.202 **	0.245 **	-0.098
HUB14×T1	-9.587	-0.376	0.209	-0.203 *	0.046	-33.095 **	0.341 **	-0.182 **
HUB14×T2	-2.945	0.494	-0.792 *	-0.259 *	-0.022	9.798 **	-0.554 **	-0.183 **
HUB14×T3	12.532 *	-0.117	0.583	0.462 **	-0.024	23.298 **	0.213 **	0.365 **
HUB15×T1	19.754 **	-0.293	0.054	-0.441 **	0.129	1.571	0.001	-0.215 **
HUB15×T2	14.622 *	0.927 *	0.078	0.167	0.061	-1.536	0.246 **	0.304 **
HUB15×T3	-34.376 **	-0.634	-0.132	0.274 **	-0.19	-0.036	-0.247 **	-0.088
HUB36×T1	-2.596	-0.326	-0.049	0.255 *	0.071	9.905 **	0.206 **	0.325 **
HUB36×T2	-13.078 *	0.194	-0.375	0.284 **	-0.047	-9.702 **	0.046	0.289 **
HUB36×T3	15.674 **	0.133	0.424	-0.539 **	-0.024	-0.202	-0.252 **	-0.613 **
HUB45×T1	11.529 *	0.107	-0.267	-0.208 *	-0.012	-2.262	-1.034 **	0.220 **
HUB45×T2	6.372	-0.373	-0.029	0.351 **	0.045	-3.869 **	0.401 **	0.084
HUB45×T3	-17.901 **	0.266	0.296	-0.143	-0.032	6.131 **	0.633 **	-0.303 **
HUB46×T1	-0.554	0.14	0.174	-0.121	-0.154	24.238 **	0.078	-0.089
HUB46×T2	7.039	-0.14	0.208	0.197	0.153	18.631 **	-0.032	0.225 **
HUB46×T3	-6.485	0	-0.382	-0.076	0.001	-42.869 **	-0.045	-0.137 *
HUB47×T1	7.596	-0.543	0.156	0.425 **	-0.179	6.905 **	-0.354 **	-0.187 **
HUB47×T2	-19.486 **	0.377	-0.045	-0.356 **	-0.072	-8.202 **	0.091	0.312 **
HUB47×T3	11.890 *	0.166	-0.111	-0.069	0.251 *	1.298	0.263 **	-0.125
S.Em. ±	5.6509	0.3656	0.3302	0.0995	0.1151	1.2803	0.0678	0.0642
CD @ 5%	11.4123	0.7384	0.6669	0.2009	0.2325	2.5857	0.137	0.1298
CD @ 1%	15.264	0.9876	0.892	0.2687	0.3109	3.4584	0.1832	0.1735

* - Significant at 5% and **- Significant at 1%, T1-PKM-1, T2- DMT-2, T3- Arka Vikas

discussed here, two lines viz., HUB6 (0.193), HUB3 (0.176) and tester Arka Vikas (0.065) showed significant positive gca effects whereas three lines HUB36 (-0.265), HUB10 (-0.232) and HUB46 (-0.140) revealed significant negative gca effects for fruit pH. Lines, HUB47 (40.595), HUB36 (34.095), HUB45 (33.262) and DMT-2 (4.536) observed significant positive gca effect for shelf life. For polar diameter, lines HUB45 (1.998), HUB15 (0.598) and testers DMT-2 (0.047), Arka Vikas (0.155) revealed significant positive gca effects. Whereas for equatorial diameter, HUB15 (1.023), HUB3 (0.497), HUB13 (0.433), HUB10 (0.215), HUB47 (0.210) and tester DMT-2 (0.061) showed highest positive gca values and are said to be good general combiners.

An overall appraisal of GCA effects revealed that among lines HUB46 for fruit firmness and number of locules, HUB36 for fruit pH (-ve direction) and shelf life, HUB3 for fruit pH (+ve direction), equatorial diameter and TSS, HUB45 for pericarp thickness and polar diameter whereas, among testers Arka Vikas for fruit firmness, pericarp thickness, fruit pH (+ve direction), polar diameter and DMT-2 for shelf life and equatorial diameter exhibited significant gca effects and considered as good general combiners. Similar work was reported by several researchers [3, 5-9].

The superior hybrid combination which has depicted the maximum significant SCA effects in positive direction indicates that the particular cross combination is good to produce hybrid of high performance. Highest positive values of SCA effects, for which means that the parents of this particular cross can combine well to produce a hybrid with a high general performance. For fruit firmness crosses, HUB6×PKM-1 (30.821), HUB3×DMT-2 (28.564) and HUB13×DMT-2 (22.789) revealed as specific combiners for fruit firmness. For number of locules sca effects in negative direction are desirable and only one hybrid HUB10×DMT-2 (-0.773) noticed significant negative sca effects. For pericarp thickness out of 42 cross combinations, only three crosses viz., HUB3×PKM-1 (0.905), HUB6×Arka Vikas (0.873) and HUB9×PKM-1 (0.708) exhibited significant highest positive sca effects. For TSS hybrids, HUB2×PKM-1 (0.629), HUB3×Arka Vikas (0.552) and HUB14×Arka Vikas (0.462) had maximum significant positive sca effects. HUB47×Arka Vikas (0.251) showed significant positive sca effect for fruit pH. For shelf-life crosses viz., HUB13×DMT-2 (40.298), HUB46×PKM-1 (24.238) and HUB14×Arka Vikas (23.298) noticed maximum significant sca effects. For polar and equatorial diameter crosses, HUB45×Arka Vikas (0.633), HUB10×PKM-1 (0.488), HUB45×DMT-2 (0.401) and HUB4×PKM-1 (0.456), HUB14×Arka Vikas (0.365), HUB36×PKM-1 (0.325) revealed significant maximum sca effects respectively. The overall summary of SCA effects revealed that cross combinations HUB3×DMT-2 for fruit firmness and pericarp thickness, HUB10×DMT-2 for number of locules, HUB47× Arka Vikas for fruit pH (+ve direction), HUB14× Arka Vikas for TSS, shelf life and polar diameter, HUB4×PKM-1 for equatorial diameter exhibited significant positive sca effects and regarded as good specific combiners. Similar work was reported by several researchers.

Conclusion

The results illustrated that presence of non-additive gene effects exist for most of the traits which encouraged for heterosis breeding. From the present study it can be said that lines, HUB46 for fruit firmness and number of locules, HUB36 for fruit pH (-ve direction) and shelf life, HUB3 for equatorial diameter and TSS, HUB45 for pericarp thickness and polar diameter whereas, among testers Arka Vikas for fruit firmness, pericarp thickness, fruit pH (+ve direction), polar diameter exhibited significant gca effects and considered as good general combiners. This outcome of research finding can be successfully utilized for the selection of elite parent to be used in the hybridization programme. These parents with maximum combining ability effects had favourable genes in high concentration for several traits and can be utilized very well in crossing programmes. The results revealed that the cross combinations HUB3×DMT-2 for fruit firmness and pericarp thickness, HUB10×DMT-2 for number of locules, HUB47× Arka Vikas for fruit pH (+ve direction), HUB14× Arka Vikas for TSS, shelf life and polar diameter, HUB4×PKM-1 for equatorial diameter exhibited significant positive sca effects and regarded as good specific combiners for hybrid development.

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