Indian J. Genet., **64**(2): 125-129 (2004)

Genetical analysis for quantitative and qualitative traits in tomato (*Lycopersicon èsculentum*) under open and protected environment

R. P. Bhatt[1], R. S. Adhekari[2], V. R. Biswas and Narendra Kumar

Defence Agricultural Research Laboratory, Pithoragarh 262 501

(Received: January 2004; Revised: August 2004; Accepted: August 2004)

Abastract

Twelve divergent lines of tomato and their 66F_1 hybrids were studied to investigate the extent of heterosis and general and specific combining ability effects for five quantitative and three qualitative traits under open and polyhouse environments in mid hill conditions of Central Himalayas. The additive as well as non-additive gene effects played significant role in the inheritance of the yield and other traits. Higher proportion of *gca* × environment interaction variance as compared to *sca* × environment estimates were recorded. Additive genetic variances were more sensitive than non-genetic variances to changing environment. Parent Azad T-2 and DARL-64 were adjudged best general combiner for yield per plant, while parent EC 386037 and Sel-7 were the good general combiner for all the quality traits studied. Significant heterosis was found for yield per plant under open and polyhouse environment respectively over mid and top parent and commercial control revealed that there was a great scope of realizing higher yield in tomato through heterosis breeding. The cross combinations EC 386032 × BL-342, Mechin × EC 386023 and Azad T-2 × Hawaii-7998, Azad T-2 × DARL-64, were identified as the best heterotic combinations under open and protected environments respectively.

Key words: Tomato, additive and non-additive gene action, open and protected environment, heterosis

Introduction

Tomato is an important vegetable crop of hill farmers and now a days grown round the year under open and protected conditions. Earlier study [1, 2] conducted under open codnitions in mid hills suggests a great scope of improvement through heterosis breeding. In recent past, exploitation of heterosis and selection of parents on the basis of combining ability have been important breeding approaches in crop improvement. Information about genetical analysis and genotype × environment interaction for quantitative as well as quality traits under open conditions in mid hills are very meager but no such information is available for protected environment. Cultivation of tomato crop in protected environment has been a very important technological as well as economical advancement and now a days gaining momentum, especially for winter cultivation in mid and high altitude areas. Hence, the present investigation was undertaken to study and generate information about genotype × environment interaction, nature and magnitude of heterosis and general and specific combining ability effects for five quantitative and three qualitative traits in a diallel fashion using 12 diverse parents of tomato under open and protected environments for mid and higher altitude areas.

Materials and methods

A set of 12 × 12 diallel cross of tomato without reciprocals along with their parents *viz.*, Azad T-2 (1), Machin (2), DARL-64 (3), Hawaii-7998 (4), EC 386032 (5), EC 386037 (6), BL-342 (7), Sel-7 (8), EC 386019 (9), EC 386023 (10), Mani Thoiba (11), Mani Leima (12) and the commercial control ARTH-3 were evaluated in a randomized block design with three replications. The study was conducted at Defence Agricultural Research Laboratory, Pithoragarh during 2001-2003 under two environments i.e. open and polyhouse conditions. Recommended package of practices were adopted during the cropping period. Observations were recorded on 5 randomly-selected plants per entry for yield per plant, fruits per plant, fruit weight, early maturity and plant height. For ascorbic acid determination red ripened fruits were selected randomly, extracted with metaphosphoric acid and estimation was done by 2, 6, dichloro-phenol indophenol, titration method [3]. Total soluble solids of fruits were recorded with a hand refractometer calibrated in 0 brix and values were corrected at 20°C. Lycopene was estimated by the method of Ranganna [4], Combining ability analysis as per method 2, model 1 of Griffing [5] as further extended by Singh [6] for pooled analysis and heterosis as per Allard [7].

[1]Part of Ph.D. thesis submitted to Kumaon University, Nainital; [2]Present address: Govt. P. G. College, Pithoragarh 262 501

Results and discussion

Data presented in Table 1, predicted highly significant effects (mean squares) of genotypes for all eight traits in both the environments. Further, the analysis of variance for combining ability for the pooled data over two environments (Table 2) revealed that the estimates of the mean squares due to GCA and SCA were highly significant for all the characters, indicating the importance of both additive as well as non additive components of genetic variance for controlling these traits.

conclusion. Further, the combining ability means squares, in general, were larger than those due to combining ability × environment interaction. The genotype × environment interaction was also found highly significant for all the traits studied. Significant interaction for genotypes and genotype × environment interaction for fruit weight, number of fruits per plant, yield per plant and for early maturity was observed by other workers [8].

Table 1. Analysis of variance (MS) for eight traits over two environment (open and polyhouse) in 12 × 12 diallel in tomato

Source	Environment	D. F	Yield per plant (kg)	Fruits per plant (no.)	Fruit weight (gm)	Maturity (days)	Plant height (cm)	Ascorbic acid (mg/100g)	Lycopene (mg/100g)	TSS (%)
Replication	Open	2	0.039	13.81	2.14	14.18	111.01	0.13	0.048	0.072
	Protected	2	0.025	83.88	1.59*	11.27**	153.32	0.23*	0.13**	0.140
Genotypes	Open	77	0.56**	1903.10**	472.02**	36.47**	2936.56**	93.71**	5.03**	1.48**
	Protected	77	1.24**	4592.02**	539.67**	40.49**	5185.54**	97.45**	12.31**	2.33**
Error	Open	154	0.01	24.67	0.73	0.66	10.32	0.17	0.047	0.008
	Protected	154	0.03	62.28	0.39	0.90	46.71	0.05	0.017	0.011
Environment		1	52.4**	65924.08**	4.01**	1429.75**	219440.0**	1.09**	92.96**	19.06**
Replication × Environment		2	0.009	33.18	0.086	0.70	1.87	0.11	3.97	0.03
Genotypes		77	1.14**	5596.63**	932.14**	62.98**	6226.22**	147.09**	14.00**	2.58**
Environment × Genotype		77	0.66**	898.49**	79.55**	13.99**	1395.85**	44.07**	3.11**	1.23**
Error		154	0.027	0.431	0.56	0.78	28.51	0.031	0.03	0.010

*, **Significant at 5% and 1% respectively

Table 2. Pooled analysis of variance of combining ability over two environment (open and polyhouse) in 12 × 12 diallel in tomato

Source	D.F	Yield per plant (kg)	Fruits per plant (no.)	Fruit weight (gm)	Maturity (days)	Plant height (cm)	Ascorbic acid (mg/100g)	Lycopene (mg/100g)	Total soluble solids (%)
GCA	11	0.66**	8052.42**	166.61**	57.06**	9109.93**	101.30**	2.15**	0.29**
SCA	66	0.33**	834.40**	84.73**	14.98**	1097.55**	40.32**	5.28**	0.95**
Environment	1	17.49**	21974.49**	1.21**	476.76**	73147.87**	0.37**	30.99**	6.36**
GCA × Envi.	11	0.41**	717.85**	41.04**	9.66**	586.33**	12.30**	0.86**	0.16**
SCA × Envi.	66	0.19**	229.77**	24.09**	3.83**	445.11**	15.09**	1.07**	0.45**
Error	308	0.009	14.49	0.19	0.26	9.51	0.04	0.01	0.04

*, **Significant at 5% and 1% respectively

The differences between the environments were also highly significant. As regards mean square due to *gca* × environment and *sca* × environment, these estimates were highly significant for all the eight characters studed. Usually the estimates of *gca* × environment mean square were higher than those of the *sca* × environment mean square except for ascorbic acid, total soluble solids and lycopene content, where the *sca* × environment mean square were higher. In self fertilized, crops since emphasis is more on addiive gene effects and relatively higher proportion of *gca* × environment interaction variances as compared to *sca* × environment estimates were recorded, adequate sampling of environment is essential for reaching reliable

It, generally, suggested that additive genetic variance was more sensitive to changing environments as compared to non-additive genetic variance; it further suggests that the additive and non-additive components of variation were important for the characters studied. However, significant of interaction variances warrants collection of data over environments for obtaining unbiased estimates of genetic variance.

The general combining ability effects (Table 3) revealed that among the parents EC 386037, EC 386023, Azad T-2 and Sel-7 were good general combiners for as many as four to six characters on the strength of the magnitude of gca effects for various traits. Under pooled analysis parents EC 386037 and

Table 3. Pooled general combining ability of parents over two environment (open and polyhouse)

Parents	Yield per plant (kg)	Fruits per plant (no.)	Fruit weight (g)	Maturity (days)	Plant height (cm)	Ascorbic acid (mg/100g)	Lycopene (mg/100g)	Total soluble solids (%)
Azad T-2	0.17**	–8.78	4.64**	–2.27**	–24.63	0.61**	–0.31	–0.02
Machin	0.12**	–5.59	4.07**	0.26	19.42**	–2.16	–0.35	0.09
DARL-64	0.17**	–7.31	5.37**	–0.87**	–2.87	–1.35	–0.22	–0.09
Hawaii-7998	–0.12	0.83	–2.37	1.94	26.13**	0.63**	–0.10	0.11**
EC-386032	–0.12	–5.42	–0.30	1.42	–16.19	–0.84	–0.33	0.02
EC-386037	–0.18	49.45**	–20.38	–2.17**	34.96**	1.90**	0.54**	0.16**
BL-342	0.05	–14.18	11.84**	2.22**	–6.18	0.81**	0.29**	–0.02
Sel-7	–0.11	–6.95	–0.96	0.14	2.36**	0.81**	0.20**	0.04**
EC-386019	–0.06	–0.43	–1.59	–0.37**	–7.81	0.88**	0.11**	0.02
EC-386023	0.12**	11.02**	–3.09	–0.31**	–3.10	3.22**	0.13**	–0.10
Mani Thoiba	–0.21	–12.39	2.82**	–0.18	–16.63	–3.13	0.05	0.02
Mani Leima	0.06*	–0.34	0.69**	0.57	–5.07	–1.79	0.02	–0.16
SE (gi)	0.024	0.974	0.112	0.130	0.623	0.051	0.026	0.016
SE (gi-gi)	0.036	1.439	0.165	0.193	1.166	0.076	0.038	0.024

*, **Significant at 5% and 1% respectively

EC 386023 were found good general combiner for most of the traits including yield. Only two parents Sel-7 and EC 386037 exhibited significant gca effects for all the three quality traits studied. These observations revealed that the quality traits with yield could be improved by using these parents in hybrid breeding programme for the accumuation of favourable genes.

From specific combining ability (Table 4), it was observed that the cross EC 386032 × BL-342 under open-air and Azad T-2 × Hawaii-7998 under polyhouse and pooled analysis found superior for yield per plant. Hawaii-7998 × EC 386037 was the best specific combiner for fruits per plant in both the environments and also in pooled analysis. For early maturity, BL-342 × Mani Thoiba under open and DARL-64 × Hawaii-7998 under polyhouse and in pooled analysis was found best while cross DARL-64 × EC 386037, EC 386023 × Mani Thoiba and DARL-64 × BL-342 was identified as best crosses for plant height under open, polyhouse and pooled analysis.

Ascorbic acid is the most important vitamin present in tomato and it is as important dietary source of vitamin C. The cross Hawaii-7998 × Sel-7, EC 386032 × EC 386037 and BL-342 × 386023 were exhibited highest SCA for this trait under open, protected and pooled analysis respectively, where as for lycopene content cross DARL-64 × EC 386019 performed best in both environments and pooled analysis. EC 386032 × BL-342 had the highest sca effect in open and BL-342 × Sel-7 in polyhouse and pooled analysis for total soluble solids.

The top two crosses were selected on the basis of higher SCA effects, presented in (Table 4) for each trait, had also recorded higher per se performance. These crosses had involved high × low, low × low and high × high general combiner parents. High SCA effects manifested by crosses where both the parents were good general combiners might be attributed sizeable additive × additive gene action. The high × low combinations, besides expressing the favorable additive effect of the high parent, manifested some complementary gene interaction effects with a higher SCA. An appreciable amount of the heterosis expressed by low × low crosses might be ascribed to dominance × dominance types of non-allelic gene action producing over dominance and are non-fixable. Thus it appears that the superior performance of most hybrids may be largely due to epistatic interaction. The SCA effects of the crosses exhibited no specific trends in cross combinations between parents having high, medium and low GCA effects. No cross combination showed significant positive SCA effect and high per se performance along with parents having good general combining ability effects for all the eight characters. Most of the crosses showing high SCA effects involved at least one high general combining parents. However, the crosses with high SCA effects involved low × low gca parents were highly responsive to environments in heterozygous state due to non-additive effects [9].

The mean (Table 5) of F_1 crosses was higher than those of the parents in all characters except in maturity (days). It was found that the range of mean values were higher both in parents and F_1s under protected in comparison to open environment except ascorbic acid and maturity. Highest significant heterosis (181%) over the mid parent for yield per plant was expressed by the cross 5 × 7 under open environment. However the cross 2 × 10 had highest heterosis (62.09 and 43.35%) over the top parent and the commercial control respectively. Under polyhouse, the highest significant heterosis (120.41%) over the mid parent was

Table 4. Top two crosses selected on the basis of specific combining ability effects

Character	Environment	Crosses	*per se* performance	*Sca* effect	General combining ability effect
Yield per plant (kg)	Open	EC 386032 × BL-342	2.300	0.97**	L × H
		Mechin × EC 386023	2.480	0.89**	H × H
	Protected	Azad T-2 × Hawaii-7998	3.600	1.28**	H × L
		Azad T-2 × DARL-64	3.700	1.14**	H × H
	Pooled	Azad T-2 × Hawaii-7998	2.650	0.95**	H × L
		EC 386032 × BL-32	2.510	0.94**	L × L
Fruits per plant (no.)	Open	Hawaii-7998 × EC 386037	134.67	57.02**	L × H
		EC 386037 × EC 386019	124.67	45.27**	H × L
	Protected	Hawaii-7998 × EC 386037	191.67	62.92**	H × L
	Pooled	Hawaii-7998 × EC 386037	163.17	59.97**	L × H
		EC 386037 × EC 386019	152.50	50.56**	H × L
Fruit weight (g)	Open	EC 386032 × BL-342	62.33	16.11**	L × H
		DARL-64 × Mani Leima	58.17	15.18**	H × H
	Protected	DARL-64 × Mani Leima	53.83	11.58**	H × L
		Hawaii-7998 × EC 386023	40.50	11.16**	L × L
	Pooled	DARL-64 × Mani Leima	56.00	13.38**	H × H
		Hawaii-7998 × Mani Thoiba	50.00	13.00**	L × H
Maturity (days)	Open	BL-342 × Mani Thoiba	83.33	–7.08**	L × L
		DARL-64 × Hawaii-7998	83.00	–6.32**	H × L
	Protected	DARL-64 × Hawaii-7998	81.67	–6.17**	H × L
		EC 386037 × BL-342	81.67	–5.41**	H × L
	Pooled	DARL-64 × Hawaii-7998	82.33	–6.25**	H × L
		EC 386019 × EC 386023	80.33	–5.62**	H × H
Plant height (cm)	Open	EC 386037 × Sel-7	76.33	33.77**	L × L
		Azad T-2 × Mechin	42.33	32.23**	H × L
	Protected	EC 386023 × Mani Thoiba	166.67	64.82**	L × L
		Sel-7 × Mani Leima	179.33	60.80**	H × L
	Pooled	DARL-64 × BL-342	148.33	58.74**	L × L
		Mechin × EC 386023	172.50	52.43**	H × L
Ascorbic acid (mg/100g)	Open	Hawaii-7998 × Sel-7	35.56	12.08**	H × L
		BL-342 × EC 386019	32.23	11.24**	L × L
	Protected	EC 386032 × EC 386037	36.46	13.74**	L × H
		BL-342 × EC 386023	37.11	12.52**	H × H
	Pooled	BL-342 × EC 386023	35.01	9.93**	H × H
		EC 386032 × Sel-7	31.43	9.72**	L × H
Lycopene (mg/100g)	Open	DARL-64 × EC 386019	6.80	2.90**	L × L
		EC 386037 × BL-342	7.70	2.66**	H × H
	Protected	DARL-64 × EC 386019	09.10	4.08**	L × H
		EC 386037 × BL-342	09.50	3.68**	H × H
	Pooled	DARL-64 × EC 386019	7.95	3.49**	L × H
		BL-342 × Mani Thoiba	8.32	3.39**	H × L
Total soluble solids (%)	Open	EC 386032 × BL-342	6.33	1.53**	L × L
		BL-342 × Sel-7	6.23	1.43**	L × L
	Protected	BL-342 × Sel-7	07.60	2.61**	H × H
		Mechin × Mani Leima	07.50	2.36**	L × L
	Pooled	BL-342 × Sel-7	6.33	1.79**	L × H
		BL-342 × Mani Leima	6.23	1.46**	L × L

**Significant at 1% H, high, L, low general combiner.

expressed by the cross 1 × 4 however, cross 1 × 3 exhibited highest heterosis (54.17 and 48.00%) over the top parent and the commercial control respectively.

Highest significant heterosis was recorded in cross combination 4 × 6 for fruits per plant and 6 × 7 for lycopene over top parent and commercial control under

Table 5. Range, mean values of parents, F_1 hybrids and heterosis under open (OE) and polyhouse environment (PE) in 12 × 12 diallel in tomato

Particulars		Yield per plant (kg)	Fruits per plant (no.)	Maturity (days)	Ascorbic acid (mg/100g)	Lycopene (mg/100g)	Total soluble solids (%)
Mean range	OE	0.530-1.530	17.00-73.33	84.00-98.67	13.64-32.20	1.90-6.30	3.77-5.37
Parengts	PE	1.200-2.400	22.23-116.33	80.67-98.67	10.95-37.11	2.67-7.30	4.10-6.10
F_1s	OE	0.480-2.480	13.33-134.67	81.33-96.00	10.54-35.56	1.60-7.70	3.50-6.57
	PE	0.750-3.700	21.0-191.67	79.17-91.67	10.71-30.71	0.53-9.50	3.80-7.70
Range of heterosis over							
MP	OE	0.18-181.63	3.36-189.41	−0.11 to −12.43	1.14-87.33	1.85-154.55	0.74-71.56
	PE	0.47-120.41	0.39-148.78	−0.19 to −11.55	2.29-89.78	2.01-145.32	1.06-78.82
TP	OE	2.61-62.09	37.0-83.65	−0.79 to −3.17	2.20-10.43	7.93-22.22	1.11-22.22
	PE	2.92-54.17	3.44-64.78	−1.67 to −1.89	15.48-20.84	13.70-30.14	3.28-26.23
CC	OE	2.31-43.35	2.68-438-68	−0.20 to −6.52	0.43-91.49	4.19-148.38	2.33-53.49
	PE	4.80-48.00	2.71-299.31	−0.20 to −7.94	0.20-81.73	2.04-176.97	1.81-40.00
Top parents with their mean values							
	OE	P12 (1.530)	P6 (73.33)	P1 (84.00)	P10 (32.20)	P11 (6.30)	P6 (5.37)
	PE	P12 (2.400)	P6 (116.33)	P1 (80.67)	P10 (30.71)	P6 (7.30)	P6 (6.10)
Top F_1s with their mean values							
	OE	P 12 (2.480)	4 × 6 (134.67)	1 × 6 (81.33)	4 × 8 (35.56)	6 × 7 (7.70)	2 × 4 (6.57)
	PE	1 × 3 (3.700)	4 × 6 (191.67)	8 × 11 (79.17)	7 × 10 (37.11)	6 × 7 (9.50)	8 × 9 (7.70)
Top F_1s with their heterosis % over							
MP	OE	5 × 7 (181.00)	8 × 10 (189.41)	7 × 11 (-12.43)	7 × 9 (87.33)	3 × 7 (154.55)	7 × 8 (71.56)
	PE	1 × 4 (120.41)	1 × 3 (148.78)	3 × 4 (-11.55)	3 × 12 (89.78)	2 × 8 (145.32)	7 × 8 (78.82)
TP	OE	2 × 10 (62.09)	4 × 6 (83.65)	1 × 6 (-3.17)	4 × 8 (10.43)	6 × 7 (22.22)	2 × 4 (22.22)
	PE	1 × 3 (54.17)	4 × 6 (64.78)	8 × 11 (-1.89)	7 × 10 (20.84)	6 × 7 (30.14)	8 × 9 (26.33)
CC	OE	2 × 10 (43.35)	4 × 6 (438.68)	1 × 6 (-6.52)	4 × 8 (91.49)	6 × 7 (148.38)	2 × 4 (53.49)
	PE	1 × 3 (48.00)	4 × 6 (299.31)	8 × 11 (-7.94)	7 × 10 (81.73)	6 × 7 (176.97)	8 × 9 (40.00)

MP-mid parent; TP-top parent; CC-commercial control cultivar

open and polyhouse environment, however, 1 × 6 for early maturity, 4 × 8 for ascorbic acid content and cross 2 × 4 for total soluble solids had exhibited the highest heterosis over the top parent and commercial control under open environment. However, F_1 crosses 1 × 3 and 4 × 6 for fruits per plant, 3 × 4 and 8 × 11 for early maturity, 3 × 12 and 7 × 10 for vitamin C and 7 × 8 and 8 × 9 for total soluble solids exhibited maximum heterosis over their respective mid, top parent and commercial control respectively under polyhouse environment. The potential crosses can be further tested and recommended for commercial cultivation to boost the fruit yield coupled with good quality. In conclusion, the present investigation suggests that hybrid breeding can be used efficiently to improve tomato production together with quality in open as well as in protected environment.

References

1. **Bhatt R. P., Biswas V. R. and Kumar N.** 2001 a. Heterosis, combining ability and genetics for Vitamin C, total soluble solids and yield in tomato (*Lycopersicon esculentum*) at 1700 m altitude. J. Agri. Sci., Cambridge., **137**: 71-75.
2. **Bhatt R. P., Biswas V. R and Kumar N.** 2001b. Combining ability studies in tomato (*Lycopersicon esculentum*) under mild hill conditions of Central Himalayas. Indian J. Genet., **61**: 74-75.
3. Association of Official Analytical Chemists. 1970. Official Methods of Analysis. Washington, DC: Association of Official Analytical chemists.
4. **Ranganna S.** 1976. In manual of Analysis of fruit and vegetable products. Mcgrew Hill Pub. 77 pp.
5. **Griffing B.** 1956. Concept of general and specific combining ability in relation to diallel crossing system. Australian J. Bio. Sci., **9**: 463-93.
6. **Singh D.** 1973. Diallel cross analysis for combining ability over several environment-II. Indian J. Genet., **33**: 469-481.
7. **Allard R. W.** 1960. Principles of plant Breeding. John Wiley and Sons. Inc, New York.
8. **Aravindkumar J. S., Mulge R and Patil B. R.** 2003. Stability of yield and its component character in tomato (*Lycopersicon esculentum*). Indian J. Genet., **63**: 154-157.
9. **Jinks J. L and Jones R. M.** 1958. Estimation of component of heterosis. Genet., **43**: 223-234.