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Morpho-chemical quality improvement in tomato (*Solanum lycopersicum*) through heterosis breeding

ASHISH K SINGH[1,4], S S SOLANKEY[2], MEENAKSHI KUMARI[3] and NEERAJ SINGH[4]

Bihar Agricultural College, Sabour, Bihar 813 210, India

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ABSTRACT

The demand of tomato (*Solanum lycopersicum* L.) and its products continue to rise due to its excellent source of antioxidants including lycopene, total carotenoids, ascorbic acid and total soluble solids. The present experiment was carried out during the autumn-winter season of 2014–2016. The seven parents were crossed in half diallel fashion and the resultant 21 F_1 hybrids along with their parents and one hybrid check (BSS - 488) were evaluated in randomized complete block design with three replications for eight morpho-chemical quality component traits in tomato. The highest standard heterosis were observed in the cross Selection-12 × Pusa-120 (12.16%) for pericarp thickness, Pusa Rohini × Selection-12 (25.95%) for total soluble solids, H-86 × Pusa Rohini (23.53) for ascorbic acid, Selection-12 × CLNB (38.79) for total phenolics, Arka Alok × CLNB (46.49) for total antioxidant capacity, Pusa Rohini × Arka Alok (25.95) for lycopene and total carotenoids (29.53). Among the crosses Pusa Rohini × CLNR, Arka Alok × CLNB, H-86 × Pusa-120 and H-86 × CLNR were found to be better for most of the quality traits and these crosses could be considered as most promising specific combiners. Among the parents, Selection-12, CLNB, Pusa Rohini and Arka Alok were identified as most promising general combiners for quality traits and these may be used as valuable donors in the hybridization programme for producing promising varieties.

Key words: Antioxidants, Ascorbic acid, Carotenoids, Half diallel, Lycopene

Tomato (*Solanum lycopersicum* L.) is a popular vegetable of Solanaceae family which grows extensively in the tropical and subtropical regions of the world. Tomatoes are major contributors of antioxidants such as carotenoids (especially, lycopene and β-carotene), phenolics, ascorbic acid (vitamin C) and small amounts of vitamin E in daily diets (Rai *et al.* 2012). The nutritional importance of the tomato indicates there is need to formulate breeding programmes to develop cultivars rich in lycopene and possessing other processing traits. Moreover, earlier studies have indicated that the quality of the tomato is strongly correlated with its lycopene content (George *et al.* 2004). Efforts are being made to increase its productivity by developing superior hybrids. High total soluble solids (TSS) of fruits is desirable, as 1% increase in TSS content of fruits results in 20% increase in recovery of processed products (Berry and Uddin 1991). A considerable degree of heterosis has been documented and utilized in tomato for various characters even since the first official report by Hedrick and Booth (1907). Since then a number of workers have reported heterosis in tomato (Tamta and Singh 2018 and Raj *et al.* 2018). Heterosis breeding in tomato has several advantages like superiority in adaptation, quality, disease resistance, maturity and general vigour over its non-hybrid cultivars. Knowledge of gca and sca helps in choice of parents or hybrids, respectively. Therefore considering the present need, the study was undertaken to estimate the heterosis and combining ability in tomato for better quality and its component characters.

MATERIALS AND METHODS

The experiment was conducted at vegetable research farm, Bihar Agricultural University, Sabour, Bhagalpur, Bihar during the autumn-winter season of 2014–2016. Seven parents, viz. Kashi Vishesh, Pusa Rohini, Selection-12, Arka Alok, CLNR, CLNB and Pusa-120 were selected (Table 1) and crossed in half-diallele mating design during 2014–2015. The resulting 21 F_1s along with seven parents and BSS-488 (check, F_1 hybrid) were evaluated during autumn-winter season of 2015-16. The experiment was laid out in randomized complete block design with three replications. The transplanting was done in raised bed accommodating 12 plants/plot with row-to-row spacing of 70 cm and plant-to-plant spacing of 60 cm. All recommended package and practices were followed to raise a good crop (Fageria *et al.* 2003). The data was recorded from each line and each replication for 8 morpho-chemical traits by selecting 5

[1]PG student (ashish. horti1991@gmail. com), [2]Assistant Professor (shashank. hort@gmail. com), [3]PG student (meenakshisinghupcs@gmail. com), Department of Horticulture (Vegetable and Floriculture). [4]Ph D student (neerajsingh9838@gmail. com), Department of Vegetable Science, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar.

Table 1 Genotypes of tomato used in the present investigation

Genotype	Source	Specific traits
Kashi Vishesh	IIVR, Varanasi	Fresh market, good GCA, large size fruits, high yielding, thick pericarp
Pusa Rohini	IARI, New Delhi	Thick pericarp, processing variety
Selection -12	HAU, Hisar	Thick pericarp, high TSS, vitamin C rich
Arka Alok	IIHR, Bengaluru	Table purpose variety, green shoulder, high TSS content
CLNR	AVRDC, Taiwan	Lycopene and vitamin C rich
CLNB	AVRDC, Taiwan	Lycopene and vitamin C rich
Pusa 120	IARI, New Delhi	Low acidity, less seeded, resistant to nematode.
Check		
BSS - 488 (F1)	Bejo Sheetal Seed Company, Coimbatore	Large size fruits, thick pericarp, lycopene rich

randomly selected plants. The morphological character for pericarp thickness was recorded as per the DUS guidelines (Anonymous 2009). Moreover for 7 biochemical traits, firm, ripened and freshly harvested fruits were selected. The TSS was recorded with help of digital hand refractometer, in per cent. Titratable acidity was determined by using titration method of AOAC. (2000). Total phenolic content was determined by the method of Singleton *et al.* (1999). Total antioxidant capacity was estimated by the method of Apak *et al.* (2008). Total carotenoids content of tomato fruit was determined by the method given by Roy (1973) and total lycopene content was determined by the method of Lee (2001). The analysis of variance (ANOVA) for RCBD was estimated crosswise according to the formula given by Panse and Sukhatme (1989). The combining ability analysis was carried out following the method 2 model 1 of Griffing (1956).

RESULTS AND DISCUSSION

The analysis of variance for combining ability exhibited significant differences among the genotypes, parents and hybrids for all the characters. It suggested presence of considerable variability for all the traits. The ratio of general combing ability (GCA) and specific combing ability (SCA) variance revealed preponderance of non-additive genetic variances for all the studied traits (Table 2). Similar views had been expressed by earlier workers (Kumar *et al.* 2013 and Singh *et al.* 2016).

Among the parents, H-86, Pusa Rohini and Arka Alok exhibit positive significant GCA effects for pericarp thickness in similarity with the findings of Singh *et al.* (2016). Pusa Rohini and CLNB exhibited positive significant GCA effect for TSS, antioxidant, lycopene and total carotenoid contents in consonance with Mondal *et al.* (2009), whereas Selection-12 exhibited positive and significant GCA effect for TSS, ascorbic acid, total phenolics content and antioxidant contents (Table 3).

Out of 21 cross combinations, the hybrids Selection-12 × Pusa-120 (1.21%) and H-86 × CLNR (1.15%) possessed highest SCA effect for pericarp thickness and findings were at par with the result of Joshi *et al.* (2015). The cross Pusa Rohini × CLNR exhibited positive and significant SCA effect for TSS content (0.61%) followed by Pusa Rohini × Selection-12 (0.56%) in consonance with Yadav *et al.* (2013). The cross combinations CLNR × CLNB (6.02%) and Pusa Rohini × CLNR (5.45%) possesses highest significant SCA effect for ascorbic acid and similar results were supported by Joshi *et al.* (2006). Moreover, for total phenolics content the Selection-12 × Pusa-120 (4.15%) and H-86 × CLNR (3.82%) exhibited highest SCA effect (Table 3). For antioxidant capacity, Pusa Rohini × CLNR (0.65%) and Arka Alok × CLNB (0.50%) possessed highest SCA

Table 2. Analysis of variance (ANOVA) for combing ability in parents and F1s for quality component in tomato

Source	DF	Locules per fruit	Pericarp thickness (mm)	Total soluble solids (%)	Ascorbic acid content (mg/ 100g FW)	Titrable acidity (%)	Total phenolics content (mg catechol equivalent/ 100g FW)	Total antioxidant capacity (μ Mol Te/G)	Lycopene content (mg/100g FW)	Total carotenoids (mg/100g FW)
Replication	2	0.02	0.27	0.03	0.02	0.00	0.02	0.00	0.01	0.00
Treatment	27	2.35**	2.16**	0.42**	87.77**	0.02**	144.19**	1.01**	1.89**	1.62**
Parents	6	1.03**	2.03**	0.25**	186.08**	0.02**	184.43**	0.73**	2.23**	2.30**
Parents vs Hybrids	1	0.34	1.36*	1.05	27.98**	0.00**	101.85**	0.21**	1.20**	0.41**
Hybrids	20	2.84**	2.24**	0.44**	61.27**	0.02**	134.23**	1.13**	1.83**	1.47**
Error	54	0.09	0.16	0.01	0.04	0.00	0.05	0.00	0.01	0.00
GCA(σ2g)	6	0.67**	1.68**	0.30**	97.54**	0.02**	173.86**	1.07**	2.22**	1.97**
SCA(σ2s)	21	0.82**	0.45**	0.09**	9.75**	0.00**	12.12**	0.13**	0.18**	0.13**
σ2g/ σ2s		0.82	3.73	3.33	10.00	0.00	14.34	8.23	12.33	15.15
Error	54	0.03	0.05	0.00	0.01	0.00	0.02	0.00	0.00	0.00

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

Table 3 Top three heterotic hybrids and combiners (GCA and SCA) for yield and quality traits in tomato

Trait	Range of heterosis (%) over		Three superior crosses based on standard heterosis (%)	Three superior crosses based on heterobeltiosis (%)	Promising parents based on GCA	GCA (%)	Promising F1's based on SCA	SCA (%)
	SP	BP						
Pericarp thickness (mm)	-34.95% (CLNB × Pusa- 120) to 12.16% Selection-12 × Pusa-120	-26.28% (H-86 × Arka Alok) to 16.64% Arka Alok × Pusa-120	Selection-12 × Pusa-120 (12.16%) H-86 × CLNR (10.41%) H-86 × Pusa-120 (4.43)	H-86 × Arka Alok (16.64%) Selection-12 × Pusa-120 (15.99%)	H-86 Pusa Rohini Selection-12	0.53 0.37 0.37	Selection-12 × Pusa-120 H-86 × CLNR Arka Alok × Pusa-120	1.21 1.15 0.90
TSS (%)	-7.63% (H-86 × Pusa Rohini) to 25.95% (Pusa Rohini × Selection-12)	-11.64% (H-86 × Selection-12) to 19.70% (Pusa Rohini × CLNR)	Pusa Rohini × Selection-12 (25.95%) Selection-12 × CLNB (25.19%) Pusa Rohini × CLNR (20.61%)	Pusa Rohini × CLNR (19.70%) Pusa Rohini × Selection-12 (13.01%) Selection-12 × CLNB (12.33%)	Selection-12 CLNB Pusa Rohini	0.23 0.21 0.08	Pusa Rohini × CLNR Pusa Rohini × Selection-12 Selection-12 × CLNB	0.61 0.56 0.40
Titrable acidity (%)	-28.86% (Selection-12 × CLNB) to 6.94% (H-86 × Pusa Rohini)	-21.76% (H-86 × Pusa-120) to 10.28% (CLNR × Pusa-120)	Selection-12 × CLNB (-28.86%) Selection-12 × Arka Alok (-27.85%) CLNB × Pusa-120 (-27.40%)	H-86 × Pusa-120 (-21.76%) H-86 × CLNR (-19.21%) CLNB × Pusa-120 (-17.74%)	Selection-12 CLNB	-0.05 -0.03	H-86 × Pusa-120 H-86 × CLNR	-0.10 -0.09
Ascorbic acid (mg/ 100g FW)	-23.08% (CLNB × Pusa- 120) to 23.53% (H-86 × Pusa Rohini)	-24.11% (Selection-12 × CLNR) to 29.16% (CLNR × CLNB)	H-86 × Pusa Rohini (23.53%) Pusa Rohini × Selection-12 (17.95%) Pusa Rohini × CLNR (15.51%)	CLNR × CLNB (29.16%) Arka Alok × CLNB (6.82%) H-86 × Pusa Rohini(5.83%)	Pusa Rohini Selection-12 H-86	3.68 3.48 2.60	CLNR × CLNB Pusa Rohini × CLNR Arka Alok × CLNB	6.02 5.45 3.68
Total phenolics (mg CE/ 100g FW)	-0.14% (Arka Alok × Pusa- 120) to 38.79% (Selection-12 × CLNB)	-16.89% (CLNB × Pusa-120) to 10.17% (Pusa Rohini × CLNR)	Selection-12 × CLNB (38.79%) Selection-12 × Arka Alok (36.81%) H-86 × Selection-12 (35.19%)	Pusa Rohini × CLNR (10.17%) H-86 × CLNR (6.89%) Pusa Rohini × Pusa-120 (5.81%)	Selection-12 CLNB Arka Alok	8.29 2.64 -0.62	Selection-12 × Pusa-120 H-86 × CLNR Selection-12 × Arka Alok	4.15 3.82 3.31
Total antiox-idants capacity (μ Mol/ Te/G)	-36.37% (Arka Alok × Pusa-120) to 46.49% (Arka Alok × CLNB)	-37.26% (Arka Alok × Pusa-120) to 25.68% (Pusa Rohini × CLNR)	Arka Alok × CLNB (46.49%) Selection-12 × CLNB (44.08%) Pusa Rohini × Selection-12 (37.76%)	Pusa Rohini × CLNR (25.68%) CLNR × Pusa-120 (22.76%) Pusa Rohini × Selection-12 (15.92%)	CLNB Selection-12 PusaRohini	0.52 0.24 0.12	Pusa Rohini × CLNR Arka Alok × CLNB CLNR × Pusa-120	0.65 0.50 0.48
Lycopene content (mg/ 100g FW)	-66.04% (H-86 × Pusa- 120) to 25.95% (Pusa Rohini × Arka Alok)	-39.99% (H-86 × Pusa- 120) to 25.12% (H-86 × CLNR)	Pusa Rohini × Arka Alok(25.95%) Arka Alok × CLNB (11.70%) Pusa Rohini × Selection-12 (8.16%)	H-86 × CLNR (25.12%) Pusa Rohini × Selection-12 (14.64%) Pusa Rohini × Arka Alok (14.06%)	Arka Alok Pusa Rohini CLNB	0.71 0.49 0.25	Pusa Rohini × Pusa-120 H-86 × Arka Alok Pusa Rohini × CLNR	0.64 0.60 0.59
Total carot-enoids (mg/ 100g FW)	-41.03% (CLNR × Pusa- 120) to 29.53% (Pusa Rohini × Arka Alok)	-34.79% (CLNR × Pusa-120) to 10.42% (Pusa Rohini × CLNR)	Pusa Rohini × Arka Alok (29.53%) Arka Alok × CLNR (21.90%) Pusa Rohini × CLNR (19.87%)	Pusa Rohini × CLNR (10.42%) Pusa Rohini × Selection-12 (10.00%) H-86 × Pusa-120 (4.29%)	Arka Alok Pusa Rohini CLNB	0.62 0.54 0.04	Pusa Rohini × CLNR Arka Alok × CLNR H-86 × Pusa Rohini	0.43 0.42 0.42

effect in consonance with Kumar *et al.* (2013). The cross Pusa Rohini × Pusa-120 was displayed a good specific combiner for lycopene content (0.64%) followed by H-86 × Arka Alok (0.60%) (Table 3). For total carotenoides content the cross Pusa Rohini × CLNR (0.43%) and H-86 × Pusa Rohini (0.42%) recorded highest SCA effect, similar findings were recorded by Kumar *et al.* (2013) and Yadav *et al.* (2013).

Out of 21 crosses, Selection-12 × Pusa-120 displayed highest standard heterosis (12.16%) for pericarp thickness followed by H-86 × CLNR (10.41%), whereas, highest heterobeltiosis was exhibited by H-86 × Arka Alok (16.64%) in paralleled with the findings of Aisyah *et al.* (2016) and Singh *et al.* (2016). The Pusa Rohini × Selection-12 showed highest standard heterosis (25.95%) for TSS content (%) followed by Selection-12 × CLNB (25.19%), whereas highest heterobeltiosis was observed in Pusa Rohini × CLNR (19.70%) followed by Pusa Rohini × Selection -12 (13.01%) in consonance with the study of Kumar *et al.* (2013) and Singh *et al.* (2016). The Selection -12 × CLNB exhibited highest negative standard heterosis (-28.86%) for titrable acidity in desirable direction followed by Selection-12 × Arka Alok (-27.85%), whereas highest negative better parent heterosis was exhibited in H-86 × Pusa-120 (-21.76%) followed by H-86 × CLNR (-19.21%) in consonance with the findings of Mondal *et al.* (2009). The cross H-86 × Pusa Rohini revealed highest standard heterosis (23.53%) for ascorbic acid content followed by Pusa Rohini × Selection-12 (17.95%), although highest heterobeltiosis was exhibited by cross CLNR × CLNB (29.16%) followed by Arka Alok × CLNB (6.82%), that is in similarity with the findings of Kumar *et al.* (2013). The hybrid Selection-12 × CLNB expressed highest standard heterosis (38.79%) for total phenolics content followed by Selection-12 × Arka Alok (36.81%), thus highest heterobeltiosis was observed in cross Pusa Rohini × CLNR (10.17%) followed by H-86 × CLNR (6.89%) in consonance with Kumar *et al.* (2013). The cross Arka Alok × CLNB displayed highest standard heterosis (46. 49%) for antioxidant capacity followed by Selection -12 × CLNB (44.08%), whereas highest heterobeltiosis was exhibited by Pusa Rohini × CLNR (25.68%) followed by CLNR × Pusa-120 (22.76%), in similarity with the results of Kumar *et al.* (2013). The Pusa Rohini × Arka Alok cross displayed highest standard heterosis (25.95%) for lycopene content followed by Arka Alok × CLNB (11.70%), although highest heterobeltiosis was recorded in H-86 × CLNR (25.12%) followed by Pusa Rohini × Selection-12 (14.64%). For total carotenoids, Pusa Rohini × Arka Alok displayed highest standard heterosis (29.53%) followed by Arka Alok × CLNR (21.90%), whereas, highest heterobeltiosis was exhibited in Pusa Rohini × CLNR (10.42%) followed by Pusa Rohini × Selection-12 (10.00%) in similarity with the findings of Kumar *et al.* (2013) and Yadav *et al.* (2013).

Thus in present study the top performing F_1 hybrids for quality characters are, Selection-12 × Pusa-120 for pericarp thickness, Pusa Rohini × Selection-12 for total soluble solids content, H-86 × Pusa Rohini for ascorbic acid, Selection-12 × CLNB for total phenolics, Arka Alok × CLNB for total antioxidant capacity, Pusa Rohini × Arka Alok for lycopene and total carotenoids. While none of the crosses showed significant positive heterosis in desirable direction over standard variety (BSS-488) for titrable acidity. Among the parents, Selection-12, CLNB, Pusa Rohini and Arka Alok were identified as most promising general combiners for quality traits and are valuable donors in the hybridization programme for producing promising hybrids in quality improvement programme of tomato. Among the crosses, Pusa Rohini × CLNR, Arka Alok × CLNB, H-86 × Pusa-120 and H-86 × CLNR were found better performing F_1 hybrids for most of the morpho-chemical quality traits and these crosses could be considered as most promising specific combiners.

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