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Inheritance of Yield and Quality Traits in Tomato

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Abstract:
This research was conducted to check combining ability effects and heterotic effects among six parents and nine F1 crosses. Hybrids were developed through Line x Tester technique at NARC in the year 2013-2014. Hybrids along their parents were sown in four replications by following RCBD technique. Genotypes were evaluated on the basis of heterotic effects over better parent & mid parent and combining ability effects. Positive heterosis were found for plant height, fruits per cluster, total number of fruits per plant, fruit weight, yield per plant, Total Soluble Solids, lycopene and beta carotene contents while negative heterosis were found for days to maturity by cross Peto-86 × Naqeeb. Analysis of variance for line x tester was highly significant for days to flowering, maturity, fruit weight, yield per plant, TSS, lycopene and beta-carotene contents. Among parents, best general combiner was Naqeeb followed by peto-86 found for majority of traits under considered. Hybrid Peto-86 x Naqeeb followed by NTH-1004 x Pakit and Peto-86 x Riograndi showed high specific combining ability effects among crosses. Dominance or epistatic type of gene actions were observed for all parameters under studied.

Keywords: *inheritance studies, line x tester analysis, gene action yield, quality, tomato*

1. Introduction

Tomato (Solanum lycopersicumL., formerlyrecognized as Lycopersiconesculentum Mil., is a member of Solanaceae/night shade family with the chromosome number of 2n=2x=24. It was originated from Central and South America having 96 generaand over 2800 species which are further disbursed into three sub families i.e. Solanoideae, Cestroideae and Solanineae (Knapp et. al., 2004). Tomato is a self-pollinated,herbaceous, dicot, indeterminate crop and has a great breeding potential. Due to its small genome size, short life cycle and sequenced genomic resources, it is considered as one of the extensively studied model crop. The genome size is of 950 Mb consisting of approximately 35,000 genes. Tomato is considered as highly consumable vegetable in the world (Mueller et al., 2005). Tomato is widely used in eating or cooking purposes and processed in many forms as sauces, ketchups, preserves, paste, juices and puree (Tiwari & Choudhury, 1986).

In Pakistan during the fiscal year 2014-15 it was cultivated on 60.7 thousand hectares and 570.6 thousand tons was produced (Agri. Statistics, 2014-15). Tomato is anexcellentsource of antioxidants, vitamins like A and C, carotenoids, and lycopene, therefore it protectshumans from different diseases such as cancer, cardiovascular and neural issues (Jaramillo et. al., 2007 andOlaniyiet. al., 2010). The quality traits such as size and shape of fruit, total soluble sugars, level of anthocyanin, lycopene and beta-carotene, inflexibility, dietary value, pH, acidity level are important attributes for determining both the processing and commercial value of the produce (Foolad, 2007). Yield of tomato is a quantitative trait governed by many genes and each individual gene contributes towards it. Heterosis is a significant tool in evaluation of hybrids in comparison to their parents.

There are many mating designs like Line × Tester which involve mating between female as lines and male as testers in one to one fashion, producing f × m = fm hybrids. The concept of Line × Tester analysis (also called as FS/HS analysis) was developed by Kempthorne (1957).Phundan& Narayanan(2004)reported that this analysis of contains high level of precision as compared to diallel and partial diallel analysis and it involves both first and second order of statistics. This technique helps the breeder to select best genotypes for hybridization, to isolate the segregating genotypes and to determine the gene action. Line× Tester is the best technique for obtaining information on parent's and offspring's genetic potential.

In view of importance of aforementioned detail the aim of study was:

- To identify the superior parents for fruit yield and quality characters of tomato on the basis of Line × Tester analysis.
- To find out merging ability effects both GCA and SCA, nature of gene action, estimation of hybrid vigor on basis of Line × Tester analysis.

2. Materials and Methods

Fifteen genotypes (six parents along with their nine F1 hybrids) lines (female) i.e., Tomato-1211, NTH-1004, Peto-86 and testers (male) were Naqeeb, Riograndi and Pakit were included in research material for this study. This study was conducted in Horticultural Research Institute (HRI), National Agriculture Research Center (NARC) Islamabad during the years 2013-14. During fall 2013, nine F1 crosses were made by adopting Line × Tester technique (Table 1). The seeds of hybridized materials were harvested and kept for spring season, 2014.

Their F1 progeny/seeds were grown in research area of HRI in four replications by following Randomized Complete Block Design (RCBD). The experimental unit was of 16.76 m long, 6.24 m wide and plot area was 104.58 m2. The spacing between rows and between plants was about 88.4 cm and 34 cm, respectively.

Observations on days to 50 percent flowering, days to ripeness, plant height (cm), quantity of fruits per cluster, total number of fruits per plant, average fruit weight (g), fruit size (cm) fruit yield per plant (kg), quality parameters total solvable solids lycopene and β-carotene contents (mg/100g) were recorded on the basis of five selected plants from each replication. Lycopene and Beta carotene (mg/100g) was determined by the technique of Steel et al. (1997).

Study of variance (ANOVA) was applied on unprocessed data of above said characters were with the help of AGRI STAT software. Heterotic effects over both mid and better parent were obtained by the method was given by Matzingeret. al., (1962) and (Fonseca & Patterson, 1968). Merging ability effects over both GCA and SCA were projected according to Griffing (1956) with a computer program AGRI STAT.

3. Results

3.1. Heterosis

In case of days to floweringno negative and highly significant MPH and BPH was found in any cross (Table. 2). While cross Peto-86 × Naqeeb (-4.19 MPH and -4.42 BPH) showed negative and significant MPH and BPH for days to maturity (Table. 2).

In case of plant height, only one cross combination i.e. Peto-86 × Pakit (33.33 MPH and 33.09 BPH) expressed positive and highly significant and significant heterotic effects over mean of parents better parents respectively (Table 2). Highly significant and positive heterosis for fruits per cluster was observed in Peto- 86 × Pakit (38.76 for MPH and 37.51for BPH) followed by Peto-86 × Riograndi (31.47 for MPH and 28.35 for BPH) (Table 2).

Regarding total number of fruits per plant, out of total nine cross combinations, seven cross showed positive and highly significant mid parent heterotic effects. Highest and highly significant MPH heterosis was observed in cross Peto-86 × Naqeeb (60.42) (Table 2). In case of better parent heterosis, two crosses were highly significant. Highest and highly significant (BPH) was observed in Peto-86 × Naqeeb (51.16) (Table 2).

For fruit weight, In case of mid parent heterosis, out of nine cross combinations, seven cross were highly significant and positive, while only two were significant only for mid parent heterosis. Highest, positive and highly significant MPH and BPH was observed in Peto-86 × Pakit (52.70 and 51.34 respectively) (Table 2).

For fruit size, Regarding mid parent heterosis out of nine cross combinations only one cross Peto-86 × Naqeeb (8.79) showed positive as well as significant heterotic effects, In case of heterobeltiosis, no cross showed highly significant or significant positive heterotic effects (Table 2). For fruit yield per plant, the highest heterotic effects over mean of parents and better parents were found in Peto-86 × Naqeeb (185.96 and 170.11) followed by Tomato -1211× Naqeeb(141.13 and 116.64) which were positive and highly significant (Table 2).

In case of total soluble solids (TSS), cross Tomato-1211× Naqeeb expressed maximum, positive and highly significant MPH (81.48) and BPH (81.48) followed by Peto-86 × Riograndi for MPH (42.31) and NTH-1004 × Riograndi for BPH (29.03) (Table 2). For lycopene contents, Maximum positive and highly significant MPH and BPH were observed in cross NTH-1004 × Riograndi (1475.00 and 1100) followed by Peto- 86 × Riograndi (1458.78 and 972.73) (Table 2).For beta-carotene contentsmaximum positive and highly significant heterotic effects over both types parents were found in Tomato-1211 × Riograndi (206.96 and 168.70) followed by Tomato 1211 x Pakit (187.38 MPH and 169.74 BPH) (Table 2).

3.2. Combining Ability Analysis and Gene Action

3.2.1. General Combining Ability Analysis

From ANOVA for merging ability exposed that lines showed highly significant differences for days to flowering, average fruit weight, yield per plant, lycopene and Beta-carotene contents. Testers showed highly significant difference among days to maturity, total fruits in a plant, yield from a plant, TSS, lycopene and beta-carotene contents. While crosses exhibited highly significant differences for days to flowering, days to maturity, total fruits in a plant, average weight of fruit, yield per plant, TSS, Lycopene and beta-carotene contents. For Line x Tester interaction highly significant difference was observed in days to blooming,days to maturity, average weight of fruit, plant's yield, TSS, Lycopene and beta-carotene contents. It means genetic variability existed among the genotypes and population can be improved through selection procedures.

Dominance or non additive type of gene action was observed for all parameters under studied because ratio between σ2GCS /σ2SCA was found greater than unity(Table 3).

None of the parent was observed as a best general combiner for all parameters under studied. However, Line Tomato-1211 exhibited as best combiner for days to blooming, maturity and beta carotene contents (Table 4). General Combining ability effects of Line Peto-86 for fruits per cluster, weight of fruit, size of fruit, and per plant yield were significant and highly significant(Table 4). Line NTH-1004 proved as bestgeneral combiner for height of plant, lycopene as well as beta carotene contents. In case of testers, Naqeeb was observed as a true general combiner for all traits except lycopene and beta-carotene contents. Pakit and Riograndi were reported as good general combiner for only lycopene and beta-carotene contents (Table 4).

In this study no cross exhibited as best specific combiner for all traits under study, however Specific Combining Ability effects for more than one parameter are exhibited by some F1 Hybrids. For example days to flowering maximum, negative and highly significant SCA effects were found in Peto-86 × Riograndi (-7.83) and NTH-1004 × Pakit (-7.50). Cross Peto-86 × Naqeeb (-3.61) and NTH-1004 × Pakit (-4.86)exposed negative and highly significant Specific Combining ability effects for days to maturity. In case of plant height positive and highly significant SCA effects were observed in cross NTH-1004 x Naqeeb (5.62).

Positive and highly significant SCA effects were observed in Peto-86 x Naqeeb (0.36 and 5.99) for total number of fruits per cluster and total number of fruits per plant respectively. Significant and positive SCA effects for fruit size was found in Peto-86 x Riograndi (0.10) was obtained for this parameter.

In average fruit weight best specific combiner for fruit weight was NTH-1004 × Naqeeb (11.50) and Peto-86 x Riograndi (6.75). Maximum SCA effects for fruit yield per plant was observed in Peto-86 x Naqeeb (0.24). Best specific combiners for TSS were tomato-1211 x Naqeeb (6.17) followed by NTH-1004 x Riograndi (2.50) and NTH-1004 x Pakit (2.33).For lycopene contents best specific combiner was NTH-1004 x Riograndi (0.09) followed by NTH-1004 × Pakit (0.04). For beta carotene maximum SCA effects was observed in NTH-1004 x Naqeeb (0.20) (Table 5).

4. Discussion

4.1. Heterosis

Heterosis is an important phenomenon which is related to hybrid vigor or superiority of progeny produced from a single cross between its parents. Taslim (2006) reported that this this classical phenomenon was observed by Shull & East during 1905-12.

Highly significant and negative heterotic effects over mid and better parents were observed in days to maturity indicating F1 hybrid showed high vigor than parents and can be utilized in development of early maturing variety in breeding programs. Positive and highly significant mid parent Heterosis was observed in plant height, total no. of fruits per cluster, total no. of fruits per plant, average fruit weight, fruit yield per plant, lycopene contents, TSS and beta-carotene contents. Positive and highly significant better parent heterosis was observed in fruits per bunch, fruits per plant, average fruit weight, and yield per plant, TSS, lycopene and beta-carotene contents.Highly significant heterosis for different parameters indicated that F1 hybrid showed higher hybrid vigor than parents. While the fruit size showed significant and positive effects for fruit size. In present study positive and highly significant heterosis in yield is due to increase in weight, size and number of fruits per plant. Such heterotic effects indicated that more genetic diversity was present among parents. In different research studies Islam et. al., (2012):Kumar et. al., (2009): Kumari and Sharma (2011): Saleemet. al., (2009)and Singh et. al., (2012) also compiled quite similar results as well.

4.2. Combining Ability

Combining ability plays a very important role to develop a pure line. Kumari and Sharma (2012) reported that the total combining ability can be partitioned in to GCA and SCA effects. GCA effects mainly contribute to additive gene effects (fixable) while the SCA effects contribute to dominance effects. The analysis of variance for parents (lines and testers), crosses Line x tester interactions revealed that the highly significant and significant differences for most of the characters under study therefore considerable type of genetic diversity exists among genotypes and can be further utilize in coming breeding programs.In this study, dominance or epistatic gene action was observed for all parameters therefore exploitation of Heterosis would be successful and selection in early generations would be ineffective.

The existence of non-additive/epistatic gene action for such characters also indicated that population requires maintenance of heterozygosity. Therefore, follow modified breeding techniques such as bi-parental cross or triple test cross design or any other form of recurrent selection method in early generations, which is more useful for exploitation of non-additive gene action.SCA effects are independent to general combiners because such effects can be developed through minimum or poor GCA combiners and can be exploited in further breeding programs. High SCA effects manifested by poor x poor General combiners are may be due to non-allelic interaction or genetic diversity among the parents. Negative SCA effects for days to flowering and days to maturity were observed due to poor x poor and poor x good general combiners respectively. In this study Positive and highly significant SCA effects for plant height, total number of fruits per group, total number of fruits per plant, average fruit weight, fruit size, yield per plant, TSS, lycopene and Beta-carotene contents were observed due combination of poor x poor, good x poor, poor x good, good x poor, good x poor, good x good, poor x good,

good x good and good x poor combiners respectively. Similar findings were also obtained byKumar et. al., (2013),Kumar et. al., (2013): Singh et. al., (2010), Sekharet. al., (2010),Saleemet. al., (2013), Shankar et. al., (2013) and Usha (2011),

5. Conclusion

In present study cross Peto-86 x Naqeeb and Peto-86 x Riograndiwere found best ones because they had high heterotic effects over both mid and better types of parents. Best general combiner was reported in Lines as line Peto-86 and in Tester as Naqeeb. Cross Peto-86 x Naqeeb and NTH-1004 x Pakit had highest SCA effects for yield and its contributing traits. Therefore we concluded that Peto-86 and Naqeeb can be utilized in future tomato breeding programs as donor for most of characters for yield and quality improvement.

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	Genotypes	Name of Genotypes	Detail of Genotypes
P1	L1	Tomato -1211	Cultivar
P2	L2	Peto-86	Cultivar
P3	L3	NTH-1004	Line
P4	T1	Naqeeb	Cultivar
P5	T2	Riogrande	Cultivar
P6	T3	Pakit	Cultivar
C1	L1× T1	Tomato -1211 × Naqeeb	Single cross
C2	L1 × T2	Tomato -1211 × Riograndi	Single cross
C3	L1 × T3	Tomato -1211 × Pakit	Single cross
C4	L2 × T1	Peto- 86 × Naqeeb	Single cross
C5	L2 × T2	Peto-86 × Riograndi	Single cross
C6	L2 × T3	Peto- 86 × Pakit	Single cross
C7	L3 × T1	NTH-1004 × Naqeeb	Single cross
C8	L3 × T2	NTH-1004 × Riograndi	Single cross
C9	L3 × T3	NTH-1004 × Pakit	Single cross

Table 1: Tomato Genotypes Used in the Study

	Days to Flowering		Days to Maturity		Plant Height		Fruits Per Cluster		Fruits Per Plant		Fruit Weight	
Crosses	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH
C1	2.73	-0.88	0.87	-0.25	2.6	-3.32	0.93	-4	34.06**	22.03	8.82*	-6.15
C2	-0.68	-4.39	-1	-2.22	-2.07	-7.41	8.51	-2.83	22.72	13.44	7.33*	-10.45**
C3	0.45	-1.75	0.25	0	10.29	-1.83	-4.21	-11.6	41.89**	29.46*	36.16**	36.16**
C4	19.24**	18.4**	-4.19**	-4.42**	11.07	4.34	17.6*	12.921	60.42**	51.16**	27.03**	8.74**
C5	7.14**	6.64	2.09	1.97	2.63	-3.92	31.47**	28.35**	50.56**	61.05*	34.77**	11.64**
C6	31.15**	28.44**	7.08**	5.9**	33.33**	33.09*	38.76**	37.51**	4.72	-1.08	52.70**	51.34**
C7	5.21	4.72	0	-0.74	11.55	-7.12	18.66*	16.46	53.21**	33.22*	28.84**	11.33**
C8	33.49**	33.18**	8.07**	7.14**	-7.18	22.49	5.93	-2.32	50.98**	46.62**	10.00**	-4.78**
C9	-3.749	-5.5	-2.63	-2.76	8.85	-13.64	5.58	0.44	44.65**	26.06*	16.70**	16.44**
	Fruit size		Yield per plant		Total soluble solids		Lycopene contents		Beta carotene			
Crosses	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH		
C1	-0.02	-4.75	141.13 **	116.64 **	81.48**	81.48**	-60.30**	-78.39**	-60.06 **	-62.60 **		
C2	-6.63	-10.86*	-13.52	-31.56 **	-10.71**	-13.79*	-55.12**	-76.29**	206.96 **	168.70 **		
C3	2.77	-0.78	0.77	-18.93 *	-16.67**	-24.24**	-39.35**	-51.55**	187.38 **	169.74 **		
C4	8.79*	3.78	185.96 **	170.11 **	32**	22.22**	304.78**	150 **	-60.85 **	-61.07 **		
C5	7.59	2.86	8.18	-17.66 *	42.31**	27.59**	1458.78**	972.73**	91.69 **	77.39 **		
C6	3.8	0.34	1.43	-21.60 **	-7.14	-21.21**	106.43**	6.9	70.68 **	51.40 **		
C7	5.02	1.92	20.47 *	-8.80	-3.45	-9.68	179.79**	157.14**	-39.23 **	-65.73 **		
C8	2.79	-0.04	-23.80 **	-27.47 **	33.33**	29.03**	1475.00**	1100 **	-43.73 **	-68.78 **		
C9	-2.01	-3.61	-13.22 *	-15.64 *	6.25	3.03	75.18**	3.45	-65.94 **	-80.13 **		

Table 2: Heterosis over Mid Parent and Better Parent Values in Different Tomato Genotypes Used in the Study
**Significant, ** Highly Significant*

Source of Variation	Degree of Freedom	Days to Flowering	Days to Maturity	Plant Height	Fruits Per Cluster	Total Fruits Per Plant	Fruit Weight	Fruit Size	Yield Per Plant	Total Soluble Solids	Lycop ene	Beta-Carotene
Replications	3	11.43	6.39	43.49	0.59	154.06	3.74	0.071	0.01	2.18	0.0004	0.00024
Crosses	8	186.31**	72.56**	391.00	0.59*	284.30**	404.56**	0.22*	0.69**	65.50**	0.02**	0.11**
Lines	2	161.58**	28.77*	1009.05*	1.17*	56.02	855.08**	0.44*	0.35**	3.00	0.03**	0.080**
Testers	2	13.08	56.77**	350.63	0.088	553.79**	89.33*	0.15	1.7471**	54.33**	0.04**	0.150**
Line x tester	4	285.27**	102.36**	102.16	0.55	263.86*	336.91**	0.14	0.349**	102.33**	0.01**	0.118**
Error	24	8.27	5.10	202.94	0.26	84.01	16.55	0.08	0.6606	1.10	0.004	0.0075
σ^2 GCA		-4.12	-1.24	12.03	0.001	0.8551	2.8186	0.003	0.0146	-1.53	0.0004	-0.0001
σ^2 SCA		69.26	24.31	-25.19	0.073	44.96	80.090	0.015	0.0805	25.30	0.0048	0.0296
σ^2GCS /σ^2SCA		-0.059	-0.051	-0.488	0.013	0.019	0.035	0.2	0.1825	-0.060	0.083	-0.0033

Table 3: ANOVA for Combining Ability Analysis and Its Variances.
**Significant, ** Highly Significant*

	DF	DM	PH	FC	TNFP	FW	FS	Yield	TSS	LCPN	BCTN
L1	-3.58**	-1.72*	-4.48	-0.27	-2.49	-3.25*	-0.21*	0.02	0.00	-0.05**	0.06 **
L2	3.75**	1.28	-6.07	0.35*	1.37	9.58**	0.17*	0.16 **	-0.50	-0.00	-0.09 **
L3	-0.17	0.44	10.55*	-0.08	1.12	-6.33**	0.03	-0.18 **	0.50	0.05**	0.04 **
T1	-1.00	-2.06**	2.49	0.09	7.29*	3.00*	0.13	0.44 **	1.83**	-0.07**	-0.13 **
T2	1.08	2.28**	-6.20	-0.07	-6.16*	-0.67	-0.04	-0.25 **	0.50	0.05**	0.07 **
T3	-0.08	-0.22	3.71	-0.02	-1.13	-2.33	-0.09	-0.19 **	-.33**	0.02*	0.06 **

Table 4: General Combining Ability Effects in Different Tomato Genotypes Used in the Study
**Significant, ** Highly Significant*
DF= Days to Flowering, DM= Days to Maturity, PH= Plant Height, FC= Fruits per Cluster, TNFP= Total Number of Fruits per Plant, FW= Fruit Weight, FS= Fruit Size, TSS= Total Soluble Solids, LCPN = Lycopene, BCTN= Beta Carotene

Cross	DF	DM	PH	FC	TNFP	FW	FS	Yield	TSS	LCPN	BCTN
C1	1.83	3.14*	-1.77	-0.00	-3.82	-5.08*	-0.04	0.14	6.17**	0.04**	-0.17 **
C2	-2.25	-2.49*	3.51	0.21	-3.95	1.08	-0.19	-0.12	-4.5**	-0.07**	0.04 **
C3	0.42	-0.19	-1.74	-0.21	7.77	4.00	0.23	-0.02	-1.67**	0.02*	0.13 **
C4	0.75	-3.61**	-3.85	0.36**	5.99**	-6.42**	-0.00	0.24 **	-1.33*	0.00	-0.03 **
C5	-7.83**	-1.44	-0.74	0.00	4.35	6.75**	0.10*	-0.03	2.00**	-0.02	-0.01
C6	7.08**	5.06**	4.59	0.36	-10.34*	-0.33	-0.09	-0.21 *	-0.67	0.02	0.04 **
C7	-2.58	0.47	5.62**	0.37	-2.18	11.50**	0.05	-0.38 **	-4.83**	-0.04**	0.20 **
C8	10.00**	4.39**	-2.77	-0.21	-0.40	-7.83**	0.10	0.15	2.50**	0.09**	-0.04**
C9	-7.50**	-4.86**	-2.85	-0.15	2.57	-3.67	-0.14	0.23 *	2.33**	0.04**	-0.16**

Table 5: Specific Combining Ability Effects in Different Tomato Genotypes Used in the Study
**Significant, ** Highly Significant*