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Research Paper

Heterosis and inbreeding depression for fruit yield and related characters in tomato (*Lycopersiconesculentum* Mill.)

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Abstract

A set of 28 crosses were generated by crossing eight inbred lines namely Gujarat Tomato 1 (GT 1), Pusa Ruby, H 24, EC 490190, Arka Vikas, EC 163599, EC 177371 and EC 398704 of tomato. Eight parents, 28F_1 hybrids and 28 F_2 populations using randomized complete block design with three replications were evaluated for yield and other important horticultural characters at Junagadh (Gujarat, India).Significant genetic differences were observed among the parents, F_1 hybrids and F_2 populations for all the characters under study. The cross GT 1 x H 24 exhibited higher heterobeltiosis as well as standard heterosis along with considerable inbreeding depression indicating that this cross could be suitable for exploitation of hybrid vigour on commercial scale for fruit yield. The cross, Pusa Ruby x Arka Vikas had stable performance in both generations hence, can be exploited for development of high yielding stable lines and or isolation of desirable segregants. Negative estimates of heterotic effects were observed in some traits may be attributed to inter-allelic interactions.

Keywords: Heterosis, inbreeding depression, F_1 hybrids, F_2 population, tomato, generations.

Introduction

Tomato (*Lycopersiconesculentum* Mill, 2n = 2x = 24) is a member of Solanaceae family and is a major vegetable crop grown throughout the world both for the fresh fruit market and the processed food industry. It is self pollinated crop but a certain extent of cross pollination may take place. It is a warm loving crop so easily tolerate heat and drought stress. Tomato is being produced in most of the countries of the world with an estimated global production of over 162 million metric tons from an area of 4.83 million hectares [1]. The United States, China, Turkey, Italy and India are the major producers where tomato is consumed as salad, cooked or processed into several preferred by products like ketchup, juice, puree, sauce and whole canned fruit. In India it is the second most important vegetable crop next only to potato. During 2012-13, tomato was cultivated over an area of 8.88 lakh hectares with a production of 182.28 lakh tones [2]. Tomato is a rich source of antioxidants (mainly lycopene and β-carotene), Vitamin A, Vitamin C and minerals like Ca, P and Fe in diet[3]. It is a rich source of lycopene antioxidant that reduces the risk of prostate cancer[4].

Realizing the economic potential of tomato crop in India, there is need to identify suitable cross combinations which have desirable horticultural traits with high yield. Heterosis of tomato crop has been exploited since past century. Hedrick and Booth [5] were the first research workers to observe phenomenon of hybrid vigour in tomato. Heterosis breeding is expected to make a quantum increase in production in cope up with the increasing demand for domestic and export purposes[6, 7]. However hybrid seed production is a high level technology and cost intensive venture. Only wellorganized seed companies with good scientific manpower and well equipped research facilities can afford hybrid seed production. The public sector in developing countries frequently does not have sufficient capacity to supply adequate quantities of good quality vegetable seed to poor farmers and at present, there are few private sector seed companies adapting cultivars to local environments, especially in the poorer countries [8].

Inbreeding is the basic mechanism for providing the raw (base) material for selection. The information regarding nature and magnitude of inbreeding depression is helpful in determining the effectiveness of selection. Thus, the role of inbreeding in the genetic improvement of tomato crop is essentially of great consequence. Farmers themselves often produce seeds of locally preferred or traditional landraces, as the individual markets are too small and private companies have little interest in producing open pollinated cultivars [9]. Therefore, residual heterosis if manifested in the F_2 generation would offer further scope as the grower need not get the highly priced F_1 seeds every year. Manifestation of hybrid vigour in F_1 and its retention in F_2 generation of tomato has been reported earlier[10 and11]. Hence, the present studies were undertaken to study the desirable heterosis in yield and its component traits to develop superior F_1 hybrids and to study the inbreeding depression for better understanding of the plant behavior in hybrid and selfed condition.

Materials and Methods

Experiment was conducted at Instructional farm, Junagadh Agricultural University, Junagadh. Geographically Junagadh is located at 21.5^0 N latitude and 70.5^0 E longitudes with an altitude of 60 m above the mean sea level. Eight tomato diverse inbred lines *viz.,* Gujarat Tomato 1(GT 1), Pusa Ruby, H 24, EC 490190, ArkaVikas, EC 163599, EC 177371and EC 398704were crossed in half diallel fashion to get F_1 seeds. All the F_1 seed was sown, and at the time of pollination about 10 plants were selfed to get F_2 seeds. All the 64 genotypes (8 parents, 28 F_1 hybrids and 28 F_2) were evaluated; the seedlings were transplanted in a randomized block design with three replications at the spacing of 75 cm between rows and 60 cm between plants. Recommended cultural practices and plant protection measures for the region were followed to raise crop successfully. The observations were recorded on five randomly selected competitive plants in parents and F_1s and 20 plants in F_2s for seven characters (Table 1).

Heterosis and inbreeding depression for each trait was worked out by utilizingthe overall mean of each hybrid over replications for eachtrait. Heterosis over better parent (BP) and heterobeltiosis was calculated as per [12] while standard heterosis (SH) using Junagadh Ruby variety as standard check was calculated [13]. The significance of relative heterosis and standardheterosis was carried out by adopting't' test as suggested by[14] and heterobeltiosis was tested by't' test as suggested by[15]. The formula used for estimating various heterosis estimates are as follows:

1) **Relative Heterosis** (RH) = $\dfrac{\overline{F_1} - \overline{MP}}{\overline{MP}} \text{ x } 100$

Where,

$\overline{F_1}$= Mean of F_1 of respective cross

$\overline{MP}$ = mean value of the parents of respective F_1 *i.e.*$(\overline{P_1} + \overline{P_2})/2$ and

S.E. $(F_1 - MP) = (3\ Me/2b)^{0.5}$

Where, $\overline{P_1}$ = Mean performance of parent 1

$\overline{P_2}$ = Mean performance of parent 2

Me = Error mean square and

b= Number of replications

CD $(\overline{MP})$= SE $(\overline{F_1} - \overline{MP})$ x t 0.05 ne

2) **Heterobeltiosis** (BH) = $\dfrac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$

Its significance was tested using student 't' test.

The t{(l-1) (g-1)}={$(F_1 – \overline{BP})$}/ $\overline{SE}$ $(F_1 – \overline{BP})$}

Where,

BP = Mean of better parent (desirable one) of the respective cross

SE $(\overline{F_1} - \overline{BP})$ = (2 Me/b) $^{0.5}$

CD $(\overline{BP})$ = SE $(\overline{F_1} – \overline{BP})$ x t $_{0.05}$ ne

3) **Standard heterosis** = $\dfrac{\overline{F_1} - \overline{SC}}{\overline{SC}} \times 100$

Student 't' test was applied for testing its significance.

t{(l-1) (g-1)}= {$(F_1 - \overline{SC})$}/{(SE $(F_1 - \overline{SC})$}

Where,

$\overline{F_1}$ = Mean performance of hybrids over replications

SC = Mean value of standard check variety (Junagadh Ruby)

$\overline{SE}$ $(\overline{F_1}\text{-}\overline{SC})$ = (2Me/b) $^{0.5}$

CD $(\overline{SC})$ = SE $(\overline{F_1} – \overline{SC})$ x t $_{0.05}$ ne

4) **Inbreeding depression** (ID) = $\dfrac{\overline{F_1} - \overline{F_2}}{\overline{F_1}} \times 100$

Where,

$\overline{F_1}$ = Mean performance of F_1

$\overline{F_2}$ = Mean performance of F_2

The standard error of difference for computing the value of inbreeding depression was calculated as follows

S. Ed = (2 Me/b) $^{0.5}$

Where,

Me = Error mean square for the parents, F_1 and F_2 joint analysis.

Results and Discussion

Estimates of mean sum of squares (Table 1) due to genotypes, parents, and hybrids were highly significant for all the characters indicating the presence of significant variation among the genotypes as well as crosses studied. This emphasized the need of selecting parents for maximization of hybrid vigour with respect to fruit and its related traits. Considerable genetic variation for various traits including fruit yield have been reported by many workers [11, 16and 18]. The mean sum of squares for parents vs.F1 generation respective crosses were also found significant for all yield and its components traits, which indicated presence of substantial amount of heterosis in all cross combinations.

The mean square due toF1vs.F2revealed that the F1differed significantly from their F2 for all characters suggesting the presence of considerable amount of inbreeding depression in F_2 for all the traits. However, all the characters irrespective of the generation were significantly influenced by environmental factors except number of primary branches plant^{-1}, fruits plant^{-1}; hence these characters further can be improved by enacting process of selection.

The mean performance, various heterotic effects and inbreeding depression as well as promising crosses identified for the characters studied are presented in Table 2. The range of mean performance was wide for all characters studied except for days to 50 per cent flowering and number of primary branches plant^{-1}.Flowering is a complex trait and sensitive to photoperiod and temperature. All the crosses exhibited wide range as compared to their parents for almost all the traits. Various heterotic effects were medium to high for all characters.

Table 1: Analysis of variance for fruit yield and related traits in tomato

Source	D. F.	Days to 50 % flowering	Plant height (cm)	Primary branches plant^{-1}	Fruits plant^{-1}	Harvest span (days)	Fruit weight (g)	Fruit yield (Kg plant^{-1})
Replications	2	241.31**	31059.2**	140.95	2.04	7714.39**	6228.44**	3.92**
Genotypes	64	41.23**	580.95**	5.35**	258.14**	106.12**	357.82**	0.38**
Parents	7	32.39**	609.24**	3.13**	127.27**	30.53**	372.28**	0.12**
F1	27	47.76**	591.42**	5.06**	200.24**	84.71**	205.37**	0.34**
F2	27	27.19**	493.86**	4.89**	366.61**	133.86**	350.76**	0.41**
P Vs F_1	1	109.69**	2152.16**	43.09**	58.08**	524.72**	831.91**	2.74**
P Vs F_2	1	15.93**	304.08**	38.84**	61.94**	172.02**	315.55**	1.01**
Error	128	2	19.67	0.28	4.58	9.47	7.69	0.023

*,** Significant at 5 % level and 1 % level, respectivelyResults and Discussion

Table 2: Range of *per se* performance, heterobeltiosis (BP), standard heterosis (SH), inbreeding depression (ID), along with most heterotic crosses and inbreeding depression for fruit yield and related characters in tomato

Characters	Range						Better parent based on *per se* performance	Number of hybrids with significant heterosis and inbreeding depression						Best cross combination *Per se*		Best hybrid with maximum		
	Per se performance			Heterosis		ID (%)		Over BP		Over SH		ID				Heterosis effect over		Inbreeding Depression
	Parents	Crosses		BP (%)	SH (%)			+ve	-ve	+ve	-ve	+ve	-ve			BP	SC	
		F 1	F2											F_1	F_2			
Days to 50 per cent floweri	4 to 6	31 to 44	33 to 48	-29 to 12	-14 to 20	-37 to 6	P_4 (35) P_8 (37)	1	19	14	6	1	13	P_1 x P_8 & P_5	P_7 x P_8 (35)	P_5 x P_8 (-29)	P_1x P_8 (-14)	-38

ng													x P_8 (31)				
Plant height (cm)	63 to 107	81 to 134	77 to 131	-23 to 30	10 to 59	-16 to 28	P_1 (106) P_7 (106)	4	4	19	0	13	3	P_4 x P_7 (67)	P_2 x P_6 (59)	P_2 x P_3 (30)	P_1 x P_2 (59)	4
Primary branches plant^{-1}	3 to 6	4 to 11	4 to 10	32 to 78	-29 to 74	-149 to 38	P_8 (6) P_2 (6)	16	3	11	4	10	10	P_1 x P_8 (4)	P_4 x P_5 (5)	P_4 x P_5 (78)	P_4 x P_5 (74)	17
Fruits plant $^{-1}$	20 to 37	17 to 45	13 to 59	-44 to 33	-48 to 39	-55 to 41	P_7 (37) P_2 (35)	5	10	7	9	13	11	P_5 x P_8 (6)	P_4 x P_8 (5)	P_1 x P_3 (33)	P_1 x P_3 (39)	21
Fruit weight (g)	22 to 54	31 to 67	22 to 59	-44 to 50	-21 to 74	-41 to 62	P_2 (54) P_4 (47)	7	8	12	2	19	3	P_4 x P_7 (67)	P_2 x P_6 (59)	P_6 x P_7 (50)	P_4 x P_7 (74)	33
Harvest span (days)	46 to 57	22 to 57	40 to 66	-33 to 17	-26 to 18	-43 to 18	P_7 (57) P_1 (54)	1	18	3	8	6	12	P_4 x P_7 (2)	P_4 x P_8 (2)	P_3 x P_6 (17)	P_3 x P_6 (18)	18
Fruit yield (Kg plant^{-1})	0.6 to 1	1 to 2	1 to 2	31 to 99	-29 to 75	-29 to 47	P_1 (1) P_2 (1)	11	0	1	8	5	12	P_4 x P_8 (1)	P_4 x P_8 (1)	P_1 x P_3 (99)	P_1 x P_3 (76)	47

P_1- GT1 P_2 – Pusa Ruby P_3-H 24 P_4-Ec 490190 P_5–ArkaVikasP_6 - Ec 163599 P_7- Ec 177371 P_8- Ec 398704

Heterosis

Most of the crosses exhibited significant and desirable heterosis over better parent (heterobeltiosis)for days to 50 per cent flowering,primary branches plant^{-1} and fruit yield (kg plant^{-1}), whereas greater magnitude of desirable standard heterosis was observed for all the characters except harvest span (days) and fruit yield (kg plant^{-1}). The negative heterosis observed in some of the crosses may be attributed to non-allelic interaction with the large number of decreasing alleles.Some of the crosses did not display significant heterosis that could be due to internal cancellation of positive and negative effects and the dominance not being of unidirectional in nature [19].

A perusal of the crosses with heterotic effects revealed that none of the crosses were superior for all the traits studied. No clear cut relationship between *per se* performance and heterosis effect. However,the cross ArkaVikas x EC 398704 for days to 50 per cent flowering, EC 490190 x ArkaVikas for primary branches plant^{-1} and GT1 x H 24 for fruit yield plant^{-1} showed significant heterobeltiosis in desired direction. The cross GT 1 x Pusa Ruby for plant height, EC 490190 x ArkaVikas for fruits plant $^{-1}$ and H 24 x EC 490190 showed significant and positive standard heterosis.Crosses Pusa Ruby x H 24 for fruits plant^{-1}and fruit yield plant^{-1} showed significant and positive heterobeltiosis as well as standard heterosis. High heterosis for fruit yield and its contributing traits has been reported [20- 24].

Inbreeding depression

The inbreeding depression studied in the F_2s showed that cross,EC 490190 x EC 398704 was among five crosses recorded highest significant and positive inbreeding depression for harvest span, fruits plant $^{-1}$and fruit yield plant^{-1}. The cross EC 177371 x EC 398704, Pusa Ruby x EC 163599, EC 490190 x EC 398704 showed high inbreeding depression for days to 50 per cent flowering, plant height and fruits plant^{-1}, respectively. Similar findings also cited for different traits [11, 17, 23, 25, 26, 27 and28].

Improvement in a complex attribute like fruit yield may be convenient if breeding programme will be made through attributing agro economical characters. The comparison of three crosses with high heterobeltiosis for fruit yield with other yield attributing traits (Table 3) revealed that manifestation of heterosis for fruit yield by GT 1 x H 24, also showed heterotic effects for other traits. Hence, it is suggested that this may be advanced and exploited hybrid vigour in future breeding programme for improving fruit yield in tomato. The crosses that showed higher estimates of heterosis in general did not show high inbreeding depression.

Table 3: Comparative study of three heterobeltiotic crosses

Name of Cross	Percent heterosis over better parent (heterobeltiosis)						
	Days to 50 per cent lowering	Plant height (cm)	Primary branches plant^{-1}	Fruits plant $^{-1}$	Harvest span (days)	Fruit weight (g)	Fruit yield (Kg plant^{-1})
GT 1 X H 24	-21.98	17.46	10.73	32.52	-18.49	6.92	98.67
Pusa Ruby X ArkaVikas	-18.29	5.78	-5.55	19.89	-11.69	-9.01	88
Pusa Ruby X Ec 163599	-22.49	-1.99	11.22	-21.12	-7.37	-21.19	67

Conclusion

The results revealed that both additive and non additive gene effects are main components which control fruit yield and its contributing traits. Therefore, the breeding methods will have to be modified in respect to capitalize the genetic variance due to fixable and non fixable gene interactions. The crosses with high heterotic effects for characters under study in general also showed inbreeding depression, suggesting that heterosis was mainly due to non additive gene action. Hence the crosses GT 1 x H 24, Pusa Ruby x H 24 and Pusa Ruby x Arka Vikas may be advanced and be exploited for production of F_1 hybrid.

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