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***Research article***

# STUDIES ON HYBRID VIGOUR IN $F_1$ AND ITS RETENTION IN $F_2$ FOR FRUIT FIRMNESS AND RELATED TRAITS IN TOMATO

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**ABSTRACT:** Tomato varieties having less number of locules, thicker pericarp and good firmness are preferred by the consumers. A set of 28 half diallel crosses were generated by crossing 8 inbred lines of tomato (*Lycopersicon esculentum* Mill) namely Gujarat Tomato 1 (GT 1), Pusa Ruby, H 24, Ec 490190, Arka Vikas, Ec 163599, Ec 177371 and Ec 398704. Parents, $F_1$ hybrids and $F_2$ populations using randomized complete block design with three replications were evaluated for fruit weight, equatorial and polar diameter, number of locules, pericarp thickness and firmness at Junagadh Agricultural University, Junagadh (Gujarat, India). Significant genetic differences were observed among the parents, their $F_1$ hybrids and $F_2$ populations for fruit firmness related characters except locules fruit$^{-1}$ under study.

The cross Arka Vikas x Ec 398704 followed by GT 1 X Ec 490190 and Pusa Ruby X Ec 163599 exhibited higher heterobeltiosis as well as standard heterosis along with considerable inbreeding depression for fresh fruit firmness hence, is desired for firm fruited tomato plants and would score over yield when tomato are cultivated for distant markets. This cross also involved at least one parent having grater firmness as well pericarp thickness and few locules, hence, can be recommended for breeding improved fruit firmness lines in future.

**Key words:** Heterosis, inbreeding depression, $F_1$ hybrids, $F_2$ population, tomato, fruit firmness

## INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most consumed vegetable in the world and an excellent plant genetic analysis system. There is demand for development of high yielding open pollinated and or hybrid cultivars of tomato. Hybrids are usually known to be characterized by good quality characters and high yield. Therefore, tomato hybrid cultivars were, extensively, used in commercial production Solieman *et al*. (2013). The improvement of vegetable quality requires knowledge of consumers needs and desires.

Quality has gained importance in India after signing and notification of the GATT recommendations under WTO.

The straight implication of this development is the gross reductions in the import duties leading to cheaper imports, which includes fresh as well as processed vegetables. It is a well-known fact that food items imported from abroad are much better in terms of quality owing to stringent production process. Thus, to meet the challenge posed by cheaper imports, it is high time to redefine our breeding and production objectives to include market quality as integrated objective. Fruit firmness is an important quality character for marketing, transportation and domestic use. Consumer perception of the quality of tomato fruits for fresh consumption is determined by appearance, firmness and flavor Stevens (1986). Average fruit weight plays key role in acceptance of produce by the consumer. Medium sized fruit weighing 65 to 85 g are most preferred in the market Thakur *et al.* (2005). Whereas Sharma *et al*. (2001) stated that fruit equatorial as well as polar diameter had direct influence on fruit weight. However, pericarp thickness alone accounts for 64 % of fruit firmness Athrens *et al*. (1987). Tomato varieties having less number of locules, higher pericarp and good firmness are preferred by the consumers Joshi *et al*. (2005a). Locules present in tomato fruit play an important role in governing its quality as it is primarily correlated with fruit size and number of fruits Bhutani and Kalloo (1991) and negatively associated with fruit firmness Thakur and Kohli (2005). Hence development of firm fruited tomato having a few locules and large size is the basic need for market quality. However, it is costly to produce hybrid seeds every year by artificial emasculation and pollination.

Residual heterosis if manifested in the $F_2$ generation would offer further scope, as the growers need not get the highly priced $F_1$ seed every year. Possibilities of using $F_1$ seeds to raise $F_2$ in tomato had been reported by Larson and Currence (1944) in USA and Choudhary *et al*. (1965) in India with the hybrid retaining heterosis in $F_2$ generation. Also the information regarding magnitude of inbreeding depression will be helpful in determining the effectiveness of selection. Consequently present experiment was planned to identify such parental lines that will produce superior hybrid combinations having higher fruit firmness in tomato.

## MATERIALS AND METHODS

Eight tomato inbred lines *viz.*, $P_1$ (Gujarat Tomato 1), $P_2$ (Pusa Ruby), $P_3$ (H 24), $P_4$ (Ec 490190), $P_5$ (Arka Vikas), $P_6$ (Ec 177371), $P_7$ (IC89976) and $P_8$ (Ec 398704) were crossed in half diallel fashion to get $F_1$ seeds. Experiment was conducted at 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. All the $F_1$ seed was sown and at the time of pollination about 10 plants were selfed to get $F_2$ seeds. The parents, $F_1$ hybrids and $F_2$ population were field evaluated using randomized complete block design with three replications. 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 were followed.

The observations were recorded for fruit weight, equatorial and polar diameter, number of locules, pericarp thickness and firmness. Fruit firmness was judged as per the method reported by Nandasana (2005) using Texture Analyser TA XT2i instrument, a microprocessor analysis system developed by Stable Micro Systems England. The Texture Analyser measures force, distance and time. It consists of two separate module *viz.*, the test bed and the console (keyboard). To obtain a great amount of analytical flexibility, the texture analyser was interfaced with an IBM PC with software called ‘Texture Expert’ which facilitate to view the data in a graphical format, finding multiple peaks, areas and averages and saving of data on the disk. The results were read directly from the saved graphs in computer directly. The compression test was used to evaluate the force required to rupture the tomato fruits under quasi stable loading. The following TA XT2i setting was done for the compression test

| | |
|---|---|
| Mode | : measures force in compression |
| Option | : return to start |
| Pretest speed | : 2 mm $s^{-1}$ |
| Posttest speed | : 10 mm $s^{-1}$ |
| Distance | : 15 to 20 mm |
| Trigger type | : Auto 20 |
| Data acquisition rate | : 200 pps |
| Accessory | : 75 mm compression platen (P/75) using 20 kg load cell |

For each test a single tomato fruit was placed centrally on blank plate secured on the heavy duty platform. The static compression test of the whole fruit was carried out at predetermined speed, forcing the flat platen kept on the fruit to apply pressure around the mid region to fruit (with pedicel end at right angle to the direction of force). Once a trigger force of 20 g had been achieved the compression platen proceeded to move down on to the tomato fruit at constant loading velocity up to predetermined distance at which fruit gets rupture. At the same time, the force applied and corresponding deformations was observed from computer and results were saved on the disk. In this way this test was conducted for five tomato fruit immediately after harvest and average values are reported. The average values for fruit firmness (Kg $cm^{-1}$) were calculated using following formula. Fruit firmness (Kg $cm^{-1}$) = Fruit first rupture force (Kg)/Deformation (cm).

Heterosis over better parent (BP) as per Fonseca and Patterson (1968) was calculated, while standard heterosis (SH) using Junagadh Ruby variety as standard check was calculated as per Meredith and Bridge (1972). Inbreeding depression (ID) from $F_1$ to $F_2$ was calculated by the formula, ID (%) = $[(F_1 – F_2) / F_1] \times 100$ where $F_2$ denotes the mean of $F_2$ population for a trait. Data were compiled for analysis of variance for all these traits using method suggested by Panse and Sukhatme (1985).

## RESULTS AND DISCUSSION

Analysis of variance revealed (Table 1) highly significant differences among the genotypes, parents, and hybrids for all the characters indicating the presence of significant variation among the genotypes as well as crosses. 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 earlier researchers Falluji and Lambeth (1980), Kanthaswamy and Balakrishnan (1989), Tagle (1992), Rai *et al.* (1988), Okasha *et al.* (2001), Pandey and Dixit (2001) and Hazra *et al*. (2001). The mean sum of squares for parents vs $F_1$s were also found significant for fruit firmness and its components traits, except locules fruit $^{-1}$ which indicated presence of substantial amount of heterosis in all cross combinations.

**Table 1 Analysis of variance (mean sum of squares) for fresh fruit firmness and related traits in 8 x 8 diallel set of tomato**

| Source | D.F. | Fruit weight (g) | Fruit polar diameter (cm) | Fruit equatorial diameter (cm) | Number of locules fruit$^{-1}$ | Fruit pericarp thickness (cm) | Fruit firmness (Kg cm$^{-1}$) |
|---|---|---|---|---|---|---|---|
| Replications | 2 | 6228.44** | 1.78** | 2.61** | 1.15** | 0.032** | 0.98** |
| Genotypes | 64 | 357.82** | 0.86** | 1.76** | 2.61** | 0.030** | 1.03** |
| Parents | 7 | 372.28** | 0.97** | 1.86** | 3.24** | 0.018** | 0.42** |
| $F_1$s | 27 | 205.37** | 0.095** | 2.02** | 2.01** | 0.019** | 1.12** |
| $F_2$s | 27 | 350.76** | 1.54** | 0.88** | 3.20** | 0.040** | 1.01** |
| P Vs $F_1$ | 1 | 831.91** | 5.40** | 4.14** | 0.096 | 0.130** | 0.71** |
| P Vs $F_2$ | 1 | 315.55** | 0.25** | 0.83** | 0.093 | 0.180** | 0.023* |
| Error | 128 | 7.69 | 0.013 | 0.034 | 0.044 | 0.002 | 0.006 |

* Significant at 5 % level ** Significant at 1 % level

The mean square due to $F_1$s vs $F_2$s revealed that, the $F_1$s differed significantly from their $F_2$s for all character suggesting the presence of considerable amount of inbreeding depression in $F_2$s.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 except fruit pericarp thickness and firmness. All the crosses exhibited wide range as compared to their parents for almost all the traits in both generations. Various heterotic effects were medium to high for all characters in both directions. 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.

**Fruit weight**: Besides Ec 490190 x Ec 177371 cross, other 11 crosses recorded significantly higher SH over check variety Junagadh Ruby, hence, these $F_1$s are desired for higher fruit weight. For BH estimates, the number of negative estimates outnumbered positive estimates due to inclusion of indigenously developed parental lines as pollen receiving parents. Hence, this trait appears to be paternally inherited and geographically correlated. This also suggests non existence of variability among the indigenous parents included in the present study. The extent of inbreeding depression (ID) ranged from -41.29 to 62.30 per cent among 22 significant crosses. Nineteen crosses exhibited reduction in fruit weight, while, only three crosses showed improvement for it in $F_2$ generation. Similar reduction in fruit weight was earlier reported by Tagle (1992), Rai *et al.* (1998), Okasha *et al.* (2001) and Pandey and Dixit (2001). The crosses recording improvement in fruit weight in $F_2$ generation for tomato fruit weight could be used as promising genotypes to reduce hybrid seeds cost.

**Fruit polar diameter:** The estimates of BH and SH were low to moderate in magnitude for this trait. The number of positive estimates scored over the negative estimate which itself is indicative of considerable amount of heterosis in desirable direction. Maximum improvement for this trait was observed in the cross $P_4$ x $P_5$, whereas, the cross $P_1$ x $P_7$ exhibiting maximum BH and SH also exerted maximum ID indicating that heterosis observed in $F_1$ does not persist in $F_2$ generation. Thus crosses exhibiting significant heterosis in $F_1$ showed high ID in $F_2$ generation revealing presence of non additive gene, as reported by Pandey and Dixit (2001) and Hazra *et al*. (2001).

**Fruit equatorial diameter:** The estimates of BH and SH for varied from -33.27 to 47.25 and -29.51 to 54.73 per cent, respectively (Table 2) for this trait. Corresponding number of positive heterosis estimates were found in 10 and 17 crosses, respectively. This indicates considerable amount of heterosis among the significant crosses as earlier reported by Ghosh *et al.* (1997), Srivastava *et al.* (1998), Rai *et al.* (1998) and Sharma *et al.* (2001).The ID was observed in both directions, but 17 crosses exhibited reduction in fruit girth in $F_2$. However, when compared to its $F_1$ generation only one cross Ec 490190 x Ec 398704 exhibited 24.72 per cent improvement in fruit girth. The crosses which had highest estimates of heterosis also depicted highest inbreeding depression indicating exploitation of hybrid vigour in such cross combination in $F_1$ generation. Tagle (1992), Rai *et al.* (1998) and Pandey and Dixit (2001) also observed reduction in fruit equatorial diameter in three, 21 and 18 crosses in $F_2$ generation, respectively.

**Table 2 Range of *per se* performance, heterobeltiosis (BP), standard heterosis (SH), inbreeding depression (ID), along with most heterotic crosses and inbreeding depression for fresh fruit firmness and related traits in 8 x 8 diallel set of 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 BH | | Over SH | | ID | | | | Heterosis effect over | | Inbreeding Depression |
| | Parents | Crosses F$_1$ | Crosses F$_2$ | BH (%) | SH (%) | | | +ve | -ve | +ve | -ve | +ve | -ve | F$_1$ | F$_2$ | BH | SC | |
| Fruit weight (g) | 21.66 to 53.99 | 30.50 to 67.36 | 22.16 to 59.00 | -43.51 to 50.13 | -21.42 to 73.51 | -41.29 to 62.36 | P$_2$ (53.99) P$_4$ (47.47) | 7 | 8 | 12 | 2 | 19 | 3 | P$_4$ x P$_7$ (67.36) | P$_2$ x P$_6$ (59.00) | P$_6$ x P$_7$ (50.13) | P$_4$ x P$_7$ (73.51) | 32.72 |
| Polar diameter (cm) | 2.17 to 4.18 | 3.15 to 4.03 | 2.27 to 4.91 | -24.50 to 34.22 | 5.30 to 23.01 | -39.62 to 43.54 | P$_4$ (4.18) P$_2$ (3.51) | 13 | 12 | 17 | 0 | 17 | 5 | P$_1$ x P$_8$ (4.03) | P$_4$ x P$_5$ (4.91) | P$_1$ x P$_7$ (34.22) | P$_1$ x P$_7$ (23.01) | 43.54 |
| Equatorial diameter (cm) | 3.02 to 5.31 | 3.34 to 5.89 | 2.81 to 4.81 | -33.47 to 47.25 | -29.51 to 54.73 | -24.72 to 38.77 | P$_2$ (5.31) P$_1$ (4.68) | 10 | 8 | 17 | 3 | 17 | 1 | P$_5$ x P$_8$ (5.89) | P$_4$ x P$_8$ (4.81) | P$_5$ x P$_8$ (47.25) | P$_2$ x P$_8$ (54.73) | 38.77 |
| Number of locules fruit$^{-1}$ | 2.17 to 5.51 | 2.13 to 5.30 | 2 to 7.18 | -44.67 to 18.80 | -39.32 to 51.09 | -56.97 to 41.99 | P$_4$ (2.17) P$_7$ (2.83) | 1 | 21 | 7 | 8 | 11 | 6 | P$_4$ x P$_7$ (2.13) | P$_4$ x P$_8$ (2.00) | P$_3$ x P$_4$ (-44.67) | P$_4$ x P$_7$ (-39.32) | -33.02 |
| Pericarp thickness (cm) | 0.31 to 0.50 | 0.33 to 0.60 | 0.30 to 0.68 | -22.52 to -51.00 | 19.87 to 47.41 | -51.43 to 49.15 | P$_4$ (0.50) P$_5$ (0.42) | 0 | 13 | 6 | 0 | 8 | 8 | P$_4$ x P$_8$ (0.60) | P$_4$ x P$_8$ (0.74) | - | P$_2$ x P$_6$ (47.41) | -22.22 |
| Fruit firmness (Kg cm$^{-1}$) | 2.03 to 3.05 | 1.31 to 4.20 | 1.61 to 4.27 | -52.25 to 40.11 | -47.11 to 69.72 | -60.25 to 41.55 | P$_4$ (3.05) P$_7$ (3.00) | 11 | 14 | 20 | 7 | 15 | 9 | P$_1$ x P$_4$ (4.20) | P$_1$ x P$_7$ (4.27) | P$_4$ x P$_8$ (40.11) | P$_4$ x P$_8$ (69.72) | 33.44 |

P$_1$:GT1, P$_2$: Pusa Ruby, P$_3$:H 24, P$_4$ :Ec 490190, P$_5$: ArkaVikas, P$_6$ : Ec 163599, P$_7$: Ec 17737, P$_8$: Ec 398704

**Number of locules fruit$^{-1}$:** The BH and SH estimates of were significant for 21 and eight crosses, respectively (Table 2) in the present investigations. The maximum number of crosses registered negative heterosis estimates, which are in desirable direction. However, positive heterosis was also recorded in few crosses. Sundaram *et al.* (1994), Mandal *et al.* (1989), Reddy and Reddy (1994), Joshi *et al.* (2005a) and Joshi *et al.* (2005b) also recorded heterosis estimates in both directions with varying magnitudes. The heterobeltiosis estimates revealed lowest locule number in the cross H 24 x Ec 490190 indicating that male parents involved in the crosses ought to have lower locule number. The ID estimates were found in the range of -56.97 to 41.99 per cent among 16 significant crosses, of which 11 and six crosses had positive and negative estimates, respectively. This indicates lower magnitude of ID in desirable direction Bhutani and Kalloo (1991).On the contrary majority of the crosses showed increase in number locules indicating that desirable plants having few locule could be selected from the segregating generation in future crop improvement programme.

**Fruit pericarp thickness:** The estimates of BH and SH ranged from -22.52 to -51.00 and 19.87 to 47.41 per cent, respectively (Table 2). The crosses, Arka Vikas x Ec 177371, Pusa Ruby x Ec 177371, H24 x Ec 398704 and Pusa Ruby x Ec 163599 recorded above 60.00 RH estimates. Thus, it appears that Ec 177371 as male parent and Pusa Ruby as female parent had maximum contribution in desired direction followed by Ec 163599 and Ec 398704 for this trait under present study. The negative BH estimates were significant for 13 crosses, indicating non additive gene governance among the parents studied. Around six crosses had greater SH estimates hence, all those are preferred over check variety Junagadh Ruby. The ID value was of moderate magnitude in both directions indicating that considerable loss as well as improvement in pericarp thickness in F$_2$ generation as compared to F$_1$.Hence, progeny selection in early segregating generation would be effective for their mobilization.

**Fresh fruit firmness:** It is an important quality trait that conditions the post harvest life of the produce. Heterosis estimates were moderate to high for this trait in both directions. As many as 11 and 20 crosses depicted positive BH and SH estimates, respectively (Table 2). Earlier workers Gunasekara and Parera (1999), Jawaharlal and Vereravagavatham (2003) and Joshi *et al.* (2005a) also reported heterosis estimates ranging from lower to higher magnitude. The cross Ec 490190 x Ec 398704 had higher positive BH as well as SH estimates hence, is desired for firm fruited tomato plants and would score over yield when tomato are cultivated for distant markets as reported by Joshi *et al.* (2005a). This cross also involved a parent having grater firmness as well pericarp thickness and few locules, hence, can be recommended for breeding improved fruit firmness lines in future Wang *et al.* (1995). Like heterosis estimates, residual heterosis was also found in both directions with moderate to high magnitude. Falluji and Lambeth (1984) have reported moderate to high amount of residual heterosis in tomato. The cross H 24 x Arka Vikas recorded maximum ID value indicating moderate improvement in its fruit firmness in $F_2$ generation as compared to $F_1$ generation. While the non significance of ID in either direction in some crosses was due to the fact that, their $F_1$ hybrids themselves had registered negative or non significant heterosis as reported by Kanthaswamy and Balakrishnan (1989).

**Table 3 Comparative studies of three heterobeltiotic crosses for fresh fruit firmness and related traits in 8 x 8 diallel set of tomato**

| Name of Cross | Percent heterosis over better parent (heterobeltiosis) | | | | | |
|---|---|---|---|---|---|---|
| | Fruit weight (g) | Polar diameter (cm) | Equatorial diameter (cm) | Number of locules fruit$^{-1}$ | Pericarp thickness (cm) | Fruit firmness (Kg cm$^{-1}$) |
| Ec 490190 x Ec 398704 | -16.80 | 12.42 | -3.58 | -25.13 | -39.67 | 40.11 |
| GT 1 X Ec 490190 | -24.69 | 11.00 | -2.27 | -22.92 | 4.64 | 37.45 |
| Pusa Ruby X Ec 163599 | -21.19 | -10.58 | 10.60 | -11.61 | 13.15 | 32.98 |

The comparison of three crosses with high heterobeltiosis for fruit firmness with other related attributing traits (Table 3) revealed that manifestation of heterosis for fruit firmness by cross Ec 490190 x Ec 398704, also showed heterotic effects for other traits.

## CONCLUSION

Hybrid vigour in most of the tomato varieties is exploited for total yield and uniformity of the produce. But the quality characters like thick skinned fruit of uniform colour in hybrid tomato are of much value as far as processing and marketing of the produce are concerned. Finding out parents for suitable cross combination for commercial exploitation of heterosis in tomato is vital for the commercial success of $F_1$ hybrid. 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. In the present study cross Ec 490190 x Ec 398704 depicted highest firmness hence it may be advanced and exploited hybrid vigour in future breeding programme for improving better fruit firmness in tomato.

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