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EXPRESSION OF HETEROSIS IN FLORAL TRAITS AND FRUIT SIZE IN TOMATO (*Solanum lycopersicum*) HYBRIDS

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ABSTRACT
The present research was prompted by lack of improved tomato cultivars adapted to the humid tropical. Tomato hybrids were developed by crossing wild and cultivated tomato varieties. The average fruit size of the tomato hybrids generated did not meet the level of acceptability in the local market. A modified three way cross between the advanced generation of the tomato hybrids and an exotic variety with giant fruit size was initiated. The resulting hybrids were evaluated to determine the magnitude of heterosis in floral traits and fruit size. Highly significant differences were observed among the genotypes in all the traits studied. Highly significant heteroses were found for flower length which ranged from 2.7 to 13.4% and 7.2 to 21.9%, style length 2.6 to 14.5% and 6.8 to 43%, fruit length 1.9 to 5.1% and 4.6 to 27.4% over the better and mid parents, respectively. Similarly, a significant positive heterosis was recorded for ovary area which ranged from 1.2 to 6.2%, ovary perimeter 1.6 to 6.2%, ovary length 4.8 to 15.3%, fruit diameter 5.7 to 6.5% and number of fruits per plant 14.56 to 55.195% over mid parents only.

Key words: Heterosis, floral traits, modified three way cross, tomato, *Solanum spp*

INTRODUCTION
Tomato is one of the most important fruit vegetables in Nigeria. It is mainly grown by small scale farmers under arable conditions. Though, tomatoes are popular in Nigeria with gross production of about 600,000 tonnes annually, its yield varies from place to place. The bulk of tomato fruits are produced in northern Nigeria and transported to the southern part of Nigeria. Many constraints affect the productivity and quality of tomato. Some of such constraints are high humidity and rainfall and lack of locally adapted cultivars.
The development of tomato that can withstand the high humidity conditions of south eastern Nigeria prompted the initiation of a hybridization programme. Crosses between two commercially acceptable but poorly adapted cultivars, Roma VF and Tropica and wild variety produced tomato hybrids with prolific fruiting (Uguru and Umukoro, 2005; Atugwu and Uguru, 2012) and increased disease resistance (Uguru and Igili, 2002) under high rainfall conditions. However, the average fruit size of the tomato hybrids generated did not meet the level of acceptability in the local market. Fruit size improvement can be enhanced by considering the fruit development pattern such as floral traits and other fruit size components.

The superiority of hybrids has long been exploited in agriculture. It has been established that heterotic expression in tomato is in the form of greater vigour, faster growth and development, high yield, increased number of fruits, fruit size, improved quality, uniformity and adaptation to adverse conditions (Yordanov, 1983). Heterosis occurred in F_1 hybrids for all traits of interest but their values varied among crosses and characters. However, genotypes harboring desirable characters are vital for further improvement (Farhan *et al*., 2012). Choudhary *et al*. (1965) emphasized the extensive utilization of heterosis to step up tomato production but tomato hybrids performed differently under different agro climatic zone. Therefore, the present study was undertaken to

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evaluate and determine the magnitude of heterosis in floral traits and fruit size in tomato hybrids.

MATERIALS AND METHOD

The experimental materials for this study comprised the parent A (Roma VF and Tropica), parent B (wild tomato, *Solanum pimpinefollium*), parent C (large fruited inbred tomato variety, *S. lycopersicum*, supersteak imported from USA, round shape medium size and oval shape medium size), advanced generations of tomato lines (F_{12}), S1E, S3S and S4S (progenies of parent A and B) and F_1 (progenies of advanced generations of tomato line of parent (A and B) and parent C.

The evaluations of the floral traits and fruit size characters were carried out in the Department of Crop Science screenhouse, University of Nigeria, Nsukka in 2013 and 2014. The seeds were raised in nursery boxes filled with sterilized soil, well cured poultry manure and river sand mixed at a ratio of 3:2:1 by volume. The experiment was laid out in a Completely Randomized Design with three replications. The seedlings were transplanted into polybags arranged in the screenhouse at four weeks after planting. The flowers were harvested and immediately placed in plastic bag and taken to the laboratory for the measurement of the floral traits at anthesis. Flowers were cut longitudinally to expose floral parts and data were collected on flower length and width, stalk width, stigma diameter, length and diameter of the style, anther diameter and length, ovary diameter, length, area and perimeter. The measurements were done using ocular micrometer. The full matured fruits were also harvested and cut longitudinally for the observations and determination of number of locules per fruit, fruit diameter and length.

Heterobeltiosis or better parent heterosis (BPH) was estimated in terms of percent increase or decrease of the F_1 hybrid over the better parent as:

BPH (%) = [F_1-BP/BP] x 100

Mid- parent heterosis (MPH) was calculated in terms of percent increase (+) or decrease (-) of the F_1 hybrids over the mid parent as:

MPH (%) = [F_1-MP /MP] x 100 (Allard, 1960 and Uguru, 2005).

Test of significance was done as described by Kumar *et al*.(2011) using Critical Difference (CD) as:

$$CD = \sqrt{\frac{2me}{r}} \times t$$

Where

t = t tabulated at 5% probability

me = error mean square

r = number of replications

RESULTS

The results of the heterosis over better and mid parents are presented along with the mean performances of the parents and hybrids in Tables 1 and 2. The results showed variations among the tomato lines in all the characters studied.

Table 1 contains information on estimation of heterosis of floral traits. Positive heterosis was obtained for flower length in all the six the hybrids and the values ranged from 2.7 to 13.4% and 7.2 to 21.9% over the better and mid parents, respectively. A significant negative heterosis was found for flower width in all the hybrids and they ranged from -37.6% to -4.3% and -19.2% to -2.2% over the better and mid parents, respectively. Positive heterosis was found for the style length in all the six hybrids. The values ranged from 2.6 to 14.5% and 6.8 to 43% over the better and mid parents, respectively.

The results with respect to style diameter, stigma diameter, stigma length and ovary diameter are presented in Table 1. A significant negative heterosis was obtained for the style diameter in all the six hybrids and the values ranged from -81.9% to -20.6% and -68.3% to -1.6% over the better and mid parents, respectively. Similarly, a significant negative heterosis was obtained for the stigma diameter that ranged from -81.9% to -20.6% over the better parent. Positive significant heteroses (2.4 and 10.9%) were obtained in two hybrids, MO x (W x R) and MO x (W x T) over the mid parents. All cross combinations in this study showed a significant negative heterosis in stigma length except for the MR x (W x T). Significant negative heteroses were obtained for the ovary diameter in all the hybrids except MO x (W x R). The range for the negative heterosis was -58.6 to -2.9% and -38.3 to -3.2% over better and mid parents, respectively.

The heterotic values with respect to ovary length and ovary area are also contained in Table 1. The range for the negative heterosis was -27.5 to -6.4% and -17.7 to -1.7% over better and mid parents, respectively. For the ovary length, only the hybrid (MO x (W x T)) was found with significant positive heterosis (1.7%) over the better parent. Three hybrid (MO x (W x R), (MO x (R x W) and (MO x (W x T) were found with positive heterosis (7.1, 4.8 and 15.3%, respectively) over the mid parent. Negative heteroses were obtained for the ovary area in all the six hybrids and the values ranged from -77.7 to -16.0% over the better parent. Three hybrids (MO x (W x R), (MO x (W x T) and (MR x (W x T) were found with positive heteroses (3.6, 6.2 and 1.2%) over the mid parent.

Table 1: Mean performance of parents and F1 hybrids and extent of heterosis for floral traits.

Character	Cross	P1	F1	P2	BPH	MPH	CD (P=0.05)
Flower length	(i)	0.341	0.527	0.523	0.823	21.916	0.04159
	(ii)	0.437	0.511	0.497	2.747	9.388	
	(iii)	0.437	0.514	0.523	-1.582	7.240	
	(iv)	0.437	0.499	0.480	3.969	8.863	
	(v)	0.441	0.544	0.480	1.513	18.198	
	(vi)	0.341	0.531	0.523	1.641	22.905	
Flower width	(i)	0.245	0.154	0.133	-37.677*	-19.200*	0.01009
	(ii)	0.166	0.145	0.132	-12.221*	-2.169*	
	(iii)	0.166	0.145	0.133	-12.230*	-2.665*	
	(iv)	0.166	0.141	0.130	-14.885*	-4.702*	
	(v)	0.162	0.155	0.130	-4.263*	6.100*	
	(vi)	0.245	0.142	0.133	-41.914*	-24.694*	
Style length	(i)	0.167	0.431	0.433	-0.594	43.484	0.04623
	(ii)	0.346	0.416	0.401	8.224	11.391	
	(iii)	0.346	0.416	0.433	-3.985	6.796	
	(iv)	0.346	0.402	0.391	2.641	8.980	
	(v)	0.347	0.448	0.391	14.517	21.461	
	(vi)	0.167	0.433	0.433	0.433	44.272	
Style diameter	(i)	0.109	0.019	0.016	-81.874*	-68.287*	0.00552
	(ii)	0.031	0.018	0.016	-42.099*	-22.951*	
	(iii)	0.031	0.021	0.016	-20.575*	-10.554*	
	(iv)	0.031	0.020	0.015	-24.287*	-13.633*	
	(v)	0.026	0.020	0.015	-34.906*	-1.606*	
	(vi)	0.109	0.020	0.016	-81.684*	-67.958*	
Stigma diameter	(i)	0.119	0.026	0.022	-78.539*	-63.729*	0.00552
	(ii)	0.035	0.025	0.020	-29.383*	-10.484*	
	(iii)	0.035	0.032	0.022	-10.199*	10.925*	
	(iv)	0.035	0.029	0.021	-18.393*	2.380*	
	(v)	0.034	0.026	0.021	-23.098*	-4.712*	
	(vi)	0.119	0.025	0.022	-78.346*	-0.634*	
Stigma length	(i)	0.023	0.011	0.012	-6.397*	-9.333*	0.01235
	(ii)	0.015	0.013	0.009	-12.826*	7.114*	
	(iii)	0.015	0.013	0.012	-11.801*	-1.704*	
	(iv)	0.015	0.013	0.011	-17.112*	-4.376*	
	(v)	0.015	0.010	0.011	-27.564*	-17.65*	
	(vi)	0.023	0.012	0.012	-3.783*	-0.774*	
Ovary diameter	(i)	0.243	0.100	0.083	-58.563*	-38.315*	0.01860
	(ii)	0.096	0.086	0.081	-10.461*	-3.218*	
	(iii)	0.096	0.093	0.083	-2.878*	3.973*	
	(iv)	0.096	0.084	0.082	-12.061*	-5.225*	
	(v)	0.110	0.100	0.082	-8.637*	4.548 *	
	(vi)	0.243	0.090	0.083	-63.029*	-44.964*	
Ovary length	(i)	0.188	0.105	0.100	-43.738*	-26.712*	0.01595
	(ii)	0.125	0.117	0.094	-3.600*	7.097*	
	(iii)	0.125	0.118	0.100	-5.414*	4.839*	
	(iv)	0.125	0.127	0.095	1.726*	15.315*	
	(v)	0.122	0.105	0.095	-13.649*	-3.17*	
	(vi)	0.188	0.091	0.100	-51.937*	-37.391	
Ovary area	(i)	0.440	0.098	0.077	-77.716	-62.103	0.04146
	(ii)	0.124	0.091	0.070	-26.600	-5.995	
	(iii)	0.124	0.104	0.077	-16.066	-16.066	
	(iv)	0.124	0.104	0.071	-16.431	6.190	
	(v)	0.120	0.097	0.071	-19.390	1.225	
	(vi)	0.440	0.092	0.077	-79.167	-64.916	

BPH = Better parent heterosis; MPH = Mid parent heterosis; CD = critical difference; W x R = Wild x Roma; R x W = Roma x Wild; W x T = Wild x Tropica; S = Supersteak; MR = Round medium size; MO = Oval medium size; (i) S x (W x R), (ii) MO x (R x W), (iii) MO x (W x R), (iv) MO x (W x T), (v) MR x (W x T) (vi) (W x R) x S; *P = 0.05

Table 2: Mean performance of parents and F1 hybrids and extent of heterosis for fruit size.

Character (P=0.05)	Cross	P1	F1	P2	BPH	MPH	CD
Fruit length	(i)	7.340	4.915	4.040	-45.411	-21.012	0.70617
	(ii)	5.140	5.200	4.040	1.910	23.552	
	(iii)	5.140	5.300	4.040	5.095	27.390	
	(iv)	5.140	4.270	4.270	-9.872	4.621	
	(v)	5.570	4.140	4.270	-40.056	-26.712	
	(vi)	4.040	4.882	7.340	-33.482	-15.894	
Fruit diameter	(i)	5.470	4.640	3.486	-23.919	6.529	4.75167
	(ii)	4.450	3.688	3.730	-31.065	-19.191	
	(iii)	4.450	4.080	3.486	-15.102	5.681	
	(iv)	4.450	3.670	3.660	-31.836	-18.734	
	(v)	5.334	4.090	3.660	-37.312	-16.299	
	(vi)	3.486	4.366	5.470	-20.178	-4.353	
No of Locule/ fruit	(i)	10.000	3.500	2.300	-65.000	-43.089	0.52743
	(ii)	4.000	2.900	2.100	-27.500	-4.918	
	(iii)	4.000	3.000	2.300	-25.000	-4.761	
	(iv)	4.000	2.700	2.300	-32.500	-14.285	
	(v)	5.900	3.000	2.300	-47.300	-26.829	
	(vi)	2.300	3.000	10.000	-70.000	-51.219	
No. of fruits/plant	(i)	14.500	119.500	139.500	-14.336	55.194	10.2667
	(ii)	50.700	91.700	99.200	-7.560	22.348	
	(iii)	50.700	87.500	139.500	-37.276	-7.991	
	(iv)	50.700	95.800	112.000	-14.464	17.763	
	(v)	61.000	112.000	112.000	-11.517	14.566	
	(vi)	139.500	70.700	14.500	-49.677	-8.83	
Single fruit weight	(i)	125.340	40.430	18.036	-67.743	-43.602	31.3205
	(ii)	37.620	25.366	19.510	-32.571	-11.196	
	(iii)	37.620	30.280	18.036	-19.510	8.810	
	(iv)	37.620	23.140	20.320	-38.490	-20.124	
	(v)	56.790	26.580	20.320	-53.195	-31.059	
	(vi)	125.340	25.151	18.036	-79.933	-64.916	

BPH = Better parent heterosis; MPH = Mid parent heterosis; CD = critical difference; W x R = Wild x Roma; R x W = Roma x Wild; W x T = Wild x Tropica; S = Supersteak; MR = Round medium size; MO = Oval medium size; (i) S x (W x R), (ii) MO x (R x W), (iii) MO x (W x R), (iv) MO x (W x T), (v) MR x (W x T) (vi) (W x R) x S; *P = 0.05

The heterotic values with respect to the fruit size characters namely; fruit length, fruit diameter, number of locules per fruit and number of fruits per plant are presented in Table 2. Two hybrids (MO x (R x W) and (MO x (W x R) recorded positive heteroses of 1.9 and 5.1% over the better parent in fruit length. Similarly, three hybrids (MO x (R x W), MO x (W x R) and MO x (W x T) had positive heteroses (23.6, 27.4 and 4.6%) over the mid parent. Negative heteroses were recorded in all the hybrids for the fruit diameter and the values ranged from -37.3 to -15.1% over the better parent. All the cross combinations studied showed negative heterosis for the single fruit weight that ranged from -67.7 to -19.5% and -43.6 to -11.2% over better and mid parents, respectively except for the hybrid (MO x (W x R) which had positive heterosis (8.8%) over the mid parent only. However, only one hybrid, MO x (W x R) had positive heterosis of 5.7%. Negative heteroses were obtained for the number of fruits per plant in all the six hybrids that ranged from -7.56 to 49.76%. The MPH results showed that S x (W x R) had the highest positive MPH of 55.5% in number of fruits per plant.

DISCUSSION

The expression of heterosis depends on the genetic divergence of the two parental varieties used in a particular cross (Rahmani Gul *et al.*, 2010). If heterosis obtained from two parental varieties is high, there is every tendency that the varieties are genetically diverse. The hybrids showing high heterosis have good chances to identify desirable lines in succeeding generations as compared to hybrids having low heterotic effects (Sharif *et al.*, 2001).

Floral traits showed significant negative heterosis over both better and mid parents except the flower and style lengths. The negative BPH and MPH could be as a result of a long distance in the traits between the exotic varieties (supersteak) and advanced generation of tomato lines that developed from wild tomato (Amaefula *et al.*, 2014). However, significant positive heterosis over mid parent recorded in few crosses, indicating a predominance of non-additive gene action in the genetic control of these traits. The majority of the studies on inheritance of fruit size in tomatoes indicate that there is hardly ever heterosis for floral traits in the hybrids. Usually, the hybrids are smaller than the parental arithmetic mean (Powers, 1952, Maluf *et al*., 1982 and Melo, 1988). Generally the hybrid vigor can be easily detected for yield by the increased number of fruit rather than by increased floral and fruit size traits (Rick and Butter, 1956).

All hybrids had fewer locules compared to the better parent as indicated by the negative heterotic values over the better parent. The results revealed that none of the crosses had number of locules/fruit higher than the better parent. Heterosis over the better and mid parents for locule number per fruit had been reported by Anbu *et al*. (1976). However, a cross having supersteak as the pistillate parent recorded higher number of locules/fruit than the crosses involving supersteak as the staminate parents. This would appear to suggest some maternal effect in the inheritance of number of locules in tomato fruits.

The study showed negative BPH and MPH in the single fruit weight. None of the hybrids had fruit weight bigger than those of the better and mid parents. This would tend to suggest the overwhelming influence of the small fruit size over the large fruit size. The finding disagrees with Larson and Currence (1994) who reported a significant positive heterosis for single fruit weight in some tomato hybrids. The hybrid with supersteak as the pistillate parent in the present study had reasonable increment in single fruit weight.

CONCLUSION

From the experiment it can be concluded that S x (W x R) is the most promising three - way hybrid that can be exploited to an advantage in the humid tropics. It is also obvious that supersteak tomato is a good donor of alleles for the improvement of fruit size in tomato.

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