LINKING FLORAL TRAITS WITH FRUIT SIZE IN TOMATO (*SOLANUM LYCOPERSICUM*)

Nnungu, S.I and Uguru, M.I
Department of Crop Science, University of Nigeria, Nsukka, Nigeria.
*Correspondence Author: nnunguh@gmail.com

Abstract
Correlation and path coefficient analyses were performed in tomato (*Solanum lycopersicum*) to determine the floral traits that contribute to fruit size. The analyses were able to estimate the magnitude of association among floral traits and fruit size such as flower length, flower width, stalk width, length and diameter of style, length and diameter of the stigma, length and diameter of the ovary, perimeter and area of the ovary, seeds and locules number, length, width and weight of fruits. Single fruit weight was found to be highly significant and positively correlated with all traits with the exception of length of flower and style, an indication that selection for the fruit size could be done at the flowering stage. For further exploration of the interrelationship between the final fruit size and its components, direct and indirect effects were measured using path coefficient analysis. Locule number per fruit showed the highest positive direct effect (0.8086) on fruit size followed closely by ovary diameter (0.7942) and stigma diameter (0.7685). On the other hand, the highest negative direct effect on fruit size was produced by style length (-0.9147). Residual effect was considerably low (0.0001833) which indicated that characters included in this study explained almost all variabilities in fruit size.

Key words: Correlation, Path coefficient analysis, floral traits, fruit size, tomato and *Solanum lycopersicum.*

Introduction

Fruit size is an important agricultural trait that determines acceptability of fresh fruits of tomato. Fruit size and variation in fruit morphology were important parameters in the domestication of tomato (Van der Knaap and Tanksley, 2001). Tomato fruit size exhibits quantitative variation and it is controlled by several genes. Genes involved in fruit size increase behave in an additive manner in different fruit developmental pathways, each contributing to the final fruit size (Ibarbia and Lambert, 1969). Developmental studies revealed that tomato fruit size is a function of the number of ovary cells before fertilization, number of successful fertilizations, number of cell divisions that occurred within the developing fruit after fertilization and the extent of cell enlargement (Bohner and Bangerth, 1981; Gillapsy *et al*., 1993). Some of the loci exerted their effects through modulation of the size of the carpel and number of locules, fruit length, fruit diameter and number of seeds (Nitsch, 1970). Development of tomato fruit begins with ovary development within the floral meristem. After successful pollination and fertilization where other floral traits such as stigma, style etc are involved, the tomato ovary develops into a fruit which proceed through a stages of cell division, followed by rapid growth stage mainly due to cell expansion (Gillaspy *et al*., 1993).

Majority of the studies on inheritance of fruit size in tomatoes indicate that number of locules per fruit played a major role in fruit size increment. Power (1950) studied the inheritance of weight per locule and indicated that the trait is polygenically controlled. Similarly, Powers (1950) and Gontijo *et al*. (1983) suggested that number of locule per fruit and average weight per locule are related to fruit size. While the final stage of fruit development and the relationship between locule number and fruit size have been studied extensively, little is known about the contribution of the floral trait to the final fruit size. Therefore, in this paper the contributions of tomato floral traits and other fruit determining traits to the final fruit size were investigated.

Materials and Methods

Plant Materials

The experimental materials comprised the parent, Roma VF, Tropica and wild tomato, *Solanum pimpinefollium*). The large fruited inbred tomato variety, *S.lycopersicum,* supersteak imported from USA) and selection from advanced generations of tomato lines, S2S, S3S, S4S, S1E (progenies of parent A and B). F_1 progenies arising from the hybridization between the progenies of advanced generations of tomato and parents were also evaluated.

Methods

Parents and their progenies (F_1) were planted at the Department of Crop Science Research Farm and Sreenhouse, University of Nigeria, Nsukka, located in the derived savannah zone (Latitude 0.6^o52N, longitude 07^o24E with an altitude of 447.26 m above sea level).

Measurement of the floral traits

The flowers were harvested and immediately placed in plastic bag and taken to the laboratory for the measurement of the floral characteristics at anthesis. Flowers were cut longitudinally to expose the ovaries and other floral parts. The shape index was obtained as the ratio of the length and the diameter of the floral traits. Other floral characteristics measured were the flower size, stigma diameter, length and diameter of the style, anther diameter and length, ovary diameter, length and fresh weight. The measurements were done using ocular micrometer. The full matured fruits were also harvested and cut longitudinally for the following observations and measurements: number of carpels, number of locules, fruit diameter and length and the number of seeds.

Results

The results of the correlation and path coefficient analysis are presented in Tables 1 – 4. Tables 1 and 2 contain information on the floral traits and fruit size components such as flower length, flower width, stalk width, style length, style diameter, stigma length and diameter, diameter, length, area and perimeter of the ovary, locule number and the diameter and length of the fruit, number of seeds, weight of 100 seeds and single fruit weight. The results showed variations in the characters among tomato lines.

The phenotypic correlations among all floral traits and fruit size related components are presented in Table 3. Significant positive correlations were observed between the fruit size and the flower width, stalk width, style diameter, stigma length and diameter, diameter, length, area and perimeter of the ovary, locule number and the diameter and length of the fruit. Number of locule per fruit showed the highest positive correlation of 0.9844, followed closely by ovary perimeter (0.9722), ovary diameter (0.9674), ovary area (0.9578), stigma diameter (0.9535), style diameter (0.9491). Fruit size was negative significantly correlated with the style length (-0.8840), flower length (-0.8078), number of seeds (-0.2386).

The results for the path coefficient analysis presented in Table 4, showed that the locule number had the highest positive direct effect (0.8086) on fruit size. Similarly, ovary diameter exhibit the positive direct effect (0.7942) on fruit size. On the other hand the highest negative direct effect was indicated by the style length (-0.9147). The highest indirect effect was exhibited by the stigma diameter and the style diameter. The residual effect was 0.0001833.

Discussion

Fruit size is a complex entity associated with number of component characters including floral traits and other fruit size related components. It is part of the yield, therefore is the crucial concern of the plant breeder and also the final factor on which selection programme is based. It is marked that tomato varieties demonstrate a considerable variation with respect to fruit size and its component such as floral traits. These variations can be attributed to both ontogenic changes in the flower traits and the environmental effect since floral traits are known to be quantitative traits (Oyiga *et al*., 2010).

A study of association of the characters related to the fruit size assist in the selection scheme for more than one character at a time. All changes in the fruit size must be accompanied by change in one or more characters (Graffius, 1964). Therefore, improvement of one character results in simultaneous improvement of all the positively related characters. In tomato fruit size improvement, the knowledge of association between the floral traits and the final fruit size is of special significance. As fruit size is influenced by many factors, studying on the contributing factors based only on correlation may produce misleading results because it measures only the mutual association between two variables. On the other hand the combination between the correlation and the path coefficient analysis go further by providing an effective means of partitioning the variation into the direct and indirect causes of association.

Fruit size was significantly correlated with the fruit length, fruit width, as reported by Prashanth *et al*. (2008) and Singh (2005). Also the locule number per fruit exhibited significant positive correlation with single fruit weight. These result are in line with Power (1950), Gontijo *et al*. (1983), Singh (2005), Singh (2007) and Prashanth et al. (2008).

This study found that all floral traits measured as flower width, stalk width, style diameter, stigma length and diameter, diameter, length, area and perimeter of the ovary were positively correlated with fruit size with the exception of flower length and style length. A positive correlation shows that the changes of the two variables are in the same direction. Therefore, high value of one variable is associated with high value of the other. For example, the positive relationship between the stigma diameter and the fruit size means that increase in stigma diameter increases fruit size. This indicates that selection of tomato varieties with large stigma diameter is one of the reliable strategies for fruit size improvement.

Among floral traits measured, the highest positive correlation was ovary perimeter (0.9722), followed by ovary diameter (0.9674), ovary area (0.9578), stigma diameter (0.9535), style diameter (0.9491). Previous researches speculated that fruit size is likely to be developmentally related to the ovary size from which the fruit develop and the ovary size may be

correlated to the other floral organs (Gillaspy *et al*., 1993, Frary *et al*., 2000, Ashman and Majestic, 2006). Similarly, high positive correlations were observed between ovary (diameter, area and perimeter) and both stigma diameter and style diameter. This indicates that the increase in ovary size depends on the increase of the stigma diameter and style diameter. According to Webb and Lloyd (1986), large stigma diameter provides a larger receptive surface area for pollen deposition. Therefore, large receptive area of the stigma is an advantage as it is able to capture higher number of pollen grains. Whereas the large style diameter and shorter style tend to ease the movement of pollen grain to ovary. The stigma diameter had highly positive correlation with the style diameter, indicating that both traits could be increased simultaneously.

Fruit size was negative correlated with the style length (-0.8840), flower length (-0.8078), number of seeds (-0.2386). This implies that the higher the style length, the smaller the fruit size. The undesirable negative association of the style length with other fruit size contributing traits could be broken down through mutation to broaden the genetic base for selection to improve fruit size (Arshad *et al*., 2005). A residual effect of 0.0001833, implies that 99.98197% had been determined.

Among the traits subjected to path analysis, locule number per fruit exhibited a very high direct effect upon fruit size. The direct effect of the ovary diameter and stigma diameter was also appreciably high toward the final size. The highest positive direct effect of locule number had already been documented. These characters with high direct effect on fruit size should be emphasized. It is likely that the selection for increased fruit size through selection for increased locule number, ovary size and the stigma diameter is a promising step in fruit size improvement in tomato.

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Table 1: Mean for various floral traits and fruit size characteristics in tomato varieties grown in Sreenhouse

Tomato varieties/ hybrids	Flower Length (cm)	Flower width (cm)	stalk width (cm)	Style length (cm)	style diameter (cm)	stigma diameter (cm)	stigma length (cm)	Ovary diameter (cm)	Ovary length (cm)
Wild tomato	0.52804	0.09070	0.03151	0.46210	0.01275	0.01509	0.00990	0.06289	0.07932
Roma VF	0.48519	0.13116	0.05892	0.37871	0.01988	0.02239	0.01741	0.07646	0.11208
Tropica	0.44791	0.18339	0.06450	0.32381	0.01757	0.02175	0.01106	0.09669	0.12301
S1S	0.52257	0.13307	0.04550	0.43331	0.01564	0.02186	0.01199	0.08363	0.10079
S2S	0.47161	0.13450	0.04422	0.38410	0.01509	0.02014	0.01106	0.08430	0.09675
S3S	0.49690	0.13159	0.04455	0.40053	0.01578	0.02039	0.00949	0.08191	0.09466
S4S	0.47487	0.12463	0.03967	0.39505	0.01514	0.02024	0.01165	0.08718	0.09761
S1E	0.47972	0.13022	0.04083	0.39137	0.01503	0.02096	0.01108	0.08241	0.09576
Supersteak	0.34176	0.24523	0.10187	0.16708	0.10925	0.11915	0.01127	0.24344	0.18830
Medium 1	0.44114	0.16183	0.05480	0.34660	0.02646	0.03414	0.01461	0.11021	0.12218
Medium 2	0.43659	0.16562	0.06128	0.34583	0.03137	0.03529	0.01510	0.09632	0.12531
Supersteak x S1S	0.52687	0.15283	0.05313	0.43074	0.01980	0.02557	0.01054	0.10087	0.10594
Medium 2 x S3S	0.51056	0.14538	0.05727	0.41569	0.01816	0.02492	0.01316	0.08624	0.11779
Medium 2 x S1S	0.51430	0.14536	0.04760	0.41604	0.02102	0.03169	0.01332	0.09355	0.11852
Medium 2 x S1E	0.49877	0.14096	0.05231	0.40170	0.02004	0.02880	0.01252	0.08470	0.12747
Medium 1 x S1E	0.54422	0.15493	0.05155	0.44818	0.02042	0.02625	0.01058	0.10069	0.10551

Table 2: Mean for various floral traits and fruit size characteristics in tomato varieties grown in Sreenhouse

Tomato varieties/ hybrids	Ovary area (sqcm)	Ovary perimeter (cm)	No. of seed/fruit	Seeds weight	Locule number	Single fruit weight	Fruit length	Fruit diameter
Wild tomato	0.04386	0.27668	38.11111	0.10000	2.00000	1.71444	1.91125	1.85998
Roma VF	0.06863	0.36145	63.10000	0.22000	4.00000	29.07000	5.48000	4.23000
Tropica	0.11187	0.42359	42.00000	0.25000	4.00000	31.22222	4.78889	4.73333
S1S	0.07756	0.34783	49.80000	0.23000	3.00000	18.03636	4.04091	3.48636
S2S	0.07570	0.34783	52.40000	0.25000	3.00000	18.62222	4.01111	3.68889
S23	0.07013	0.34019	31.50000	0.25000	3.00000	19.51000	4.04000	3.73000
S4S	0.07291	0.34250	33.88889	0.23000	3.00000	15.63333	3.96667	3.37778
S1E	0.07168	0.34400	49.77778	0.26000	3.00000	20.32000	4.27000	3.66000
Supersteak	0.44066	0.80969	30.60000	0.30000	13.00000	125.34000	7.34000	5.47000
Medium 1	0.12094	0.44362	43.80000	0.26000	6.00000	56.79000	5.57000	4.33400
Medium 2	0.12488	0.43875	45.00000	0.25000	6.00000	37.62000	5.14000	4.45000
Supersteak x S1S	0.09819	0.39494	58.10000	0.30000	6.00000	40.43000	4.91500	4.64000
Medium 2 x S3S	0.09166	0.39556	42.90000	0.25000	4.00000	25.36667	5.20000	3.68889
Medium 2 x S1S	0.10482	0.41161	32.40000	0.30000	4.00000	30.28000	5.30000	4.08000
Medium 2 x S1E	0.10436	0.41568	45.38998	0.30000	4.00000	23.14000	4.83000	3.67000
Medium 1 x S1E	0.09749	0.39220	43.20000	0.24000	4.00000	26.58000	4.14000	4.09000

Table 3: Correlation coefficients for floral traits and fruit size components among tomato varieties

	FLL	FW	SW	SL	SYD	SGD	SGL	OD	OL	OA	OP	NS	SEW	LN	FRL	FD
FLL	**1**															
FW	-0.77**	**1**														
SW	-0.78**	0.95**	**1**													
SL	0.97**	-0.87**	-0.88**	**1**												
SYD	-0.80**	0.846**	0.889**	-0.87**	**1**											
SGD	-0.79**	0.852**	0.883**	-0.86**	0.996**	**1**										
SGL	-0.18	0.063	0.213	-0.145	0.016	0.014	**1**									
OD	-0.78**	0.897**	0.888**	-0.86**	0.977**	0.981**	-0.066	**1**								
OL	-0.78**	0.924**	0.955**	-0.87**	0.894**	0.908**	0.244	0.891**	**1**							
OA	-0.80**	0.893**	0.908**	-0.88**	0.990**	0.993**	-0.024	0.990**	0.922**	**1**						
OP	-0.81**	0.936**	0.944**	-0.89**	0.968**	0.976**	0.069	0.976**	0.966**	0.98**	**1**					
NS	0.28	-0.240	-0.144	0.275	-0.351	-0.372	0.393	-0.361	-0.265	-0.371	-0.330	**1**				
SEW	-0.31	0.603*	0.490	-0.398	0.352	0.405	0.115	0.444	0.576*	0.426	0.51**	-0.002	**1**			
LN	-0.79**	0.903**	0.921**	-0.85**	0.949**	0.950**	0.117	0.954**	0.917**	0.95**	0.96**	-0.209	0.492	**1**		
FRL	-0.71**	0.846**	0.900**	-0.79**	0.786**	0.803**	0.457	0.788**	0.923**	0.81**	0.87**	-0.072	0.64**	0.872**	**1**	
FD	-0.67**	0.853**	0.794**	-0.73**	0.637*	0.642*	0.293	0.703**	0.756**	0.67**	0.74**	0.002	0.569*	0.804**	0.83**	**1**
SWF	-0.81**	0.914**	0.919**	-0.88**	0.949**	0.953**	0.117	0.967**	0.919**	0.95**	0.97**	-0.238	0.502*	0.984**	0.88**	0.83**

** Correlation is significant at 0.01 level, * Correlation is significant at 0.05 level

FLL = Flower length, FW = Flower width, SW = Stalk width, SL = Style length, SYD = Style diameter, SGD = Stigma diameter, SGL = Stigma length, OD = Ovary diameter, OL = Ovary length, OA = Ovary area, NS = Number of seeds, SEW = Seed weight, LN = Locule number per fruit, FRL = Fruit length, FD = Fruit width.

Table 4: Partitioning the phenotypic correlation into direct (bold) and indirect effect of the fruit size components

	FLL	FW	SW	SL	SYD	SGD	SGL	OD	OL	OA	NS	SEW	LN	rg
FLL	**0.3774**	-0.0880	-0.1342	-0.8905	2.2001	-3.3053	0.0243	-0.6221	-0.0522	2.2247	0.0166	0.0709	-0.6295	-0.81**
FW	-0.2922	**0.1136**	0.1634	0.7971	-2.3202	3.5837	-0.0084	0.7130	0.0617	-2.4749	-0.0145	-0.1380	0.7303	0.91**
SW	-0.2935	0.1076	**0.1726**	0.8076	-2.4384	3.7138	-0.0283	0.7059	0.0638	-2.5156	-0.0087	-0.1122	0.7453	0.92**
SL	0.3674	-0.0990	-0.1524	**-0.9147**	2.3965	-3.6252	0.0193	-0.6893	-0.0582	2.4523	0.0166	0.0910	-0.6885	-0.88**
SYD	-0.3028	0.0962	0.1535	0.7995	**-2.7417**	4.1865	-0.0021	0.7767	0.0597	-2.7429	-0.0211	-0.0805	0.7681	0.95**
SGD	-0.2968	0.0969	0.1525	0.7891	-2.7314	**4.2023**	-0.0019	0.7797	0.0607	-2.7509	-0.0224	-0.0927	0.7685	0.95**
SGL	-0.0691	0.0072	0.0368	0.1330	-0.0440	0.0616	**-0.1328**	-0.0527	0.0163	0.0688	0.0237	-0.0264	0.0949	0.117
OD	-0.2956	0.1020	0.1534	0.7938	-2.6812	4.1255	0.0088	**0.7942**	0.0595	-2.7415	-0.0218	-0.1016	0.7718	0.97**
OL	-0.2953	0.1051	0.1649	0.7972	-2.4535	3.8194	-0.0324	0.7079	**0.0667**	-2.5548	-0.0160	-0.1318	0.7420	0.92**
OA	-0.3042	0.1016	0.1568	0.8102	-2.7161	4.1753	0.0033	0.7864	0.0616	**-2.7687**	-0.0224	-0.0976	0.7707	0.95**
NS	0.1043	-0.0273	-0.0249	-0.2524	0.9625	-1.5631	-0.0522	-0.2872	-0.0177	1.0283	**0.0602**	0.0006	-0.1696	-0.24
SEW	-0.1170	0.0686	0.0847	0.3642	-0.9652	1.7038	-0.0153	0.3530	0.0385	-1.1818	-0.0001	**-0.2287**	0.3980	0.50*
LN	-0.2938	0.1026	0.1591	0.7788	-2.6044	3.9939	-0.0156	0.7580	0.0612	-2.6390	-0.0126	-0.1125	**0.8086**	0.98**

R = 0.0001833, ** Correlation is significant at 0.01 level, * Correlation is significant at 0.05 level.

FLL = Flower length, FW = Flower width, SW = Stalk width, SL = Style length, SYD = Style diameter, SGD = Stigma diameter, SGL = Stigma length, OD = Ovary diameter, OL = Ovary length, OA = Ovary area, NS = Number of seeds, SEW = Seed weight, LN = Locule number per fruit, R = Residual effect.