Estimate of Heterosis in Early Generations of Tomato (*Solanum lycopersicum* L.)

S. M. Kanneh[1], *M. K. Osei[2], R. Akromah[3] and M. Frimpong[2]
[1]Sierra Leone Agricultural Research Institute, PMP 1313 Tower Hill, Freetown, Sierra Leone
[2]CSIR - Crops Research Institute, P.O. Box 3785, Kumasi, Ghana
[3]KNUST - Departments of Crop and Soil Sciences, Faculty of Agriculture, Kumasi, Ghana

Corresponding author: oranigh@hotmail.com

Received: 14th January 2016 Accepted: 16th May 2016

Abstract:
A study was conducted to estimate heterosis of six (6) tomato genotypes involving two parents at the experimental field of Horticulture division of CSIR - Crops Research Institute, Kumasi during the rainy season of 2014-2015. Analysis of variance showed significant differences among genotypes for all the traits revealing the existence of genetic variability among the studied materials. F_2 and BC_2F_1 produced the highest total marketable fruits and F_1, F_2 and BC_2F_1 genotypes provided high competitive potential over parental. Heritability estimate were high for days to maturity, fruit flesh thickness, number of fruits per plant and stem girth. Positive and negative narrow level (<50%) of heterosis and better parent were estimated.

Keywords: Heterosis, tomato, heritability, yield, yield components

Résumé
Une étude a été menée pour estimer hétérosis de six (6) génotypes de tomate impliquant deux parents au champ expérimental de la division d'Horticulture du CSIR - Crops Research Institute, Kumasi, pendant la saison des pluies de 2014-2015. L'analyse de variance a montré des différences significatives entre les génotypes pour pratiquement tous les traits qui révèlent l'existence de la variabilité génétique parmi les matériaux étudiés. F_2 et BC_2F_1 produit les fruits les plus élevés au total négociables et F_1, F_2 et BC_2F_1 génotypes fournis potentiel concurrentiel sur parental. Estimation de l'héritabilité étaient élevés pour les jours jusqu'à l'échéance, l'épaisseur de la chair du fruit, le nombre de fruits par plante et de la tige de circonférence. Niveau positif et négatif étroite (<50%) de l'hétérosis et les meilleurs parents ont été estimés.

Mots-clés: hétérosis, tomate, héritabilité, le rendement, les composantes du rendement

Introduction

Tomato *(Solanum lycopersicum L.)* is one of the most important vegetable crops in Ghana. It is used in the daily diet of every Ghanaian household (Osei *et al.,* 2010). The national average yield is 7.5-10 tons/ha which is very low compared to that in other countries (Osei *et al.,* 2010). Moreover, according to Alam *et al.,* 1994; King *et al.,* 2008; Hasna *et al.,* 2009; Cramer et al., 2011 and McAvoy *et al.,* 2012, tomato farmers are often faced with production difficulties resulting into low yields. It is reported that heterosis in tomato gave rise to increased yield of 20 to 50% (Chowdhury *et al.,* 1965). According to Kurian *et al.,* 2001, heterosis in tomato was first detected by Hedrick and Booth (1908) for higher yield and more number of fruits. Subsequently, there have been extensive studies on heterosis for yield, its components and quality traits. Tesi *et al.* (1970) reported that apart from high total yield, the F_1 hybrid has specific advantage of higher early yield, number of fruits, fruit size, improved quality, uniformity, and adaptation to adverse conditions. Exploitation of hybrid vigour in tomato is reasonable because each fruit contains larger number of seeds as compared to other vegetables. Heterosis manifests itself most strongly in F_1 and decreases progressively in the next segregating generations. Moreira *et al.* (2003) in a study on heterocyst and combinatory ability in five (5) parents and 10 crosses of tomato with adaptation to high temperatures, it was observed that the hybrid ones overcame the parents in yield of big and medium size fruits suggesting presence of non-additive effects, indicating that heterocyst presence in hybrids of tomato is associated with the increment of plant biomass and then fruits production. Of late, farmers in Ghana are very much persuaded to grow hybrid varieties because they produce high yields and good quality fruits. It is therefore important that tomato hybrids are developed to support Ghanaian farmers. This study was thus undertaken to assess the heterosis in early generations of tomato genotypes for progression into Recombinant Inbred Lines (RILs) and subsequent development of hybrid varieties.

Materials and methods

The study was carried out at the experimental field of the Horticulture division of CSIR-Crops Research Institute during the major rainy seasons of 2015. The research station (Kwadaso) falls within the semi-deciduous rain forest zone which is characterized by a bimodal rainfall pattern, from April to July and then from September to December, with an average annual rainfall of 1500 mm. The soil is Ferric Acrisol (FAO/UNESCO legend, 1986). Average rainfall and mean sunshine recorded during the experimentation was 531.1 mm and 30.4 hours respectively. Maximum and minimum temperatures were however, 32.7°C and 22.7°C respectively. Kwadaso station lies between latitude 06, 42° North and longitude 001, 4° West.

Six tomato genotypes including two (2) parents [P_1 (097), P_2 (213), F_1, F_2, BC_1F_1 and BC_2F_1] were nursed on the April 22, 2015 and transplanted to the field three weeks thereafter. The experiment was laid out in randomized complete block design (RCBD) with three replications. The plot size was 476 m^2 and a spacing of 60 cm between rows and 50 cm within rows was used. Data were taken on 30 plants per replication for parents and F_1s, 120 F_2, 60 $BC_1$and BC_2 respectively. Standard agronomic practices such as refilling, earthen-up, weed control, fertilizer application, staking, pruning and insecticide application were done (Osei *et al.,* 2010).

Data was taken on plant height, days to flowering, number of fruits per plant, fruit weight, fruit flesh thickness, fruit length, fruit diameter, Total Soluble Solid (ºBrix), days to maturity, number of locule and fruit yield. Plant heights (cm) of 20 randomly selected plants were measured and recorded at 100% flowering. The height of each plant was measured from the base of the plant to the newly opened apical leaflet with a roll-up tape measure of 8 m length (FATMAX Blade Armor). The number of days to 100% flowering was calculated as the difference between date when 100% flowering was recorded and the date of transplanting. Similarly, the number of days to maturity was noted from transplanting date to the day the first fruit was considered mature. Total number of fruit per plant was calculated by counting the number of fruits harvested and divided by the number of plants in each plot in successive harvests. Average fruit weight (g/plant) was recorded by taking the mean weight of fruits per plant in successive harvests using sensitive scale (ACS system electronic scale). Average fruit length (cm), fruit diameter (cm) and fruit flesh thickness (mm) were measured using vernier calipers throughout the harvesting. The tomato was cut opened to count the number of locule per tomato fruit. The TSS (ºBrix) was determined and recorded using hand refractometer (ATAGO ATC-1 automatic). Total marketable fruit weight (kg) per plot of each genotype was weighed. To obtain marketable fruits, fruits with cracks, damaged by insects, disease, birds, small fruits and those with sunburn were separated from the harvest (Lemma, 2002). Those which were free from visible damage were considered marketable fruits. The data were subjected to Analysis of Variance (ANOVA) using GENSTAT (12thEdition). The Least Significant Difference (LSD) at 5% was used to separate the treatment means. Broad sense and narrow sense heritability were estimated using the formulae of Allard (1960) and Halloran *et al.* (1979) respectively.

Mid parent heterosis and better parent heterosis (heterobeltiosis) were estimated as follows:

$$\text{Mid parent heterosis (MPH)} = \frac{F_1 - MP}{MP} x100$$

$$\text{Better parent heterosis (BPH) or heterobeltiosis} = \frac{F_1 - BP}{BP} x100$$

Where,

MP = mid parent value of the particular F_1 cross $[(P_1 \bullet P_2)/2]$.

BP = better parent value in the particular F_1 cross $[(P_1 \text{ or } P_2)$.

Results

Agronomic characters as well as yield and yield components mean performance of parental, F_1, F_2 and backcrosses; heritability, heterosis and heterobeltiosis for all crosses are given in tables 1, 2, 3 and 4 respectively. F_2 (90.01cm) produced the highest plant height at 100% flowering which exceeds that of the parents and was significantly (P<0.05) different from all the other genotypes. BC_2F_1 (80.28 cm) recorded the shortest plant height at 100% flowering. The maximum and minimum mean performance for stem girth were recorded in F_2 (12.09 cm) and P_1 083 (8.44 cm) respectively. Days to flowering ranged from 28.00 to 35.00 for F_2 and P_2 respectively. In terms of days to maturity, there were significant differences among genotypes. Days to maturity varied from 56.00 to 64.00 days after transplanting. P_2 (64.33) took the longest days to mature while P_1 (56.00) took the shortest days to mature but was not significantly different from BC_1F_1 (Table 1).

The maximum and minimum mean performance per plant for fruit weight was recorded by F_2 (70.15g) and P_1 (51.89g) respectively. Significant differences were

Table 1: Mean performance of agronomic characters of tomato genotypes

Genotype	*Characters*			
	Plant height (cm)	*Stem girth (cm)*	*Days to flower-ing*	*Days to matu-rity*
P_1 (097)	84.84	8.44	30.00	56.00
P_2 (213)	82.45	9.54	34.67	64.33
F_1	87.24	10.07	29.33	59.33
F_2	90.01	12.09	28.13	59.00
BC_1F_1	81.65	10.04	30.00	57.67
BC_2F_1	80.28	10.97	32.67	59.00
Lsd (P<0.05)	2.923	1.367	3.669	2.566
CV (%)	1.90	7.40	6.50	2.40

observed among genotypes on the number of fruit per plant. This ranges from 46.32 (P_1) to 60.31 (BC_1F_1). The highest total marketable fruit weight was recorded on BC_1F_1 and F_2. P_1 however, gave the lowest total marketable fruit weight. Similarly BC_2F_1 produced the highest number of marketable fruit per plant which was significantly different from the other genotypes. P_1 again gave the lowest number of marketable fruit per plant. No significant difference was however, seen in the number of non-marketable fruit per plant among the genotypes (Table 2).

Table 3 displays mean performance of the tomato genotypes on some yield related traits. Fruit length among tomato genotypes varied significantly from 32.37 to 41.50. F_2 (41.50cm) had the longest fruit length while BC_1F_1 recorded the shortest fruit length (32.37cm). Likewise fruit diameter varied from 32.94 to 40.51 cm. F_2 gave the highest fruit diameter which was however, not significantly different from BC_2F_1, F_1 and P_2. The highest fruit flesh thickness was produced by F_2 which was significantly different from all the genotypes except F_1. The parents nonetheless gave the lowest fruit flesh thickness. Significant difference was observed on the locule number among the tomato genotypes. The maximum and minimum locule number was recorded on the F_2 and BC_2F_1 respectively. The highest and lowest brix was between 4.97 and 3.88 which were recorded by F_2 and P_1 respectively. F_2 was however, not significantly different from all the genotypes except P_1 and BC_1F_1.

Stem girth at 100% flowering recorded the highest heritability for broad sense (74 %) and a narrow sense of (33 %). Number of fruit per plant followed this with an estimated broad sense heritability of (68 %) and narrow sense of (54 %). Furthermore, days to maturity had an estimated heritability of broad sense of (61 %) and narrow sense (42 %). Fruit flesh thickness had the least broad sense heritability estimated as (51 %) and narrow sense of (42 %). Plant height at 100% flowering, days to 100% flowering, fruit diameter, fruit length, average fruit weight per plant and brix exhibited moderate broad sense heritability (20-49 %). Additionally, locule number had the lowest (~ 0 19 %) heritability. Heterosis over mid parent showed positive narrow level (<50%) with respect to fruit flesh thickness (41.98 %) and stem girth at 100% flowering

Table 2: Mean performance of yield and yield components of tomato genotypes.

	Character				
Genotype	*Fruit weight per plant (g)*	*Number of fruit per plant*	*Total marketable fruit weight (kg)*	*Number of marketable fruit per plant*	*Number of non-marketable fruit per plant*
P_1 (097)	51.89	46.32	7.04	37.44	7.92
P_2 (213)	61.18	57.70	9.19	48.01	8.81
F_1	58.84	52.65	7.47	46.59	5.85
F_2	70.15	53.55	11.77	45.91	6.74
BC_1F_1	52.86	48.41	7.78	42.90	4.61
BC_2F_1	61.66	60.31	11.12	51.79	6.48
Lsd (P<0.05)	4.177	5.848	1.338	1.816	4.818
CV (%)	3.90	6.0	8.1	14.8	5.8

Table 3: Fruit characteristics of tomato genotypes

	Character				
Genotype	*Fruit length(cm)*	*Fruit diameter (cm)*	*Fruit flesh thickness (mm)*	*Locule number*	*Brix*
P_1 (097)	35.58	32.94	3.37	4.30	3.88
P_2 (213)	36.52	38.97	3.80	4.50	4.58
F_1	38.56	36.79	5.09	3.90	4.23
F_2	41.50	40.51	5.21	5.53	4.97
BC_1F_1	32.37	35.25	4.09	4.05	4.01
BC_2F_1	38.83	40.50	4.55	3.79	4.17
Lsd (P<0.05)	1.274	4.142	1.023	1.274	0.839
CV (%)	16.1	6.1	12.9	16.1	10.7

Table 4: Estimates of broad and narrow sense heritability, heterosis and heterobeltiosis

Characters	*Broad sense heritability (h2b %)*	*Narrow sense heritability (h2n %)*	*Heterosis (%)*	*Heterobeltiosis (%)*
Plant height at 100% flowering	35.00	23.00	4.29	2.83
Stem girth at 100% flowering	74.00	33.00	12.01	5.56
Days to flowering	41.00	28.00	-9.31	15.40
Days to maturity	61.00	42.00	-1.40	8.29
Number of fruit per plant	68.00	54.00	1.23	-9.59
Fruit diameter	37.00	17.00	2.32	-5.93
Fruit flesh thickness	51.00	42.00	41.98	25.34
Fruit length	40.00	13.00	6.96	5.29
Fruit weight per plant	45.00	23.00	4.08	-3.98
Locule number	0.00	0.00	-11	-13
Brix	39.00	17.00	-11.36	-7.64

(12.01 %) fruit length (6.96 %), plant height at 100 % flowering (4.29 %), fruit weight (4.08 %), fruit diameter (2.32 %) and number of fruits per plant (1.23). On the other hand, negative narrow level (<50%) heterosis were estimated for days to flowering (-9.31 %), days to maturity (-1.40 %) and locule number (-0.11 %) respectively. Also, heterosis over better parent (Heterobeltiosis) recorded positive and negative narrow level values as follows; fruit flesh thickness (25.34 %) and days to 100 % flowering (15.40 %) days to maturity (8.29 %), stem girth at 100 % flowering (5.56 %), fruit length (5.29 %), plant height at 100 % flowering (2.83 %), (-9.59 %), brix (-7.64 %), fruit diameter (-5.93 %), fruit weight per plant (-3.98 %) and locule number (-13 %) (Table 4).

Discussion

Agronomic performance of tomato genotypes

The differences observed among tomato genotypes with respect to plant height may be attributed to differences in the genetic constitution rather than environmental conditions. Different genotypes were used in this study under the same environment conditions. The result is in agreement with (Gongolee *et al*., 2015; Blay *et al.,* 1999) who reported that different genotypes perform differently in the same environment. The significant variation among the genotypes revealed that presence of adequate variability which can be exploited through selection. The result further conforms to work reported by Singh *et al*. (2006), Dar *et al*. (2012), Singh *et al.* (2014), Pandey *et al.* (2015) and Senapati and Kumar (2015). Variations observed in stem girth among the genotypes may be ascribed to genetic differences for conducting tissues (xylem and phloem). The genotype with the highest stem girth had better conducting tissues as a result, better capacity to store food material. These results were in conformity to the findings of Manoj and Uday (2006) who reported on the significance of stem girth in crop production. Conversely, the finding does not agree with what was reported by Gongolee *et al*. (2015). Days to flowering is an important component in tomato production because it is a transition for the initiation of reproductive stage in the life cycle of the plant. It also indicates earliness to maturity. Variations observed in the number of days to 100% flowering may be attributed to differences in genetic constitution. The finding is in line with Sinnaduari (1992) who stated that flowering in tomato usually starts 50 to 65 days after sowing. The wider variations observed in days to maturity among genotypes may be attributed to weather conditions, available nutrients and moisture. This could be responsible for differences in the number of days to harvesting. This is in harmony with Manoj and Raghav (1998) that made similar observation in their study. Analogous observation was reported by Kallo *et al.* (1998) who indicated that major differences in the days to maturity could be attributed to substantial variability for days to first harvest in the tomato genotypes. It must be noted that earliness in any plant genotype is envisaged as important parameter for rainy and off-season production of tomato. This determines the adaptability of a variety to a particular environment and to some extent, incidence of pests and diseases.

Yield and yield components of tomato genotypes

The yield components of cultivated tomato fruits are most important from production point of view. The variation in the number of fruits per plant observed among the evaluated genotypes may be attributed to the differences in ability to produce and retained higher number of flowers that developed into fruit. The genotype which had the least number of fruits per plant may have had about 50% of its flowers dried up and fell off or formed tiny fruits which shriveled up and fell off without further development. Flowers of genotypes with high numbers of fruits successfully developed more fruits possibly because of better genetic components. The result is in agreement with the findings of Adelana (1975) and Olaniyi *et al.* (2010) who reported that only 50% of flowers produced developed into fruits, thus sink size (genetically controlled) influences fruit production in tomato. It may also be attributed to better genetic structure and higher potentials to transport photosynthetic materials towards economic yield as reported by Clark *et al.* (1997) and Zaki *et al.* (1999). Furthermore, the results follows what had been reported by several other authors (Khokhar *et al*., 2001; Eshteshabul *et al.*, 2010; Turhan *et al.*, 2011; Abrar *et al.,* 2011; Falak *et al*., 2011) that the mean number of fruits per plant lay between 4.46 and 98.30. Agong *et al*. (2001) showed a value between 9.70 and 158.90 while Lemma

(2002) showed a range between 26 and 62. The yield obtained from the findings varied among genotypes. This perhaps, may be ascribed to possibility of possession of higher stomata conductance, better partitioning of photosynthetic materials towards economic yield, better genetic structure from recurrent parents and higher potential to transport photosynthetic materials within plants. The result is analogous to the findings of Costa and Campos (1990), Gardner *et al.* (1990) and Zaki *et al.* (1999) who attributed the yield differences in crop cultivars with special reference to tomato plants, to stomata conductance value and differences in partitioning of photosynthetic materials towards economic yield. It is also in accord with the findings of Clark *et al.* (1997) who attributed the differences in yield and its components between crop genotypes to variations in genetic structure, mineral concentration and potentials to transport photosynthetic materials within plants. Variations among tomato genotypes for average fruit weight per plant may be attributed to higher number of fruit set, large fruit size and higher retention of matured fruits/plant as a result of genotypic combination in the development of fruit size and weight. It could also be attributed to additive and non-additive gene type action responsible for this character. The result is in agreement with Sultana (2013) who reported that variation in individual fruit weight among tomato genotypes maybe as a result of plant's GCA and SCA for that character. The observed variations in total soluble solids (TSS/°Brix) among genotypes may be attributed to differences in genetic makeup that might have influenced the performance of these genotypes for the trait. The variations in this study are in trend of those found by (Dar *et al.,* 2012; Durvesh and Singh, 2006), who reported that quality attributes like total soluble solids of the fruit ranged from 4.0 to 5.0%. Additionally, Rodica *et al.* (2008) reported that total sugar (TS) content and acidity are the most important characteristics of tomatoes taste. High sugars are required for best flavor (Kader, 1986). The results also agree with Petro-Turza (1987) who studied total sugar content of ripe tomato and reported content to be between 1.7 and 4.7%. However, Campos *et al.* (2006) and Kader *et al.* (1987) have reported minimum value of soluble solid to be around 4.5%, which is considered low for industrial tomatoes. The variations in FFT among genotypes could be perhaps ascribed to fruit firmness and possibly genetic differential for the trait. The result is in line with Dar *et al.*, 2012. Additionally, Dhaliwai et al. (1999) and Roopa *et al*. (2001) attributed FFT to gene actions which may contribute to long fruit shelf-life. Prolonged fruit shelf-life is an essential component in tomato breeding as it allows for appreciable storage period without considerable loss of value. The differences in locule number among genotypes may be related to the fact that progenies may not have genes responsible for locule number or if they do, may be recessive which is expressed in the differences in individual fruit weights. The finding conforms to (Dar *et al.,* 2012; Durvesh and Singh, 2006) who observed considerable variations in tomato genotypes with respect to number of locule. According to Barrero and Tanksley, 2004, a direct relationship between the fruit size and fruit weight on the number of locule exist. Fruits with fewer locule numbers had small fruit sizes and less fruit weight and vice versa. The gene, *fas* is a strong determinant of LN in fruit, and most large-fruited tomatoes carry the *fas* allele, which is associated with high locule number (Barrero and Tanksley, 2004). Most domesticated large fruit-bearing varieties of tomato carry both *fas* and *lc* mutations, suggesting that limited genetic variation governs locule number in domesticated tomatoes than most wild Solanaceae species of tomato (Munos *et al.*, 2011).

Variability observed in fruit length and fruit diameter is perhaps as a result of a combination of factors. Some of the factors include fruit shape (spherical, elongated, flat or pear-like), plant health and ability of plant to take up and utilize available moisture (water) and nutrients. The finding is in agreement with Regassa *et al.*, 2012; Atherton and Rudich, 1986. Variations among genotypes for marketable and nonmarketable fruits could be attributed to the number of flowers set that developed into fruits and retained by the plants onto harvest for marketable fruits. Nonmarketable fruits could be associated with cracks, damage by diseases and pest, sunburn, moisture shortage and deformed fruits. It could also be attributed to size and weight of fruit. Similar noticeable differences in fruit yield of tomato varieties were reported by and Rida *et al.* (2002).

Estimates of heritability in the broad sense genotypes

Heritability is used for predicting the progress from selection and it is of tremendous significance to breeders as its magnitude indicates the reliability with which a genotype can be recognized by its phenotypic expression. Broad sense heritability indicates the ratio of total genetic variance to the total phenotypic variance whereas in narrow sense, heritability is the ratio of additive genetic variance to the phenotypic variance. The higher magnitude of broad sense heritability percentage (>50 %) for *S*tem girth at 100% flowering, days to maturity, number of fruits per plant and fruit flesh thickness shows that the phenotype is highly correlated to the genotype and that there was limited contribution of environmental conditions for these traits. Similar finding was reported by Osekita and Adedolapo (2014) who indicated high heritability value for fruit flesh thickness. They indicated that, high broad sense heritability coupled with high genetic advance for such a trait could aid selection for the trait. Pradeepkumar *et al.* (2001) also proposed that high broad - sense heritability alone does not always entail better selection. On the other hand, Ceccarelli, 1994 suggested that the magnitude of heritability of a given trait is affected by the type of genetic material involved. The high heritability values recorded for Stem girth at 100% flowering suggests that environmental factors had little influence on the agronomic trait hence selection could be considered at early stages of the breeding programme. The result conforms to the finding of Ramzan *et al.* (2014) who reported high heritability values for fruit diameter and fruit length respectively. It is also in consonance with earlier reports by Haydar *et al.* (2007) and Mohamed *et al.* (2012). Moderate heritability values (20-49) were observed in the study may be attributed to environmental factors which had favourable influence on genotypes rather than genes. When this occurs, it does not assist in achieving selection in early segregating genotypes. The result corroborates with the findings of Boakye *et al.* (2013) and Bhateria *et al.* (2006) who referred to these values as moderate broad sense heritability. However, the result is in disagreement with Saeed *et al.* (2007) who reported high heritability values in tomato for these traits.

Heterosis and better parent value (heterobeltiosis)

Fundamentally, heterosis is an indispensable component in plant breeding and defines the enriched potency of F_1 hybrids in contrast with their parental homozygous lines. According to Veerendra *et al.* (2007), the level of heterosis can be grouped as, narrow level (<50%), intermediate level (50-100%) and high level (>100%). It is evident from the Table 4 that mid parent heterosis for fruit flesh thickness, stem girth, fruit length, plant height, number of fruit per plant and fruit diameter was significant and positive. Range of positive heterosis was 1.23 to 41.98 percent, while the highest positive heterosis percent were observed in the Fruit flesh thickness (41.98). Ahmed *et al.* (2011) also reported that most hybrids in their study showed positive heterosis over the better parent for plant height in tomato. The narrow level of mid parent heritability (MPH) was steadily smaller in most of the traits The result is in conformity with what was reported by Melchinger *et al.* (2007) who reported similar values to be positively and negatively narrow leveled heterosis for several traits for a Testcross Progenies in hybrid maize. Additionally, Udengwu (2009) reported negative or non-significant positive heterosis for days to flowering and locule number in Okra and he attributed it to consequence of overall reduced vegetative growth. Nevertheless, negative heterosis for traits such as days to flowering, days to maturity and locule number was desirous and expected because they constitute the interspecific hybrids with known barrier to gene flow. This is in agreement with the explanations of Shengbin *et al.* (2007).

Conclusions

For the development of potential plant material of *Solanum lycopersicum L.* through selection and breeding, availability of variation in the desired characters is imperative for breeding. With respect to yield, result from this study showed that genotypes F_2 and BC_2F_1 outperform parental and other genotypes in terms of total marketable fruit weight. The observed variation would be helpful for the development of desired plant material in tomato. However, a continuous study for the genetic basis of variation is essential. Heritability estimate were high for Stem girth at 100% flowering, days to maturity, number of fruits per plant and fruit flesh thickness. This indicates that the phenotype is highly correlated to the genotype and that there was limited contribution of environmental conditions for these traits. The experiment shows that mid parent heterosis for Fruit flesh thickness, stem girth, fruit length, plant height, number of fruit per plant and fruit diameter was significant and positive. Additionally, this study has set roll for further improvement through backcrosses and pedigree selections to develop inbred lines and subsequent hybrid varieties.

Acknowledgments

Authors gratefully acknowledge WAAPP Sierra Leone through SLARI for financial support. Authors are also indebted to Mr. Joseph Gyau, Mr. John Afriyie and Mr. James Owuo who are workers of the Horticulture division, CSIR - Crops Research Institute for their technical assistance during the work.

References

Ahmad, S., Quamruzzaman, 1 A. K. M. & Islam, M. R. 2011). Estimate of heterosis in Tomato (Solanum lycopersicum L.). Bangladesh J. Agril. Res. 36(3): 521-527

Abrar, H. S., Shams, U. l., Noor U. l. & Safdar, H. 2011. Evaluation of two nutrient solutions for growing tomatoes in a non-circulating hydroponics system. Journal Of Agriculture 27(4): 558-567

Adelana, B. O. 1975. Effect of flower removal in the tomato .India J. Horti. 35(1): 29-39

Agong, S. G., Schittenhelm, S. & Friedt W. 2001. Genotypic variation of Kenyan tomato (Lycopersicon esculentum Mill) germplasm. Journal of Food Technology in Africa (6): 13-17

Alam, M. Z., Ali, M., Akanda, A. M., Choudhury, D. A. M., Haque, N.M.M., Hossain, M. M. & Ogata, K. 1994. Grafting technology: An integrated pest management component for eggplant and tomato. Bulletin of the Institute of Tropical Agric ulture Kyushu University17(0): 85-91.

Allard, R. W. 1960. Principles of plant Breeding. John Wiley and Sons. Inc. New York London, Sydney.

Atherton, J. & Rudich, I. 1986. The Tomato Crop. Chapman and Hall, London, UK. 167-200

Barrero, L. S. & Tanksley, S. D. 2004. Evaluating the genetic basis of multiplelocule fruit in a broad cross section of Tomato cultivars. Theor. Appl. Genet. 109: 669679.

Bhateria, S., Sood, S. P., & Pathania, A. 2006. Genetic analysis of quantitative traits across environments in Linseed (LinuMustitatissimum L). Euphytica 150 (1- 2): 185-194.

Blay, E. T. 1999. Crop rotation to control nematode in tomato. Ghana Jnl agric. Sci. 6: 137-139.

Boakye, P. B., Kwadwo O., Asante, I. K. & Parkes, E. Y. 2013. Genetic variability of Tree cassava fruits across three locations in Ghana. African J. of Plant Science 1-3

Campos, C. A. B., Fernandes, P. D., Gheyi, H. R., Blanco, F.,F., Goncalves, C. B & Campos, S. A. F. 2006. Yield and fruit quality of industrial tomato under saline irrigation. Sci. Agric., 2:63-69.

Ceccarelli, S. 1994. Specific adaption and breeding for marginal conditions. Euphytica77: 205-219

Clark, R. B., Zeto, S. K., Baligar, V. C. & Ritchey, K. D. 1997. Growth traits and mineral concentrations of maize hybrids grown on unlimed and limed acid soil. Journal of Plant Nutrition 20(12): 1773 - 1795.

Costa, J. G. & Campos, D. A. J. S. 1990. Maize cultivars recommended for the State of Acre. Counica de Tecnicounidaded'Exeecuo de NumbitoEstand. No.56, 4pp (c.f. Field Crop Abstracts 1991, 44(12).

Cramer, G. R., Urano, K., Delrot, S., Pezzotti, M. & Shinozaki, K. 2011. Effect of Abiotic stress on plants: a systems Biology perspective. BMC Plant Biology 1(163): 14.

Chowdhury, B., R. S. Punia, H. S. & Sangha. 1965. Manifestation of hybrid vigour in F_1 and its retention in F_2 generation of Tomato. Indian J. Hort. 22 (1): 52-60.

Dar, R. A., Sharma, J. P., Nabi, A. & Chopra, S. 2012. Germplasm evaluation for yield and fruit quality traits in tomato (Solanumlycopersicon L.). Afr. J. Agric. Res. 7:6143-6149.

Dhaliwal, M. S., Singh S., Badhan B. S. & Cheema, D. S. 1999.Diallel analysis for total soluble solid contents, pericarp thickness and locule number in tomato. Vegetable Science 26(2): 120-122

Eshteshabul, M., Hakim, M. A., Amanullah, A. S. M., & Ahsanullah, A. S. M. 2010. An Assessment of physiochemical properties of some tomato genotypes and varieties grown at Rangnur. Bangladish Research publication Journal 4 (3), 135-243.

East, E. M. 1908. Inbreeding in corn. Report of the Connecticut Agricultural Experiment Station, 419428.

Falak, N. Ul-Haq, I. Asghar, S., Shah, A. S. & Rahman, A. 2011. Studies on the growth, yield and nutritional cultivars in Battal Valley of district Mansehra, Khyber Pakhunkhuwa, Pakistan. Sarhad J. Agric. 27(4): 1-3

FAO/UNESCO legend 1986. Technical paper Soil classification and characterization, FAO, Rome.

Fayaz, A. Obedullah, K., Sair, S., Akhtar, H. & Shar S. 2007. Performance evaluation of tomato cultivars at high altitude. Sarhad J. Agric. 23(3): 581-584 F

HER, W. R. 1993. Principles of cultivar development. Vol I: Theory and technique. Macmillan Pub. Co., USA

Gardner, F. P., Alle, V. & McCloud, D. E. 1990. Yield characteristics of ancient roses of maize compared to modern hybrid. Agronomy Journal. 82 (5): 864-868.

Gongolee G. A. K., Osei M. K., Akromah R., Nyadanu D. and Aboagye L. M. 2015. Evaluation of Some Introduced Tomato Cultivars. Horizon Journal of Agriculture and Food Science (HJAFS) 1(1): 001-006

Halloran, G. M.; Knight, R., McWhiter & Sparrow, D. H. B. 1979. Plant Breeding

(Ed. R. Knight). Poly-Graphic Pty. Ltd. 61-62

Hasna, M. K., Ogren, E., Persson,P., Martensson,A. and Ramert,B. 2009. Management of corky root disease of Tomato in participation with organic Tomato growers. Crop Protection 28(2): 155-161.

Haydar, A., Mandal, M. A., Ahmed, M. B., Hannan, M. M., Karim, R., Razvy, M. A., Roy, U. K. & Salahi, M. 2007. Studies on genetic variability and interrelationship among the different traits in tomato (Lycopersiconesculentum Mill.). Middle- East J. Sci. Res. 2:139-142.

Hedrick, U. P. & Booth, N. O. 1968. Mendelian characters in tomato. Proc Am Soc Hort Sci. 5: 1924. 2:139-142.

Hallauer, A. R., & Iranda , J. B. M. 1981. Quantitative genetics in maize breeding. Iowa State Univ. Press. Ames. IA, USA. IA, USA.

Kader, A. A. 1986. Effect of post-harvest Handling procedures on tomato quality. ActaHortic. 190: 209-221

Kader, A. A., Morris, L. L., Stevens, M. A. & Albright-Holton M. 1987. Composition and flavor quality of fresh market tomatoes as influenced by some postharvest-handling. J. Am. Soc. Hortic. Sci., 103: 6-11.

Kallo, G., Chaurasia, S. N. G., Major, S., & Singh, M. 1998. Stability analysis in tomato. Vegetable Research, Ghandi Nagar, India. Vegetable Sci., 25(1): 81-84.

Khokhar, K. M., Hussain, S. I., Laghari, M. H., Mahmood, T. & Mahmud, M. M. 2001.Studies on yield potential of some Exotic and local tomato cultivars grown for summer production Pakistan. Journal of Biological Science (10): 1215-1216

King, S. R., Davis, A. R., Liu, W. & Levi,A. 2008. Grafting for disease resistance. HortScience43(6): 1673-1676.

Kurian, A., Peter, K.V. & Rajan, S. 2001. Heterosis for yield components and fruit Characters in tomato. Journal of Tropical Agriculture 39(2001): 5-8

Kumar, R., Mishra, N. K., Singh, J., Rai, G. K., Verma, A. & Rai, M. 2006. Studies on yield and quality traits in tomato (Solanumlycopersicon (Mill.) Wettsd.). Veg. Sci. 33:126-132.

Kumar, S. 2010. Genetic variability and interrelationship of traits in F3 progenies of tomato (Lycoperscionesculentum Mill.) under cold desert of Leh-Ladakh. Crop Improvement 37:66-72.

Lemma, D. 2002. Training manual on horticultural crops production technologies (volume II: vegetables), Ethiopian Agricultural Research Organization, Melkasa Agricultural Research Center and World Vision Ethiopia. Melkasa, Ethiopia.

Lemma, D. 2002. Research experience and production prospects. Ethiopian Agricultural Research Organization (EARO), Addis Ababa, Ethiopia, 20-28

Mangal, J. L. & Jasim, A. M. 1987. Response of tomato varieties to pruning and plant spacing under plastic house. Haryana J. Hort. Sci.16 (3-4): 248-252.

Manoj, K. & Uday, D. 2006. Anatomical breeding for altered leaf parameters in Tomato genotypes imparting drought resistance using Leaf Strength Index. Asian J. Plant Sci. 5 (3): 414 420.

Manoj, R., & Raghav, M. 1998. Performance of F_1 hybrids and high yielding varieties of tomato under mid-west plains of Uttar Pradesh. Prog. Hort., 30(3): 194-197.

McAvoy, T., Freeman, J. H., Rideout,S. L., Olson, S. M. & Paret, M. L. 2012. Evaluation of Grafting Using Hybrid Rootstocks for Management of Bacterial Wilt in Field Tomato Production. HortScience HortScience 47(5): 621-625.

Melchinger, A. E., Piepho, H., Utz, H. F., Muminović, J., Wegenast, T., Törjék, O., Altmann, T. & Kusterer, B. 2007. Genetic Basis of Heterosis for Growth-Related Traits in Arabidopsis Investigated by

Testcross Progenies of Near-Isogenic Lines Reveals a Significant Role of Epistasis. Genetics 177(3): 1827-1837

Mishra, Y. K., & Lal, S. D. 1998. Studies on varietal performance of tomato under the Agro climatic conditions of U. P. Hills. Prog. Hort., 30(3): 153-157.

Mohamed, S. M., Ali, E. E. & Mohamed, T. Y. 2012. Study of heritability and genetic variability among different plant and Fuit characters of tomato (Solanumlycopersicon L.). Int. J. Sci. Tech. Res. 1:55-58

Moreira, C., Echandi, M. A. Y. & Méndez, C. R. 2003. Heterosis y habilidadcombinatoria en líneas de tomate para mesa con adaptaciónaaltastemperaturas. Rev. Agric. Trop. 33:51-58.

Mohamed, S. M., Ali, E. E., & Mohamed, T. Y. 2012. Study of Heritability and Genetic Variability among Different Plant and Fruit Characters of Tomato (SolanumlycopersiconL.) IJSTR. (1): 55-58

Muños, S., Ranc, N., Botton, E., Bérard, A., Rolland, S., Duffé, P., Carretero, Y., Le Paslier, M. C., Delalande, C. & Bouzayen, M. 2011. Increase in tomato locule number is controlled by two single-nucleotide polymorphisms located near WUSCHEL. Plant Physiol. 156: 22442254.

Olaniyi, J. O., Akanbi, W. B., Adejumo, T. A. & Akande, O. G. 2010. Growth, fruit yield and nutritional quality of tomato varieties. African Journal of Food Science 4(6): 398-402.

Osei, M. K., Akromah, R., Shilh, S. L. & Green, S. K. 2010. Evaluation of some tomato Germplasm for resistance to Tomato Yellow leaf curls Virus disease (TYLCV) in Ghana. Aspects Appl. Biol. 96: 315-323.

Osekita, O. S & Adedolapo, T. A. 2014. Genetic advance, heritability and character association of component of yield in some genotypes of tomato lypersicones-Culentum (Mill.) Wettsd. Academia Journal of Biotechnology, 2 (1): 6-10

Pandey, P., Pandey, V. R., Tiwari, D. K. & Yadav, S. K. 2015. Studies on direct selection parameters for seed yield and its component traits in pigeonpea [Cajanuscajan (L.) Millsp]. Afr. J. Agric. Res. 10:485-490

Papadopoulos, A. P. & Ormorod, D. P. 1991. Plant spacing effect on growth and development of green house tomato. Can. J. Plant. Sci., 71: 297-304.

Pradeepkumar, T., Bastian, D., Joy M., Radharkrishnam, N. V. & Aipe, K. C. 2001. Genetic variation in tomato for yield and resistance to bacterial wilt. J . Trop. Agric 39:157-158

Ramzan, A., Khan, T. N., Nawab, N. N., Hina, A., Noor, T & Jillani, G. 2014. Estimation of genetic components in F_1 hybrids and their parents in determinate tomato. (Solanumlypersicum L.) J. Agric. Res., 52(1): 65-75.

Reddy, B. R., Reddy, M. P., Begum, H. and Sunil, N. 2013. Genetic diversity studies in tomato (Solanum lycopersicum L.) OSR Journal of Agriculture and Veterinary Science 4(4): 53-55

Regassa, M. D., A. Mohammed & Bantte, K. 2012. Evaluation of tomato (Lycopersiconesculentum Mill.) genotypes for yield and yield components. Afr. J. Plant Sci. Biotechnology., 6: 45-49.

Rida, A. S., Muhammad, A. A., Ereifij, I. E., & Hussain, A. 2002. Evaluation of thirteen open pollinated cultivars and three ybrids of tomato (Lycopersiconesculentum Mill.) for yield, physiological disorders, seed production and vegetative growth. Pak. J. Agric. Res., 17(3): 290-296.

Rodıca, S., Apahıdean, S. A., Apahıdean, M., Manıtıu, & Paulette, L. 2008. Yield, Physical and Chemical Characteristics of Greenhouse TomatoGrown on Soil and Organic Substratum. 43rd Croatian and 3rd Int. Symposium on Agric. Opatija . Croatia. 439-443.

Roopa, K. V., Saddashiva A. T., Reddy, K. M. Rao K. P. G. & Prasd B. C. 2001. Combining ability studies for long shelf life in tomato. Vegetable Science 28:24-26

Saeed, A., Hayat, K. Khan, A. A., Iqbal, A &Abbas, G. 2007. Assessment of Genetic Variability and Heritability in Lycopersiconesculentum Mill. International Journal of Agriculture & Biology 9(2) : 375377

Senapati, B. K. & Kumar, A. 2015. Genetic assessment of some phenotypic variants of rice (Oryza spp.) for some quantitative characters under the Gangatic plains of West Bengal. Afr. J. Biotechnol. 14:187-201.

Shengbin, T., Luan,L., Liu,Y., Long W. & Kong, F. 2007. Production and heterosis analysis of rice autotetraploid hybrids. Crop Sci., 47: 2356-2363.

Shull, G. H. 1908. The composition of a field Of maize. Am. Breed. Assoc. Rep. 4: 296301.

Singh, A. K. 2009. Genetic variability, heritaability and genetic advance studies in tomato under cold arid region of Ladakh. Indian J. Hortic. 66:400-403.

Singh, A., Singh, A. K., Singh, V., Singh, N., Singh, V. N., Shamim, M., Vikram, P. & Singh, S. 2014. Genetic variability among traits associated with grain yield of rice (Oryza sativa L.) exposed to drought at flowering stage. Afr. J. Agric. Res. 9: 1252-1264

Singh, J. K., Singh, J. P., Jain, S. K., Aradhana, J. & Joshi, A. 2002. Studies on genetic variability and its importance in tomato (Lycopesicumesculentum Mill.). Progressive Horticulture, 34: 77-79.

Singh, P. K., Singh B. & Pandey, S. 2006. Genetic variability and character association analysis in tomato. Indian J. Plant Genet. Resour. 19:196-199.

Sinnadurai, S. 1992. Vegetable Cultivation. Asempa Publishers, Accra 59-60.

Sultana, S. 2013. Development of high yielding and quality tomato lines through Diallel cross. M. Sc. Thesis. Bangladesh Agricultural University, Mymensingh 44-45

Tesi, R., A. Grainfenberg and M.E. Creatim. 1970. Heterosis and quality in F1 hybrids of L. esculentum Mill, growth under glass. Riv. Ortoflorofruttic Ital. 54: 269-92.

Turhan, A., Ozmen, N., Serbeci, M. S. & Seniz, V. 2011. Effects of grafting on different rootstocks on tomato fruit yield and quality. Horticultural Science 38(4): 142-149

Udengwu, O. S. 2009. Studies on Heterosis in Abelmoschusesculentus (L.) Moench and A. callei(A. Chev) Stevels Cultivars During Shorter Day Photoperiods in South Eastern Nigeria. Pakistan Journal of Biological Sciences, 12: 1388-1398..

Veerendra, K., Behera V. & Behera, T. K. 2007. Heterosis studies in ash gourd (Benincasahispida (Thunb) Cogn.) for yield and related traits. J. Trop. Agric., 45:51-51.

Wang, Y. Y.; Tang, G. Y., Xia, X. M. & Liao, B. S. 1998. Heritability of characters in groundnut. Oilcrops China., (4): 12-16.

Zaki, N. M. El - Gazar, M. M.; El - Din, K. M. G. & Ahmed, M. A. 1999. Partition and Migration of photosynthates in some maize hybrids. Egypt Journal of Applied Sciences 14(6): 117139

Žnidarcic, D., Trdan, S. & Zlatic, E. 2003. Impact of various growing methods on tomato (Lycopersiconesculentum Mill.) Yield and sensory quality. Journal of Agricultural Science (87): 235-243