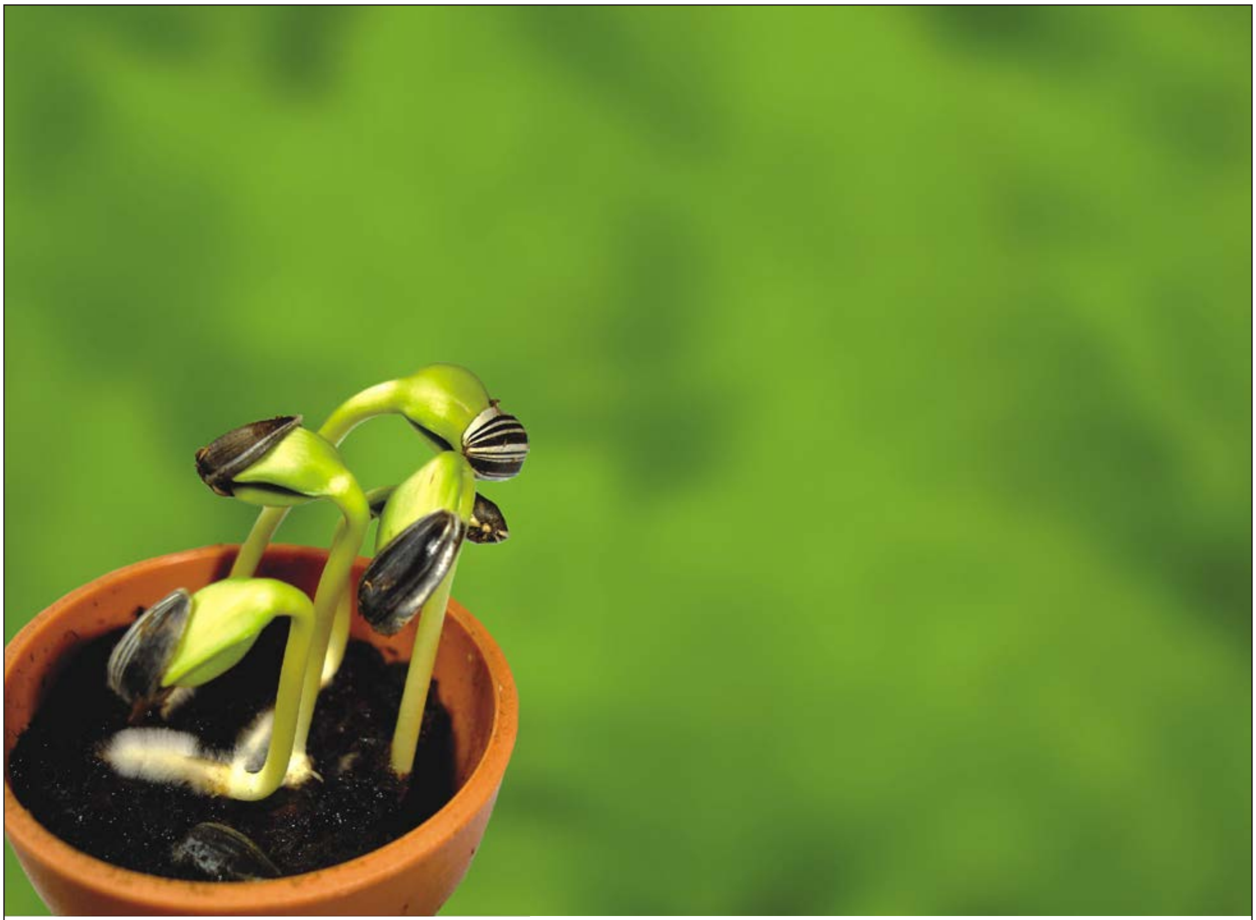

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## Research Article

# Generation Mean Analysis of Yield and Yield Components of Early Generations of Interspecific Crosses of Tomato (*Solanum lycopersicum* L.)

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## Abstract

**Background and Objective:** Yield is the most important agronomical trait; thus, it is involved in virtually all tomato selection programmes. The aim of this study was to assess the performance of early generations of tomato genotypes and improve on the characters of yield and yield components. **Methodology:** The trial included six tomato genotypes $P_1$, $P_2$, $F_1$, $F_2$, $BC_1F_1$ and $BC_2F_1$. They were grown at the Horticulture Division of the Council for Scientific and Industrial Research (CSIR), Crops Research Institute (CRI) Kwadaso, Kumasi during 2014/2015 cropping season. It was laid out in a randomized complete block design with three replications. **Results:** The $F_2$ genotype was superior for plant height, stem girth, total marketable fruit yield, fruit length, fruit diameter and brix. It was however, late maturing. The $F_1$, $BC_1F_1$ and $BC_2F_1$ genotypes outperformed the parentals in terms yield. **Conclusion:** Considering yield and yield components, $F_2$ was found to be better than the rest of the genotypes for most of the characters. The $F_1$ was found to be the poorest performer for almost all parameters measured.

Key words: Early generations, genotypes, performance, tomato, yield

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

Tomato is a very important and popular vegetable crop and its cultivation is a key economic activity for low-income farmers[1]. Every Ghanaian household eats tomato almost every day[2]. Furthermore, tomato is consumed in large amounts as flavouring in stews and soups and in uncooked state in pepper sauces and sometimes in salads. They can also be processed by factories into secondary merchandises such as tomato paste, tomato puree and ketchup[2].

Regardless of government efforts that include the establishment of a number of tomato processing factories, tomatoes of the right quality and quantity for commercial agro processing are not being grown. Many farmers plant local varieties, characteristically low yielding and poor yield components such as high water content, many seeds, poor colour and low brix against the increasing demand at local and international levels. In order to overcome this, the development of high yielding varieties is imperative in the cultivation of tomato to meet the increasing demand[3].

Yield is the most essential agronomical trait; thus, it is included in almost all tomato selection programmes. The adequate choice of parental lines possessing the potential to produce high yielding hybrids is essential[4]. Nevertheless, yield is a multifaceted trait, influenced by genetic and environmental effects, such as numerous abiotic[5,6] and biotic factors, applied agrotechic procedures[7] and growing location[8]. A valuable selection criterion is prerequisite for achieving the inherent yielding ability of a species. Moreover, yield, yield components or other yield contributing agronomic characters may be utilized for breeding for yield increase. In tomato, yield per plant depends on fruit weight and number of fruits per flower branch; however, they are both determined by numerous genetic and environmental factors[9-12]. Therefore, an understanding of the mode of inheritance of the yield and its components is crucial for the adequate choice of selection strategy for developing high-yielding cultivars and hybrids. Food uncertainty in many parts of the world, especially Africa, had practically become unmanageable snags[13]. Undoubtedly, therefore, there is a strongly positive correlation existing between quantity of food available and quantity of food produced.

The study was undertaken to evaluate yield and yield components of some early generations of tomato genotypes. This was to determine the yield components that affect yield to a greater extent in order to define efficient selection strategy for increasing yielding ability in tomato.

Table 1: Physio-chemical properties of the top soil (0–15 cm depth) of the study site

| Properties | Soil depth (0–15 cm) |
|---|---|
| pH (1:1$H_2O$) | 6.54 |
| Organic carbon (%) | 0.78 |
| Total nitrogen (%) | 0.14 |
| Organic matter (%) | 1.34 |
| **Exchangeable cations (me/100 g)** | |
| Ca | 5.07 |
| Mg | 1.6 |
| K | 0.14 |
| Na | 0.08 |
| Available P (ppm) | 92.48 |
| **Particle size distribution** | |
| Sand (%) | 64.52 |
| Clay (%) | 16.02 |
| Silt (%) | 19.46 |
| Soil texture | Sandy loam |

Ca: Calsium, Mg: Magnesium, K: Potassium, Na: Sodium, P: Phosphorus

## MATERIALS AND METHODS

The trial was conducted during the major rainy seasons from May, 2015 to July, 2015. The research field area of Kwadaso lies within the semi-deciduous rain forest zone and is characterized by a bimodal rainfall pattern, from April-July with an average annual rainfall of 1500 mm. The soil is ferric acrisol[14]. Total rainfall and mean sunshine recorded during the experiment was 531.1 mm and 30.4 h, respectively. Maximum and minimum mean temperatures were however, 32.7 and 22.7°C, respectively. Kwadaso station lies between latitude 06, 42° North and longitude 001, 4° West. A composite soil samples from the experimental sites were collected from six different locations of the planting field at a depth of 0-15 cm for laboratory analysis at the Soil Analysis Division of CSIR-CRI, Kwadaso (Table 1).

Two tomato genotypes $P_1$(083) and $P_2$(042) of local origin differing in yield components and morphology (indeterminate and semi determinate) were chosen from tomato germplasm collection of the Crops Research Institute, Kwadaso, Kumasi. The genotypes have been crossed during the tomato growing season of 2013 in order to produce $F_1$ hybrids. In 2014, $F_2$ generation has been obtained and the backcrosses ($BC_1F_1$ and $BC_2F_1$) have been performed (Fig. 1 and 2). In the following year, a comparative field trial including six tomato genotypes (parents, $F_1$, $F_2$ and backcross populations) was carried out in a randomized complete block design with three replications at the Horticulture Division of the Crops Research Institute (CRI) Kwadaso, Kumasi. Standard agronomic practices such as weed control, fertilizer application and insecticide application etc., were applied. The plot size was 72 $m^2$, with

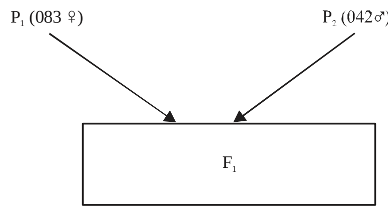


Fig. 1: Systematic presentation of crosses $P_1$ (083 ♀)x$P_2$ (042 ♂)

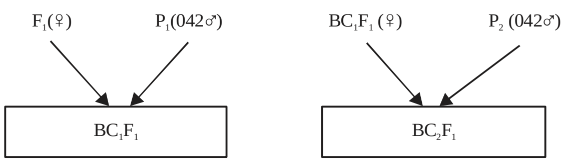


Fig. 2: Schematic illustrations of backcrosses

50 cm within-row spacing and 60 cm between-row spacing. Data were taken on plant height (cm), stem girth (cm), days to flowering, days to maturity, fruit weight, locule number, fruit flesh thickness, number of fruits per plant, fruit length, fruit diameter, brix, marketable and non-marketable fruits. Data recorded were subjected to Analysis of Variance (ANOVA) using the Genstat (12th edition) Statistical package. The LSD at 5% was used to separate the treatment means.

## RESULTS

The mean values of plant height, stem girth, days to flowering and days to maturity for six tomato genotypes together with the corresponding coefficients of variation are listed in Table 2. The days to 100% produced significant differences among the tomato genotypes. The $BC_2F_1$ and $F_1$ genotypes took the longest and shortest number days to hundred percent flowering. Stem girth varied from 7.69-10.31 cm. The maximum stem girth was recorded by $BC_2F_1$, whereas $P_1$ (083) had the minimum stem girth. Plant height at 100% flowering ranges 78.45-93.54 cm. Significant differences exist among the genotypes for plant height. The $F_2$ and $BC_2F_1$ genotypes produced the tallest (93.54 cm) and shortest (78.45 cm) plant, respectively. For the days to maturity, $F_2$ gave the longest days to maturity (63), while $P_1$ (083) had shortest days to maturity (58.67).

Table 3 displays mean values for number of fruit per plant, number of marketable fruit per plant, number of non-marketable fruit per plant number, fruit weight per plant and total marketable fruit weight. There were no significant differences among the tomato genotypes: $P_1$ (083), $P_2$ (042), $F_1$, $F_2$ and $BC_2F_1$ for the number of fruit per plant. Nevertheless, $BC_1F_1$ genotype produced the least number of fruit per plant.

Table 2: Estimates of agronomic performance of tomato genotypes

| Genotype | Parameters: Days to 100% flowering | Stem girth (cm) | Plant height (cm) | Days to maturity |
|---|---|---|---|---|
| $P_1$ 083 | 24.67 | 7.69 | 85.59 | 58.67 |
| $P_2$ 042 | 26.67 | 9.40 | 82.59 | 59.00 |
| $F_1$ | 23.00 | 7.83 | 86.43 | 60.67 |
| $F_2$ | 28.33 | 9.81 | 93.54 | 63.00 |
| $BC_1F_1$ | 27.67 | 8.63 | 79.83 | 60.33 |
| $BC_2F_1$ | 29.00 | 10.31 | 78.45 | 62.33 |
| LSD ($p<0.05$) | 2.47 | 1.61 | 0.18 | 3.48 |
| CV (%) | 5.10 | 9.90 | 0.10 | 3.20 |

LSD: Least significance different, CV: Coefficient of variance

The highest number of marketable fruits was recorded on $P_2$, $F_2$ and $BC_2F_1$ which were significantly different from $P_1$, $F_1$ and $BC_1F_1$. Similarly tomato genotypes $P_1$, $P_2$ and $F_1$ had the highest number of non-marketable fruits which was significantly different from $F_2$, $BC_1F_1$ and $BC_2F_1$. The mean maximum and minimum fruit weight was produced by $P_2$ (32.82 g) and $F_2$ (26.71). Tomato genotypes $P_2$, $F_1$, $F_2$ and $BC_2F_1$ produced the highest total marketable fruit weight which was significantly different from $P_1$ and $BC_1F_1$. There was however, no significant different between $P_1$ and $BC_1F_1$. The mean values of fruit length, fruit diameter, fruit flesh thickness, locules number and brix are presented in Table 4. Significant differences were observed among the tomato genotypes for fruit length and fruit diameter. The highest fruit length and fruit diameter was found on tomato genotype $F_2$. Tomato genotypes $P_1$ and $P_2$ gave the least fruit length. Tomato genotype $F_1$ however, produced least fruit diameter. The biggest fruit flesh thickness was recorded on $P_2$, $F_2$, $BC_1F_1$ and $BC_2F_1$ which was significantly different from $P_1$ and $F_1$ tomato genotypes. Tomato genotypes $P_1$, $P_2$, $F_1$ and $F_2$ gave high number of locules which was significantly different from tomato genotypes $BC_IF_I$ and $BC_2F_1$. The highest brix was observed on tomato genotype $F_2$. Tomato genotype $F_1$ however, produced the lowest brix.

## DISCUSSION

Morphological variations in comparison to the tomato genotypes were registered for all the generations. This may be due to differences in genetic and environmental conditions. This is in agreement with[15,16] who reported that different genotypes perform in a different way in the same environment. Moreover variations in the climatic conditions particularly the soil nutrient status during the experimentation may have considerably contributed to the differences existed in the performance of the genotypes. Understanding the performance of genotypes for breeding purpose, assortment

Table 3: Estimates of yield and yield components of tomato genotypes

| | Parameters | | | | |
|---|---|---|---|---|---|
| Genotypes | No. of fruit per plant | No. of marketable fruit per plant | No. of non-marketable fruit per plant | Fruit weight per plant (g) | Total marketable fruit weight (kg) |
| $P_1$ 083 | 27.00 | 20.00 | 7.00 | 27.81 | 4.24 |
| $P_2$ 042 | 29.00 | 22.33 | 6.67 | 32.82 | 5.01 |
| $F_1$ | 26.33 | 19.33 | 7.00 | 28.12 | 5.36 |
| $F_2$ | 27.33 | 22.00 | 5.33 | 26.71 | 5.36 |
| $BC_1F_1$ | 22.33 | 17.00 | 5.33 | 29.40 | 4.43 |
| $BC_2F_1$ | 27.67 | 22.00 | 5.67 | 28.12 | 5.85 |
| LSD ($p<0.05$) | 4.56 | 4.57 | 1.19 | 4.63 | 0.86 |
| CV (%) | 9.40 | 12.30 | 10.7 | 8.80 | 10.1 |

LSD: Least significant difference and CV: Coefficient of variance

Table 4: Yield components of tomato genotypes

| | Parameters | | | | |
|---|---|---|---|---|---|
| Genotype | Fruit length (cm) | Fruit diameter (cm) | Fruit flesh thickness (mm) | Locules number | Brix |
| $P_1$ 083 | 25.96 | 35.88 | 2.87 | 5.00 | 4.19 |
| $P_2$ 042 | 27.66 | 37.94 | 3.50 | 5.65 | 3.96 |
| $F_1$ | 32.01 | 28.72 | 2.93 | 4.77 | 3.44 |
| $F_2$ | 36.53 | 42.18 | 3.40 | 4.84 | 5.51 |
| $BC_1F_1$ | 31.88 | 34.82 | 3.23 | 3.84 | 3.85 |
| $BC_2F_1$ | 29.77 | 36.71 | 3.74 | 4.03 | 4.43 |
| LSD ($p<0.05$) | 2.46 | 2.79 | 0.53 | 1.30 | 0.22 |
| CV (%) | 4.50 | 4.30 | 8.70 | 15.30 | 2.90 |

LSD: Least significant difference and CV: Coefficient of variance

efficiency and prediction of their performances is essential. The differences observed in the number of days to 100% flowering may be attributed to weather conditions, available nutrients and moisture in addition to genetic differences for earliness affected the growth and development of tomato genotypes. This explained for earliness of flowering in some genotypes. The result is in conformity with what was reported by Regassa *et al.*[17], Ibrahim *et al.*[18] and Sajjan *et al.*[19] further reported that genetic constitution of crop varieties influence growth characters such as plant height. Days to flowering are important component in tomato production because it is a transition for the initiation of reproductive stage in the lifecycle of the plant. The observed differences in the stem girth among the genotypes may be attributed to effective uptake and efficient utilization of available nutrients for growth and development of the crop. This is in accordance with Godia[20] who reported that plant growth can be influenced by temperature. It must be noted that one of the major site for storage of food material from photosynthesis is plant stem girth. Bigger stem girth is considered to be useful in relation to drought resistance because of its extra capacity to store food materials which is advantageous during moisture stress situation.

The yield and yield components of cultivated tomato fruits are most important from production point of view and it is the prime concern of the plant breeder and is the final factor on which selection programs are most times envisaged. The variation in the number of fruits per plant among the evaluated genotypes may be attributed to the differences in ability to produce and retain high number of flowers that developed into fruits. The genotype which had the least number of fruits per plant perhaps may have had about 50% of its flowers dried up and fell off without further development. Genotypes with higher number of flowers were successfully developed into fruits possibly because of better genetic components. The result is consistent with Turhan *et al.*[21] and Shah *et al.*[22] among several authors who reported that the mean number of fruit per plant ranged from 4.46-98.30. Additionally, the variations observed among tomato genotypes with respect to total marketable fruit weight perhaps are related to differences in the fruit cluster per plant and number of fruit per cluster per plant. It may also 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. This result is analogous to the findings of Costa and Campos[23], Gardner *et al.*[24] and Zaki *et al.*[25] who attributed the yield differences in crop cultivars with special reference to tomato plants to the stomata of its value and the differences in the allocation of photosynthetic material in economic performance. It could also be attributed to the number of flowers set, developed into fruits and retained by the plants onto harvest. Similar noticeable differences in fruit yield of tomato varieties were reported by Mishra and Lal[26] and Shibli *et al*.[27].

The considerable variability observed in fruit length and fruit diameter perhaps is as a result of combination of factors such as fruit shape (spherical, elongated, flat or pear-like), plant health and ability of plant to take up and utilizes available moisture (water), nutrients and possibly gene actions. This finding is in agreement with Regassa *et al*.[17] and Atherton and Rudich[28]. According to Lippman and Tanksley[29], increase in locule number can increase fruit size by as much as 50%. Thus, the increase in locule number is an important step in the development of larger tomato fruits. The gene, fas is a strong determinant of locule number in fruit and most large-fruited tomatoes carry 'fas' allele which is associated with high locule number[30]. 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*.[31] and Durvesh and Singh[32] who reported that quality attributes like total soluble solids of the fruit ranged from 4.0-5.0%. The variations in fruit flesh thickness among genotypes could be ascribed to fruit firmness and possibly genetic differential for the trait. This is in accordance with Dar *et al*.[31] and Durvesh and Singh[32].

## CONCLUSION

This study demonstrates the potential for some of the tomato genotypes in Ghana. Tomato genotype $F_2$ was superior for parameters such as; plant height, stem girth, total marketable fruit yield, fruit length, fruit diameter and brix. It was however, late maturing. Furthermore, $F_1$, $BC_1F_1$ and $BC_2F_1$ showed high yield potential over parental. Based on the findings of the study, it is recommended that further development is needed to obtain inbred lines and subsequently develop hybrids.

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