African Crop Science Journal, Vol. 25, No. 1, pp. 25 - 32
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ISSN 1021-9730/2017 $4.00

DOI: http://dx.doi.org/10.4314/acsj.v25i1.2

HYBRIDISATION BETWEEN CHERRY TOMATO (SMALL FRY) AND PETOMECH FOR SHORTENED FRUIT MATURATION, SIZE AND EARLINESS

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(*Received 7 January, 2016; accepted 27 January, 2017*)

ABSTRACT

Tomato (*Lycopersicon esculentum* var. cerasiforme) is among the most important vegetable crops grown world wide providing good nutritional requirements and boost incomes, especially in sub-Saharan Africa. The objective of this study was to determin the heritability of shortened fruit maturation (SFM) period in a hybrid from a cross between cherry (Small fry) tomato and Petomech. A field experiment was carried out at the Crops Research Institute (CRI), Kwadaso. A cross was made between Petomech and Small fry. Fruit maturation period (FMP) (days from anthesis to the breaker stage of fruit Colour) was 42 days for Small fry and 52 days for Petomech. Parental, F_1, F_2, and backcross generations differed in FMP, yield, estimates of broad- and narrow-sense SFM heritabilities of 61.4 and 38.8%, respectively, on a single-plant basis. A test for midparent heterosis also showed significance (P<0.05). Genetic control of SFM was quantitative in nature, and highly dominant. The F_1 and F_2 generations had FMP of 47.2 and 49.5 days, respectively. F_1, F_2, and backcross generations all differed in number of fruits per plant, giving broad- and narrow-sense heritabilities of 69.73 and 55.67%, respectively. With a mean per fruit weight of 150.1 g Petomech recorded the highest fruit weight, while Small Fry recorded the lightest fruit weight of 81.4 g. Estimated broad-and narrow sense heritability for fruit weight was 71.76 and 41.68%, respectively. There was a significant difference between Small Fry and Petomech, as well as the BC_1 and BC_2 in terms of fruit size. The highest heterotic effect was found in number of fruits per plant (27.6%) over mid-parent. The highest yield was recorded by Petomech (18.9 t ha^{-1}), while Small Fry recorded the lowest value of (14.3 t ha^{-1}).

Key Words: Genetics, heterosis, heritability, *Lycopersicon esculentum*

RÉSUMÉ

La tomate (*Lycopersicon esculentum* var. cerasiforme) est l'une des plus importantes cultures maraichères de par le monde, contribuant à satisfaire les besoins nutritionels de l'homme et générant des revenus aux producteurs, en Afrique au sud du Sahara en particulier. L'objectif de cette étude était de determiner l'héritabilité du court cycle de maturation (SFM) dans un hybride obtenu du croisement entre la tomate cerise et Petomech. Une experimentation en plein champ a été conduite à l'institut de recherché sur les cultures (CRI) à Kwadaso. Un croisement a été réalisé entre Petomech et la petite tomate cerise. La période de maturation des fruits (FMP) était de 42 jours pour la tomate cerise et 52 jours pour Petomech. Les parents, les F_1, les F_2, et les générations différaient de par leur FMP, leur rendements, les valeurs d' héritabilités au sens large et au sens strict de leurs SFM. Ces valeurs étaient respectivement de 61.4 et 38.8%, et ceci sur la base de plante unique. Le test d'hétérosis par rapport à la moyenne des parents était aussi significatif (P<0.05). le control génétique de SFM était de nature quantitative, et largement dominant. Les générations F_1 et F_2 avaient respectivement une FMP de 47.2 et 49.5 jours. Les générations F_1, F_2 et backcross différaient de par leur nombre de fruits par plante, donnant ainsi des valeurs d'héritabilités au sens large et au sens strict de 69.73 et 55.67%, respectivement. Petomech a exhibé les fruits les plus lourds (150.1 g), tandis que la tomate cerise a exhibé les fruits les plus légers (81.4 g). Les valeurs estimées d'héritabilité au sens large et au sens strict étaient respectivement de 71.76 et 41.68% pour le poids du fruit. Une difference significative a été observée entre les deux parents, ainsi que les générations backcross BC_1 et BC_2 , en ce qui concerne la taille des fruits. L'effet hétérotique le plus élevé était observé au niveau du nombre de fruits par plante (27.6%) par rapport à la moyenne des parents. Le rendement le plus élevé était enregistré chez Petomech (18.9 t ha^{-1}), tandis que la tomate cerise avait le plus petit rendement (14.3 t ha^{-1}).

Mots Clés: Génétique, hétérosis, héritabilité, *Lycopersicon esculentum*

INTRODUCTION

Tomato (*Lycopersicon esculentum* var. cerasiforme) is among the most important vegetable crops grown world wide, it is of immense value to most families, especially in sub-Saharan Africa by providing essential nutritional requirements and incomes. Globally tomato production is over 120 million metric tonnes (FAO, 2007). Early maturity in tomato cultivars is highly desirable since early season fruit harvests tend to bring the highest prices in the fresh market. Earliness in growth is an important trait to select for, especially in areas of less seasonal rainfall (Ofori *et al.,* 2005). The mechanisms controlling earliness in tomato have been widely studied (Sudarkodi and Sathyabama, 2011). Earliness can be defined in different way, but in general, measured relative earliness (or lateness) as the number of days from sowing to the first ripe fruit. The relationship between fruit size and earliness has also been widely studied in an attempt to develop early and large-fruited cultivars (Lampinen *et al.*, 2002). Day *et al.* (2008) found that selection for earliness results in a decrease in fruit size and a positive correlation between fruit size and number of degree days to ripe fruit. However, it was clear in their study that selection for large fruit size resulted in delayed maturity.

In a study by Sudarkodi and Sathyabama (2011), the environment was found to strongly influence earliness. Perez-Grajales *et al.* (2009) further showed that the environment had little influence on fruit size. In crosses between large- and small-fruited cultivars, fruit size of the F_1 hybrids typically resembles that of the smaller-fruited parent. Small fruit size is considered to be partially dominant to large fruit size (Perez-Grajales *et al.*, 2009). Crop improvement depends on the magnitude of genetic variability and the extent to which desirable characters are heritable. The objective of this study was to determine the heritability of shortened fruit maturation (SFM) period in a hybrid from a cross between cherry (Small fry) tomato and Petomech.

MATERIALS AND METHODS

Study area. The study was carried out at the Horticulture Division of the Council for Scientific Industrial Research (CSIR)-Crops Research Institute, Kwadaso, Kumasi in Ghana. The research field area of Kwadaso lies within the semi-deciduous rain forest zone, and is characterised by a bimodal rainfall pattern; an average annual rainfall of 1500 mm. The soil is Ferric Acrisol (FAO, 2007). Total rainfall and mean sunshine recorded during the experiment was 531.1 mm and 30.4 hr, respectively. Maximum and minimum mean temperatures were, however, 32.7 and 22.7 ^{o}C, respectively. Kwadaso station lies between latitude 06, 43^{o} North and longitude 001, 36^{o} West.

F_1 generation. Crosses were made between Petomech and Cherry (Small fry) tomato in September 2013 (Fig. 1). A nursery of the two parents (Small fry tomato-Parent 1, Petomech-Parent 2) was staggered such that parent 1, which was used as male was transplanted two weeks earlier than the parent 2 (female). This was to ensure flowering synchronisation. They were planted at a spacing of 100 cm x 50 cm. Bright yellow flowers of the male parent, with petals beginning to reflex, were shaken to release pollen. Pollen was then used to pollinate the female parent whose flowers (stigma) were force-opened to remove immature anthers (emasculated).

A randomised complete block design (RCBD), with three replicates was used for the field experiment. Standard agronomic practices including fertilisation with NPK at 250 kg ha^{-1} were performed (Boudreaux, 1998).

F_2 generation. The F_1 seeds were sown on the 22nd September, 2013 and 30 seedlings were transplanted at 100 cm x100 cm at three weeks after sowing, to produce seeds for the F_2 population (Fig. 2).

One thousand F_2 progenies were sown on the 14th of December, 2013 and planted at 60 cm x 50 cm at three weeks thereafter, to select superior plant types. They were planted together with the parents as checks.

Data were taken on the days to flowering (1st and 50% flowering), number of fruits per plant, fruit size and weight. Fruit size was measured based on the method described in Bertin *et al*. (2002). Fruit weight was taken fresh by weighing pericarp tissues including external, internal and transverse parts, excluding seeds, using a weighing scale.

Twenty-three fruits were collected from each of the genotypes, representing large to small size, and spherical to oblate fruit shape. For each fruit, actual fruit volume (AFV) was measured by water displacement in a beaker.

Backcrosses. The recurrent parent (Petomech) was crossed with the F_1 line to produce BC1. The BC_1F_1 was further crossed with the recurrent parent to produce BC_2F_1 progenies. Heritability was calculated both in the broad and narrow sense, using the variances computed. Heritability in the broad-sense was calculated as the ratio of the genotypic variation to the F_2 variation. Narrow-

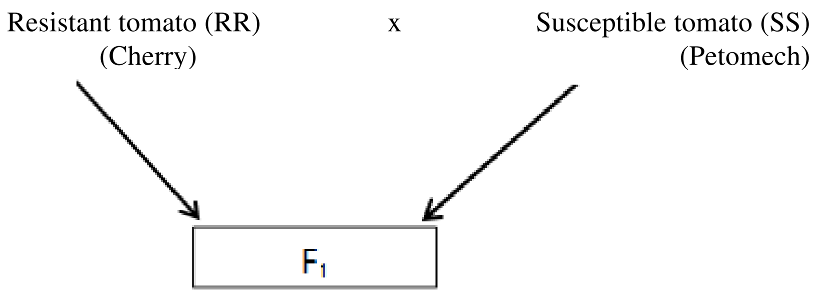

Figure 1. Illustration of tomato hybridisation.

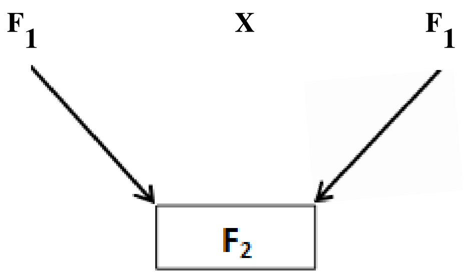

Figure 2. Selfing of F_1 to produce F_2.

sense heritability was also calculated as the ratio of the additive variation to the F_2 variation (Falconer and Mackay, 1996).

Data analysis. Data collected were analysed using the Genstat Statistical Package (9th edition). The Least Significant Difference (LSD) at $P < 5\%$ was used for comparing mean differences.

Heritability and heterosis computation:

(i) Broad-sense heritability (H^2) = V_G/V_P

(ii) Narrow-sense heritability (h^2) = V_A/V_P,

Where: V_A = Additive variance

V_P = Phenotypic variance

V_G = Genetic variance

Heterosis was also computed as:

$$\text{Heterosis} = \frac{F_1 - MP}{MP} \times 100 \quad \text{or} \quad \frac{F_1 - HP}{HP} \times 100$$

Where: MP is mid parent (P1+P2)/2,
HP is highest parent or better parent

RESULTS

Maturation period. Table 1 presents fruit maturation periods of different tomato generations. There was no significant difference (P >0.05) between the genotypes on the number of days to 1st flowering (Table 1). However, there was a significant different between the genotypes at 50% flowering. The difference in number of days from anthesis to the breaker stage of fruit maturation was greatest for the two parental lines (8.9 days). The means of BC_1 were very close to Petomech. The means of the F_2 were strongly skewed towards the mean for Small fry (Table 1). The means for the backcross (BC1) were strongly skewed towards the mean for Petomech and above the midpoint of the two parents.

Fruit yied response. The yield responses for the five tomato genotypes are presented in Table 2. Small fry produced the highest number of fruits per plant (72.7), which was significantly different from all the other genotypes. Petomech produced the lowest number of fruits per plant (36.3). Moreover, there were significant differences between the F_1, F_2, as well as BC_1 and BC_2 with mean yields of 39.7, 48.5, 45.0 and 56.0, respectively.

TABLE 1. Fruit maturation period (days from anthesis to the breaker stage of fruit ripening) of the four generations in the tomato family Petomech and Small fry in Ghana

Tomato genotype	Days to 1st flowering	Days to 50% flowering	Days to maturity
P_1-Petomech	30	38	90
P_2-Small fry	30	39	81
F_1	31	36	83
F_2	30	35	84
BC1	30	36	88
BC2	30	36	82
LSD (5%)	NS	2	7
CV (%)	17.5	18.6	5.2

BC_1 on the other hand, gave the largest fruits, with an average size of 49.8 mm, while Small Fry recorded the least fruit size with an average value of 33.6 mm.

The highest value for yield in terms of tons per hectare was recorded by Petomech (18.9) while Small fry recorded the least value of (14.3).There was a significant difference ($P <0.05$) among the two parents. However, there was no significant difference ($P > 0.05$) in yield (t ha^{-1}) among the other genotypes. The Tomato genotypes showed variability in fruit weight (Table 2).

There was a significant difference ($P <0.05$) between Small fry and Petomech, in terms of fruit size as well as BC_1 and BC_2 (Table 2). There was, however, no difference ($P > 0.05$) between the F_1, and F_2.

Heritability. Table 3 shows the calculated heritability at both the broad-sense and narrow sense. The broad-sense heritability based on single-plant selection, ranged between 71.70 and 42.80%, for fruit weight and fruit size, respectively; while narrow-sense heritability ranged between 55.70 and 24.60% for number of fruits $plant^{-1}$ and fruit size. Heritability estimates were high for the characters in all the traits, except fruit size which showed limited heritability (Table 3).

Heterosis. Values for heterosis over mid-parent are presented in Table 4. Positive heterosis ranging from 14.60 to 27.60% was recorded by the hybrids over the mid-parent, for fruit weight, number of fruits $plant^{-1}$ and fruit size. However, a negative heterosis of -

TABLE 2. Yield responses for five tomato genotypes assessed during the field hybridisation experiments in Ghana

Tomato genotype	Fruits $plant^{-1}$	Fruit size (mm)	Yield (t ha^{-1})
Petomech	36.3	48.7	18.9
Small fry	72.7	33.6	14.3
F_1	39.7	47.2	13.2
F_2	48.5	46.0	16.3
BC_1	45.0	49.8	14.4
BC_2	56.0	30.8	15.8
LSD (5%)	5.0	4.5	3.5
CV (%)	6.7	7.1	7.7

TABLE 3. Calculated heritability (broad-sense and narrow- sense)

Agronomic characteristics	Narrow-sense (%)	Broad sense (%)
Number of fruits $plant^{-1}$	55.70	69.80
Fruit size (mm)	24.60	42.80
Fruit weight (g)	41.60	71.70
Days to maturation	38.80	61.40

TABLE 4. Percentage heterosis over mid-parent in a hybridisation study of tomato in Ghana

Cross combinations	Fruits $plant^{-1}$	Fruit weight (g)	Fruit size (mm)	Days to maturation
$P_1 \times P_2$	27.60	23.90	14.60	-2.90

2.90% was recorded for days to maturation (Table 4).

DISCUSSION

Most varieties matured between 45 and 90 days. This is attributed to genetic differences and extraneous factors, such as environmental factors and husbandry (Tables 1 and 2). Earliness in growth is an important trait to select for, especially in areas of less seasonal rainfall (Ofori *et al.,* 2005). The days to maturity in tomato is not only attributed to variety, but also influence by environmental factors, such as temperature and growing conditions (Saleem *et al*., 2011).

The results indicate that SFM exhibited a high level of dominance in the crosses involved (Table 3). Results of this study were similar to those reported by Kemble and Gardner (2003) and Ahmed *et al.* (2006), although they defined earliness differently. In their studies, the values of the F_1s were below the midparent value, and close to the value of the early parent. They concluded that dominance played a major role in the expression of earliness. Earliness in growth has been found to be an important trait to select for, especially in areas of less seasonal rainfall (Ofori *et al.,* 2005). Most varieties matured between 45 and 90 days. The days to maturity in tomato is attributed to variety, but is also influenced by environmental factors, such as temperature and growing conditions (Saleem *et al*., 2011). This may be attributed to genetic differences and/or extraneous factors, including environmental factors and husbandry.

In the present study, high heritability was recorded for number of fruits per plant and fruit weight (Table 3). This indicated the importance of the considerable additive (heritable) gene effect in governing their inheritance, and phenotypic selection for their improvement could be achieved by simple methods like pure line or mass selection, or bulk method following hybridisation and selection in early generations. Therefore, these characters were more reliable for effective selection to improve the yield of tomato. These results are in agreement with the findings of Mehta and Asati (2008), and Singh (2009) who worked on genetic variability fruit yield and its traits among indeterminate tomato genotypes under open field condition. They found that that the nature and extent of genetic variability are some of the most important criteria in formulating an efficient breeding programme. Under tropical conditions, Zahedi and Ansari (2012) found significant variation in yield of tomato genotypes, and attributed it to seasonal variability, whose impact on plant growth and yield was different for different genotypes. The relatively low yields in our study compared favourably with yields reported by Olaniyi *et al.* (2010), who obtained yields of less than 20 tonnes.

Heterosis was estimated as 27.6% and -2.9% for fruits plant^{-1} and days to maturation, respectively. This indicates that heterosis influence the expression of SFM. The classical work of Shull and East 1905-12 laid the foundations for exciting advances in exploitation of heterosis in crops (Taslim, 2006). The best way to utilise heterosis in crops is to produce F_1 hybrids, which possess maximum heterozygosity (El-Gazzar, 2004). The commercial exploitation of heterosis, however, was recorded first in 1930s with maize in USA (Ahmad, 2002). Heterosis is an important genetic phenomenon, synonymous with hybrid vigour, and refers to the manifested superiority of the F_1 hybrid resulting from the cross of genetically dissimilar homozygous parents. Negative heterosis (-2.9%) was observed in the case of days to maturation showing earliness in the maturation, As the consumers prefer to eat tomato earlier, negative heterosis for this trait is preferable. This study is in accordance with the findings of Baishya *et al.* (2001) and Ahmad (2002) in southern Nigeria, who reported negative heterosis for this trait over the better parent in many of their crosses. A positive heterosis for fruit weight was recorded (23.9%), which indicated that this trait can be improved through heterosis breeding. Positive heterosis for single fruit weight/plant under high temperature environments were reported by Fageria *et al*. (2001). The hybrid provided positive heterosis of (14.6%) for fruit size. This result confirms the findings of Krieger *et al*. (2010) who estimated heterosis in tomato and reported that a positive heterosis for the hybrid is attributed to genetic difference between the two parental lines.

CONCLUSION

The high narrow-sense heritability shown in this study for fruit weight and number of fruits per plant indicates that selection and advancement of improved fruit size and number should be effective**.** Tomato genotype, Cherry (Small fry) can be incorporated into other breeding programmes for early fruit maturation.

ACKNOWLEDGMENT

The authors thank the Government of Ghana for partial funding to this study. Also, Mrs. Cynthia Adu-Brako is acknowledged for her financial support.

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