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Research Note

Estimation of genetic parameters and identification of selection indices in exotic tomato genotypes

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Abstract
A study was undertaken to evaluate and characterize seventeen exotic genotypes of tomato grown in eastern India and to identify important selection indices for the yield improvement of the crop. Significant differences among genotypes were found for all studied properties. Three (CLN2777-E, CLN2777-F and CLN2777-A) high yielding and two (Alisha Craig O^{gc} and Feb-2) having better processing quality genotypes identified in the present study could be utilized in future breeding programme. In the present study, high heritability coupled with high genetic advance were observed for number of flower clusters per plant, number of fruits per cluster, plant height, polar diameter, number of fruits per plant, fruit weight, pericarp thickness, total soluble solids, titratable acidity, ascorbic acid content, lycopene content and fruit yield per plant which were controlled by additive gene effects, indicating good response to selection for these characters. From the study of correlation and path coefficient analyses, three characters namely, number of flower clusters per plant, number of fruits per cluster and fruit weight were found most important selection indices of tomato.

Keywords
Tomato, Quantitative traits, Genetic variability, Heritability, Selection Index.

The cultivated tomato (*Solanum lycopersicum*), a fruit that is often consumed as a vegetable, is widely grown around the world and constitutes a major agricultural industry. Worldwide, it is the second most consumed vegetable after potato and unquestionably the most popular garden crop. In addition to tomatoes that are eaten directly as raw vegetable or added to other food items, a variety of processed products such as paste, whole peeled, and various forms of juice, sauces, and soups have gained significant acceptance.

Tomato and its products made its attention even in terms of value of micro-nutrients existing at low concentration. Apart from contributing nutritive elements, colour and flavour to the diet, tomatoes are also a valuable source of antioxidants, or chemo-protective compounds, and may thus be termed as "functional food" (Ranieri *et al*., 2004). Quality and flavour of the processed products depend on chemical components like total sugar, reducing sugar, acidity, ascorbic acid, lycopene, ß-carotene and Total Soluble Solids (TSS) which have been reported to vary greatly with variety/hybrid (Chattopadhyay *et al*., 2013). The desirable qualities for a tomato cultivar to be used for processing includes high total soluble solids (> 4.5^0 Brix), acidity not less than 0.4%, pH less than 4.5, uniform red colour, smooth surface, free from wrinkles, small core, firm flesh and uniform ripening (Adsule *et al*., 1980). Now-a-days, there are dozens of tomato-breeding companies which are the main players in the world market. In order to survive, seed companies must continuously develop new cultivars with added value and hence commercial tomato breeding is very innovative.

Evaluation of the potentialities of the existing cultivars is essential because it depicts the genetic diversity of the base materials on which depends the promise for further improvement. The success of a breeding programme for the improvement of quantitative attributes depends to a great extent on the magnitude of genetic variability existing in the germplasm. Burton (1952) suggested that genetic variability along with heritability should be considered for assessing the maximum and accurate effect of selection. Studies on the variability using genetic parameters like genotypic coefficient of variation (GCV), heritability and genetic advance are essential for initiating an efficient breeding programme. High yield can be achieved by selection of those characters that have high heritability values coupled with high genetic advance. Selection is an indispensable component of the variety development process. Breeders search for dependable parameters that are less affected by the environment.

Yield is a complex character controlled by a large number of contributing characters and their interactions. Knowledge in respect of the nature and magnitude of associations of yield with various component characters is a pre-requisite to bring improvement in the desired direction. A crop breeding programme, aimed at increasing the plant productivity requires consideration not only of yield but also of its components that have a direct or indirect bearing on yield. Keeping in view the importance of the study, the present investigation aimed at determination of genetic variability parameters for important growth and its attributes, fruit and quality characters influencing yield, their interrelationships including direct and indirect effects on yield.

The present investigation was undertaken during the autumn winter season of 2012-13 at "C" Block Farm under the research field of All India Coordinated Research Project on Vegetable Crops, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal, India. The experiment site is located at $22^0$56`N latitude and $88^0$32`E longitude with an altitude of 9.75 m above the sea level. This site is situated under sub-tropical humid region with an average temperature range of 11.25^0C to 29.25^0C during autumn-winter months (September-March). The soil of the experimental field was sandy loam in texture with good drainage facility and having medium soil fertility. Twelve tomato leaf curl virus (ToLCV) tolerant genotypes collected from AVRDC, Taiwan and five mutant genotypes from Institute of Genetics, Bulgarian Academy of Science, Sofia, Bulgaria (Table 1), were evaluated following Randomized Block Design with three replications. The seedlings of each genotype were raised under low cost poly tunnel. Nursery beds were covered with 200 µm ultraviolet (UV)-stabilized film supported by bamboo poles with open sides to protect seedlings from rain and direct sunlight. The sides of the nursery structure were covered with 50 mesh nylon net to prevent the attack of whitefly (*Bemisia tabaci*). Seedlings were hardened by withholding water 4 days before transplanting. Twenty-five-day-old, seedlings, at least 15 cm in height with 3–4 leaves, were used for transplanting in the main field at a spacing of 60 cm in both ways in a plot size of 12.96 m^2 areas. The crop was fertilized with 15 t FYM along with 120 kg N (Urea), 60 kg P_2O_5 (Single super phosphate) and 60 kg K_2O (Potassium chloride) ha^{-1}. $1/3^{rd}$ amount of nitrogen and full doses of phosphorus and potash were applied at the time of planting. Rest amount of nitrogen was top dressed at 30 days after planting (DAP) and 60 DAP in equal amount. The cultural practices were followed as per Chattopadhyay *et al*. (2007).

Physical-biochemical characteristics: Each genotype was characterized on 16 quantitative characters *viz.*, days to first flowering; days to 50% flowering; plant height in cm; number of flower clusters per plant; number of fruits per cluster; number of fruits per plant; polar diameter in cm; equatorial diameter in cm; pericarp thickness in mm; number of locules per fruit; average fruit weight in g; total soluble solids in ^{0}brix; ascorbic acid in mg/100 g; titratable acidity in percent; lycopene content in mg/100 g of fruit, and fruit yield per plant in kg as per IPGRI descriptor list (IPGRI,1981). Fifteen randomly selected plants from each replication were taken to record seven quantitative traits like days to first flowering, days to 50% flowering, plant height, number of flower clusters per plant, number of fruits per cluster, number of fruits per plant and fruit yield per plant. Ten randomly selected red ripe fruits were taken from each replication to record nine of the fruit and quality characters (Table 1).

Total soluble solids (TSS) of the clear juice samples were determined by digital refractometer (ATAGO, 0-32 ^{0}brix) and the result was expressed in ^{0}brix after temperature correction. The titratable acidity was estimated by titrating 5 ml of sample against 0.1N NaOH solution using phenolphthalein as an indicator. The acidity was calculated and expressed as per cent anhydrous citric acid (AOAC, 1984). Ascorbic acid content was determined by using 2,6-dichlorophenol indophenols dye method (Ranganna, 1980). Lycopene estimation was done by using AOAC method (AOAC, 1984). 5 to 10 g sample was repeatedly extracted with acetone until the residue became colourless. The acetone extract was transferred to a separating funnel containing 10 to 15 ml petroleum ether and then 5% sodium sulphate solution was added. The lower acetone phase was repeatedly extracted with petroleum ether similarly, until it became colourless. The upper petroleum ether extract was pooled and its volume was made up to 50 ml with petroleum ether. Diluted aliquot to 50 ml. with petroleum ether and the colour was measured in a 1 cm cell at 503 nm in spectrophotometer (Systronics UV-VIS double beam spectrophotometer 2201) using petroleum ether as blank.

Statistical analysis: The mean data obtained were used for determining genotypic co-efficient of variation and phenotype co-efficient of variation (Burton, 1952), heritability in broad sense (Hanson *et al*., 1956), and the expected genetic advance (Johnson *et al*., 1955). The correlation coefficients at genotypic and phenotypic levels were calculated as per the method given by Johnson *et al*. (1955). The path coefficient analysis was done as per Dewey and Lu (1959). All statistical analyses were done using SPSS Professional Statistics version 7.5 (SPSS Inc., Chicago, III.).

Characterisation of tomato genotypes: Sixteen quantitative characters from seventeen exotic genotypes of tomato were evaluated and characterized and are presented character-wise in Table-1.

Days to first flowering**:** The character differed significantly among the genotypes ranging from 25.33 to 36.00. The genotype 'Alisha Craig O^{gc}' was the earliest to flower (25.33 days) followed by 'Alisha Craig *Fulgens*' (28.67 days), 'CLN 2777-H' (28.00 days) whereas, 'CLN 2768-A' took the maximum days (36.00) to produce first flowering.

Days to 50% flowering:The genotypes 'Alisha Craig O^{gc}' (30.33 days) followed by 'CLN2777-G' (32.00 days) and 'CLN2777-E' (32.67) were earlier in 50 per cent flowering and the genotype 'CLN2777-C' (40.33 days) was recorded as late to reach 50 per cent flowering. A genotype having earliness in flowering is always preferred by the plant breeder.

Number of flower clusters per plant: The maximum number of flower clusters per plant was recorded in the genotype 'CLN2777-A' (14.46) followed by 'BCT-115 (DG)' (14.09) and the minimum was observed in 'CLN2777-G' (9.75).

Number of fruits per cluster: In case of number of fruit per cluster, the range is between 1.83 and 3.28. The germplasm 'CLN 2777-E' showed the maximum number of fruits per cluster (3.28) followed by 'CLN2777-F' (3.00) whereas, BCT-115 (DG) showed the minimum value (1.83).

Plant height: Plant height differed significantly in all the genotypes ranging from 44.70 cm to 124.47 cm, the maximum being in 'CLN 2498-D' (124.47 cm) followed by 'Alisha Craig O^{gc}' (123.30 cm) and the lowest in 'BCT-115 (DG).

Polar diameter: Polar diameter of the fruit was maximum in the genotype 'CLN2768-A' (6.19 cm) followed by 'CLN2762-A' (6.09 cm) and the minimum was recorded in 'Alisha Craig *Fulgens*' (3.78 cm). Genotypes with high polar diameter and having pear shape are desired for processing purpose as the fruit contains more pulp as reported by Tiwari (1996).

Equatorial diameter: The maximum equatorial diameter of the fruit was observed in 'CLN2777-F' (6.26 cm) followed by 'CLN2777-B' (6.11 cm) and the minimum was observed in 'Alisha Craig *Fulgens*' (4.32 cm).

Number of fruits per plant: It differed significantly among the genotypes ranging from 24.28 to 41.21. The average number of fruits per plant was found to be the highest in 'CLN 2777-A' (41.21) followed by 'CLN 2777-F' (35.57) and the lowest number was found in 'CLN 2768-A' (24.28).

Average fruit weight: Average fruit weight was maximum in 'CLN2777-H' (82.99 g) followed by 'CLN2777-E' (82.17 g) whereas; it was the minimum in 'Alisha Craig *Fulgens*' (49.39 g). A minimum of 70 g fruit weight is desirable for table as well as processing purposes.

Pericarp thickness: Pericarp thickness of the fruit was the maximum in the genotype 'CLN2460-E' (6.73 mm) and it was followed by 'Alisha Craig O^{gc}' (6.22 mm) and the minimum was recorded in 'Alisha Craig AFT' (3.56 mm). Thickness of the pericarp also bears an important quality attributes for processing purpose (Kumari *et al.,* 1998). Tomatoes with thicker pericarp would stand long distance transport and keep well (Bhutani and Kalloo, 1991). Thus, tomatoes for processing should have more than 5.00 mm of pericarp thickness which would keep the fruit firm and evaporation of water through surface would be less (Tiwari, 1996).

Locule number:The number of locules per fruit was maximum in '.CLN2777-H' (4.33), whereas the genotype 'Alisha Craig *Fulgens*'produced the minimum (3.10) locules per fruit. Number of locules in the fruit is an important trait for selection of genotype for processing. There should be minimum number of locules (2-3) for proper shape of the fruit and at the same time favour high concentration of solids and ascorbic acid content (Thamburaj, 1998).

Total soluble solids: The character total soluble solids were influenced significantly by the genotypes under study. The minimum value (3.67 ^{0}brix) was shown by the genotype 'CLN2498-D'. On the other hand, genotypes like 'Feb-2' and 'Alisha Craig O^{gc}' exhibited the maximum values (>5.0 ^{0}brix).High total soluble solids (TSS) are the main quality component for nutritional and processing purposes (Kumari *et al*., 1998).

Titratable acidity: Average titratable acidity in different tomato genotypes varied from 0.30% in 'CLN2498-D' to 0.50% in 'CLN2777-H'. Citric acid is the most abundant acid in tomatoes and the largest contributor to the total titratable acidity (Paulson and Stevens, 1974). The acidity of the fruit is also important as a contributor to the flavour of the tomato products. Minimum acidity requirement for processing tomato should be 0.40 per cent as the processed product from low acid tomato may be affected by *Bacillus coagulans* (Thamburaj, 1998). Genotypic variation on the acid content of tomato fruits was highlighted by previous workers (Davis and Hobson, 1981; Ereifej *et al*., 1997).

Ascorbic acid: The average value of ascorbic acid content of fruit varied from 10.42 mg to 41.01 mg. The minimum value was obtained from the

genotype 'CLN 2777-F' and the maximum from the genotype 'Alisha Craig $O^{gc'}$. High ascorbic acid in tomato not only improves the nutrition, it also aids in better retention of natural colour and flavour of the products (Thamburaj, 1998).

Lycopene: The genotype 'CLN2762-A' recorded maximum lycopene content of the fruit (4.84 mg) followed by the genotypes 'Feb-2' (4.76 mg) and 'Alisha Criag O^{gc}' (4.62 mg) while the minimum was observed by the genotype 'CLN2777-B' (1.87 mg). Colour of fruit is an important quality parameter both for table purpose and processing varieties. Potaczek and Michalik (1998) have observed that environmental factors especially temperature and light intensity exerted a great influence on lycopene level than on carotene contents in tomato fruits. Red-fruiting cultivars also have higher lycopene content than yellow, orange and black- fruiting cultivars (Cox *et al*., 2003).

Fruit yield per plant: The average fruit yield per plant varied from 1.21 kg to 2.75 kg, the maximum being in 'CLN2777-E' (2.75 kg) followed by 'CLN2777-F' (2.48 kg) and 'CLN2777-A' (2.39 kg) and the minimum yield was obtained by 'Alisha Craig Fulgens' (1.21 kg).

From the foregoing observations, it has been found that three genotypes namely, CLN2777-E, CLN2777-F and CLN2777-A were found to have high yield potential and two genotypes namely, Alisha Craig O^{gc} and Feb-2 possessed better processing qualities (TSS > 5.0; acidity > 0.45%, lycopene > 4.50 mg/g and low locule number). These genotypes could be utilized in future breeding programme to develop hybrid/variety having high yield coupled with good processing qualities.

Assessment of genetic variability and heritability: The development of suitable plant type is of great importance for all the crops through planned design programme. Attempts have, therefore, been made by several scientists to analyse different physico-chemical characters to provide meaningful information about the significance of characters in relation to fruit yield in tomato. An ideal plant ideotype would only be defined if the different components of fruit of tomato are analysed and their relative importance can be assessed. In the present study, genetically diverse tomato genotypes collected from different sources were examined and yield component analyses were carried out to identify important fruit yield components.

Phenotypic co-efficient of variation (PCV) agreed closely with the genotypic co-efficient of variation (GCV) except locules per fruit but the magnitude of PCV was higher than GCV for all the characters (Table- 2) which was well supported by Joshi *et al*., 2004; Kumar *et al*., 2006; Golani *et al*., 2007. High to moderate GCV and PCV values were shown by all the characters except days to first flowering, days to 50 % flowering, equatorial diameter and locules number of the fruit that showed low to moderate GCV and PCV values. These observations find support from the previous workers (Mayavel *et al*., 2005a; Samadia *et al*., 2006; Islam *et al*., 2012). High proportion of GCV to PCV is desirable in selection process because it depicts that the traits are much under the genetic control rather than the environment (Kaushik *et al*., 2007). The proportion of GCV in PCV observed in this study ranged from 47.22 % in number of locules per fruit to 99.95 % in lycopene content of fruit. The traits with high proportion of GCV in PCV are reliable for selection in genetic improvement of tomato genotypes. Trait (locules per fruit) whose expression was environmentally dependent may not be reliable descriptor for morphological characterization.

Broad sense heritability values were higher (more than 80 %) for almost all the characters which collaborates the findings of earlier workers (Samadia *et al*., 2006; Manna and Paul, 2012). Broad sense heritability values were lower (22.30 %) for locule number which find support from the earlier workers (Veershetty, 2004; Kumar *et al*., 2006). These broad sense heritability values were likely to be over estimated as in this calculation it was not possible to exclude variation due to different genetic components and their interactions. The heritability estimates were, therefore, to be considered with these limitations in view. However, genetic advance (GA) expressed as percentage of mean was high (> 20 %) for the characters like number of flower cluster per plant, number of fruit per cluster, plant height, polar diameter, number of fruit per plant, fruit weight, pericarp thickness, total soluble solids, titratable acidity, vitamin C content, lycopene content and fruit yield per plant. Moderate genetic advance as percent of mean was shown by days to first flowering, days to 50 % flowering, equatorial diameter and locule number. According to Johnson *et al.* (1955) high heritability estimates along with high genotypic coefficient of variation and genetic advance is usually more useful in predicting the response of an individual to selection than heritability values alone. In the present study, high heritability coupled with high genetic advance was observed for number of flower clusters per plant, number of fruits per cluster, plant height, polar diameter, number of fruits per plant, fruit weight, pericarp thickness, total soluble solids, titratable acidity, vitamin C content, lycopene content and fruit yield per plant indicating good response to selection for these characters. High heritability and high genetic advance for the above mentioned characters revealed that such characters are

controlled additive gene action and selection based on these characters will be effective. These results find support with the observations of earlier workers (Prashant, 2003; Samadia *et al*., 2006) irrespective of the genetic materials used and environments in which these experiments were conducted.

The low heritability is being exhibited due to high environmental effects. Low heritability accompanied with low genetic advance for the character like number of locules per fruit suggesting that this character was influenced due to favourable influence of environment rather than genotypes.

Correlation co-efficient : Association analysis of different physico-chemical characters with fruit yield of tomato genotypes and their inter-relationships were investigated through the study of both phenotypic and genotypic correlation co-efficients during autumn-winter season. In the present study, sixteen characters including growth, reproductive and quality characters were recorded and their genotypic and phenotypic correlation co-efficients were analysed (Table-3).

Phenotypic and genotypic correlation co-efficients, in general, agreed very closely. However, the genotypic correlations were higher than phenotypic correlations in most of the cases. These could occur when the genes governing two traits were similar and environmental factors played a small part in the expression of these traits.

Out of fifteen yield component characters studied, 3 characters *viz*., number of fruits per cluster, number of fruits per plant and fruit weight exhibited significantly positive correlation co-efficients with fruit yield per plant at genotypic and phenotypic levels. Besides, 5 characters like number of flower cluster per plant, equatorial diameter, pericarp thickness, locule number per fruit and lycopene content showed positive but non-significant correlation with fruit yield per plant at both levels. Positive and significant association of fruit yield per plant with number of fruits per cluster, number of fruits per plant and fruit weight have already been observed by previous workers (Singh *et al.*, 2004; Makesh *et al.*, 2006; Prashant *et al.*, 2008; Ghosh *et al.*, 2010; Kumar and Dudu, 2011; Maurya *et al.*, 2011; Madhurina *et al.*, 2012). However, days to first flowering, days to 50 % flowering, plant height, polar diameter, TSS, titratable acidity and vitamin C content of fruit exhibited negative correlation with fruit yield per plant. This indicated that early in flowering, less polar diameter and low contents of TSS, titratable acidity and vitamin C helped in improving fruit yield per plant. The inter-relationships among the characters exhibited that six correlation co-efficients were significantly positive at genotypic level. They also showed high phenotypic correlations as well.

Path Co-efficient Analysis: The complexity of character relationships among themselves and with fruit yield per plant becomes evident from the discussion alone did not provide a comprehensive picture of relative importance of direct and indirect influences of each of the characters to the fruit yield, as these traits were the resultant product of combined effects of various factors complementing or counteracting. The path co-efficient analyses developed by Wright (1921) provides an effective means of untangling direct and indirect causes of association and permits a critical examination of the specific forces acting to produce a given co-relation. In the present study, the genotypic correlations were partitioned into direct and indirect effects to identify relative importance of yield component towards fruit yield of tomato.

Among the fifteen yield component traits, number of flower clusters per plant, number of fruits per cluster and fruit weight showed highly positive direct effects on fruit yield per plant (Table-4). This was the main cause of their positive association with fruit yield per plant. The direct selection for these characters could be beneficial for yield improvement of tomato since these characters also showed positive correlation with fruit yield per plant. The direct effects of other characters were negligible. One character namely, number of fruit per plant, had significant positive correlation with fruit yield per plant but their direct effect was negligible because of high positive indirect effect via number of fruits per cluster. Residual effect was very low (0.009) suggesting inclusion of the maximum fruit yield influencing characters of tomato in the present analysis. The results are in conformity with the observations of early workers (Harer *et al.*, 2003; Singh *et al*.,2004; Mayavel *et al*., 2005b; Ramana *et al.*, 2007; Sharma and Singh, 2012; Narolia *et al.*, 2012), who observed positive and significant correlation and direct effects for number of flower cluster per plant, number of fruit per cluster and fruit weight with fruit yield per plant.

From the correlation and path coefficient analyses, it revealed that the top priority should be given to selection based on number of flower clusters per plant, number of fruits per cluster and fruit weight for fruit yield improvement and could be considered while formulating selection indices in the improvement of tomato.

Wide variability has been found in different physical-biochemical traits of exotic tomato genotypes grown in Eastern India. This information will provide breeders with the ability to develop desirable types having high yield and

better processing profiles. From the combing study of GCV, PCV, heritability, genetic advance, correlation and path coefficient, three characters namely, number of flower clusters per plant, number of fruits per cluster and fruit weight were found to be the most important selection indices of tomato.

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References

Adsule, P. G., Amba, Dan, Tikko, S. K. and Pal, A. B. 1980. Studies on the evaluation of tomato cultivars for making juice. *Indian Food Packer*, **34**:18-20.

AOAC, 1984. Official Methods of Analysis. 14th ed. Washinton DC, 16.

Bhutani, R. D. and G. Kalloo. 1991. Inheritance studies of locule number in tomato. *Haryana J. Horti. Sci.*, **20**:119-124.

Burton, G.W. 1952. Quantitative inheritance in Pearl Millet (*Pennisetum glaucum*). *Agron. J.*, **43**:409-417.

Chattopadhyay, A., Chakraborty, Ivi and Siddique, W. 2013. Characterization of determinate tomato hybrids: Search for better processing qualities. *J.Food Process. and Tech.*, **4**: 222. doi:10.4172/2157-7110.1000222.

Chattopadhyay, A., Dutta, S., Bhattacharya, I., Karmakar, K. and Hazra, P. 2007. *Technology for Vegetable Crop Production*, published by All Indian Coordinated Research Project on Vegetable Crops, Directorate of Research, Bidhan Chandra Krishi Viswavidyalaya, Kalyani: 741235, Nadia, West Bengal India, P.226.

Cox, S. E., Stushnoff, C. and Sampson, D. A. 2003. Relationship of fruit color and light exposure to lycopene content and antioxidant properties of tomato. *Canadian J. Plant Sci.*, **83**: 913-919.

Davis, J. N. and Hobson, G. E. 1981. The constituents of tomato fruit. The influence of environment, nutrition and genotype. *Critical Rev. in Food Sci. and Nutrition*, **15**:205-280.

Dewey, D. R. and Lu, K. N. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.*, **51**: 515-518.

Ereifej, K. I., Shibli, R. A., Ajlouni, M. M. and Altaf, Hussain. 1997. Physico-chemical characteristics and processing quality of newly introduced seven tomato cultivars into Jordan in comparison with local variety. *J. Food Sci. and Tech.*, **34**:171-174.

Ghosh, K. P., Islam, A. K. M. A., Mian, M. A. K. and Hossain, M. M. 2010. Variability and character association in F_2 segregating population of different commercial hybrids of tomato (*Solanum lycopersicum* L.). *J. Appl. Sci. and Environ. Management*, **14**(2):91-95.

Golani, I. J., Mehta, D. R., Purohit, V. L., Pandya, H. M. and Kanzariya, M.V. 2007. Genetic variability, correlation and path coefficient studies in tomato. *Indian J. Agrl. Res.*, **41**(2):146-149.

Hanson, C. M., Robinsen, R. R. and Comstock, R. R. 1956. Biometrical studies on yield in segregating population of Kotean, Lespedeza. *Agron. J.*, **48**:268-272.

Harer, P. N., Lad, D. B. and Bhor, T. J. 2003. Correlation and path analysis studies in tomato. *J. Maharashtra Agrl. Uni.*, **27**(3):302-303. IBPGR. 1981. Genetic Resources of Tomatoes and Wild Relatives – a Global Report. José T. Esquinas-Alcazar. AGP: IBPGR/80/103/. IBPGR Secretariat, Rome. P. 65.

Islam, M. S., Mohanta, H. C. Ismail, M. R. Rafii, M.Y. and Malek, M.A. 2012. Genetic variability and trait relationship in cherry tomato (*Solanum lycopersicum* L. var. *cerasiforme*). *Bangladesh J. Bot.*, **41**(2):163-167.

Johnson, H. W., Robinson, H. F. and Comstock, R. E. 1955. Estimation of genetic and environmental variability in soybean. *Agron. J.*, **47**:477-483.

Joshi, A., Vikram, A. and Thakur, M. C. 2004. Studies on genetic variability, correlation and path analysis for yield and physico- chemical traits in tomato *(Lycopersicon esculentum* Mil1.). *Progressive Hort.*, **36**(1):51-58.

Kaushik, N., Kumar, K., Kumar, S., Kaushik, N. and Roy, S. 2007. Genetic variability and divergence studies in seed traits and oil content of Jatropha (*Jathropha curcas* L.) accessions. *Biomass and Bioenergy*, **31:**497-502.

Kumar, M. and Dudi, B. S. 2011. Study of correlation for yield and quality characters in tomato (*Lycopersicon esculentum* Mill.). *Electron. J. Plant Breed.*, **2**(3):453-460.

Kumar, R., Kumar, Niraj, Singh, Jagadeesh and Rai, G. K. 2006. Studies on yield and quality traits in tomato. *Veg. Sci.*, **33**(2):126-132.

Kumari, Anita, Grewal, B. B., Banerjee, M. K. and Kumari, A.1998. Assessment of physico-chemical characteristics of different tomato (*Lycopersicon esculentum* Mill.) genotypes. *Veg. Sci.*, **25**:127-130.

Madhurina, M. and Paul, A. 2012. Path analysis between fruit yield and some yield components in tomato (*Lycopersicon esculeutum* Mill). *HortFlora Res. Spectrum*, **1**(3):215-219.

Makesh, S., Ramaswamy, N. and Puddan, M. 2006. Character association and path coefficient analysis in tomato (*Lycopersicon esculentum* Mill.). *Res. on Crops*, **7**(2):496-499.

Manna, M. and Paul, A. 2012. Studies on genetic variability and characters association of fruit quality parameters in tomato**.** *HortFlora Research Spectrum* **1**(2):110-116.

Maurya, V., Singh, A. K., Rai, V. K. and Mishra, R. 2011. Genetic variability, correlation and path coefficient analysis of tomato (*Lycopersicon esculentum* Mill.). *Environ. and Ecol.*, **29**(3):1076-1081.

Mayavel, A., Balakrishnamurthy, G. and Natarajan, S. 2005a. Variability and heritability studies in tomato hybrids. *South Indian Horti.*, **53**(1-6): 262-266.

Mayavel, A., Balakrishnamurthy, G. and Natarajan, S. 2005b. Correlation and path analysis in tomato (*Lycopersicon esculentum* Mill.). *South Indian Horti.,* **53**(1-6): 253-257.

Narolia, R.K., Reddy, R. V. S. K. and Padma, M. 2012. Correlation and path coefficient analysis of growth, yield and quality of tomato (*Lycopersicon esculentum* Mill.). *Indian J. Tropical Biodiversity,* **20**(1): 65-69.

Paulson, K.N. and Stevens, M.A. 1974. Relationships among titratable acidity, pH and buffer composition of tomato fruit. *J. Food Sci.,* **39**: 354–357.

Potaczek, H. and Michalik, H. 1988. Improvement of the nutritional value of tomato (*Lycopersicon esculentum* Mill.) by means of breeding for quality. *Veg. Crops Res. Bull.,* **49**: 13-20.

Prashanth, S. J. 2003. Genetic variability and divergence study in tomato (*Lycopersicon esculentum* Mill). M. Sc. (Agri.) Thesis, Uni. Agric. Sci., Dharwad (India).

Prashanth, S. J., Jaiprakashnarayan, R.P., Ravindra, M. and Madalageri, M.B. 2008. Correlation and path analysis in tomato (*Lycopersicon esculentum* Mill.). *Asian J. Horti.,* **3**(2): 403-408.

Ramana, C. V., Shankar, V. G., Kumar, S. S. and Rao, P. V. 2007. Trait interrelationship studies in tomato (*Lycopersicon esculentum* Mill.). *Res.on Crops,* **8**(1): 213-218.

Ranganna. 1980. Manual of Analysis of Fruit and Vegetable Products. Tata Mc Graw-Hill.

Ranieri, A., Giuntini, D., Lercari, B. and Soldatini, G. F. 2004. Light influence on antioxidant properties of tomato fruits. *Prog. in Nutrition*, **6**: 44-49.

Samadia, D. K., Aswani, R. C. and Dhandar, G. 2006. Genetic analysis for yield components in tomato land races. *Haryana J. Horti. Sci.,* **35**(1&2): 116-119.

Sharma, B. and Singh, J.P. 2012. Correlation and path coefficient analysis for quantitative and qualitative traits for fruit yield and seed yield in tomato genotypes. *Indian J. Horti.,* **69**(4): 540-544.

Singh, J.K., Singh, J.P., Jain, S.K. and Joshi, A.2004. Correlation and path coefficient analysis in tomato. *Progressive Horti.,* **36**(1): 82-86.

Thamburaj, S. 1998. Breeding for high quality vegetable, in Souvenir of National Symposium on Emerging Scenario in Vegetable Research and Development published by IIVR, Varanasi, India, pp. 53-59.

Tiwari, R.N. 1996. Scope for better processing and export in tomato using F_1 hybrids, in Training Manual on vegetable hybrids and their seed production published by IARI, New Delhi, pp. 75-78.

Veershety. 2004. Studies on variability, character association and genetic diversity in tomato (*Lycopersicon esculentum* Mill.). M. Sc. (Agri.) Thesis, University of Agricultural Science, Dharwad (India).

Wright, S. 1921. Correlation and Causation. *J. Agrl.Res.*, **20**: 202-209.

Table 1. Quantitative characterization of exotic tomato genotypes

Genotypes	D1stF*	D50F	NFCPP	NFPC	PH	PD	ED	NFPP	FW	PT	LN	TSS	TA	AA	LYP	FYPP
CLN 2777 'E'	28.33	32.67	10.21	3.28	91.19	4.82	4.59	33.47	82.17	5.51	3.67	4.47	0.35	21.25	4.14	2.75
CLN 2777 'F'	30.33	34.67	11.86	3.00	112.12	5.67	6.26	35.57	69.73	6.01	3.78	4.43	0.47	10.42	4.45	2.48
CLN 2768 'A'	36.00	40.00	10.81	2.25	99.30	6.19	5.68	24.28	73.64	3.67	3.11	3.90	0.40	17.84	4.60	1.79
CLN 2777 'C'	34.67	40.33	11.17	2.43	95.32	5.59	5.52	27.19	50.64	3.71	3.33	4.03	0.41	23.61	3.90	1.38
CLN 2777 'B'	33.67	38.67	11.69	2.64	90.10	6.01	6.11	30.87	54.88	6.12	3.11	4.77	0.49	16.44	1.87	1.69
CLN 2777 'H'	28.00	34.00	10.13	2.49	91.61	5.33	5.47	25.19	82.99	4.88	4.33	3.83	0.50	16.80	4.29	2.09
CLN 2460 'E'	32.33	37.00	10.52	2.79	114.38	6.00	5.63	29.34	64.89	6.73	3.67	3.90	0.47	22.33	4.21	1.90
CLN 2764 'A'	33.00	37.00	10.31	2.50	96.77	6.06	5.87	25.78	75.88	4.11	3.67	4.63	0.42	17.08	2.26	1.96
CLN 2498 'D'	30.67	35.00	12.04	2.59	124.47	5.54	5.33	31.17	65.47	6.07	3.22	3.67	0.30	32.23	3.98	2.04
CLN 2777 'G'	29.00	32.00	9.75	2.66	91.57	4.54	4.57	25.93	73.25	3.67	3.47	4.57	0.47	16.66	3.43	1.90
CLN 2762 'A'	31.33	35.33	10.08	2.93	86.18	6.09	5.67	29.50	62.62	6.02	3.22	4.23	0.42	38.04	4.84	1.85
CLN 2777 'A'	30.67	34.33	14.46	2.85	93.59	4.09	5.17	41.21	58.00	3.90	3.78	3.93	0.40	16.28	3.20	2.39
Feb-2	31.00	35.00	13.40	2.49	78.31	4.98	5.63	33.33	70.51	3.78	3.05	5.15	0.47	24.54	4.76	2.33
Alisha Craig AFT	32.67	37.00	14.05	2.13	73.97	4.82	5.70	29.92	68.29	3.56	4.00	4.10	0.44	20.58	4.60	2.04
BCT – 115 (DG)	34.33	39.00	14.09	1.83	44.70	5.33	5.72	25.83	77.25	4.00	3.50	5.01	0.45	29.88	3.61	2.00
Alisha Craig Fulgens	28.67	34.00	12.65	1.94	105.41	3.78	4.32	24.50	49.39	4.21	3.10	4.87	0.41	32.01	4.06	1.21
Alisha Craig O^{gc}	25.33	30.33	11.79	2.23	123.30	4.78	5.46	26.33	71.97	6.22	3.56	5.17	0.49	41.01	4.62	1.90
LSD *(P=0.05)*	2.09	2.24	0.36	0.02	8.67	0.08	0.08	0.96	0.63	0.30	0.87	0.28	0.02	1.12	0.03	0.06

*D1stF= Days to 1st flowering; D50F= Days to 50% flowering; NFCPP= Number of flower clusters per plant; NFPC= Number of fruits per cluster; PH=Plant height; PD= Polar diameter; ED= Equatorial diameter; NFPP= Number of fruits per plant; FW= Fruit weight; PT= Pericarp thickness; LN: Locule number; TSS=Total soluble solids; TA= Titratable acidity; AA= Ascorbic acid; LYP= Lycopene; FYPP= Fruit yield per plant

Table 2. Mean, range and estimates of genetic parameters of tomato genotypes

Characters	Mean	Range	GCV (%)	PCV (%)	GCV : PCV	Heritability (%) in b.s.	Genetic advance as (%) of mean
Days to 1st Flowering	31.20	25.33 - 36.00	8.50	9.41	90.33	81.73	15.85
Days to 50% flowering	35.69	30.00 - 40.33	7.66	8.54	89.70	80.41	14.15
Number of flower cluster per Plant	11.71	9.75 - 14.46	13.18	13.31	99.02	98.11	26.89
Number of fruit per cluster	2.53	1.83 - 3.28	15.06	15.07	99.93	99.90	31.01
Plant height (cm)	94.84	44.70 - 124.47	19.93	20.67	96.42	92.93	31.01
Polar diameter (cm)	5.27	3.78 - 6.19	13.78	13.81	99.78	99.59	28.33
Equatorial diameter (cm)	5.45	4.32 - 6.26	9.70	9.74	99.59	99.27	19.91
Number of fruit per plant	29.38	24.28 - 41.21	15.54	15.67	99.17	98.44	31.77
Fruit weight (g)	67.68	49.39 - 82.99	14.85	14.86	99.93	99.86	30.57
Pericarp thickness (mm)	4.83	3.56 - 6.73	23.53	24.30	96.83	93.74	46.93
Locule number	3.60	3.10 - 4.33	6.79	14.38	47.22	22.30	6.61
Total soluble solids (^{0}brix)	4.39	3.67 - 5.17	10.83	11.48	94.34	89.04	21.05
Titratable acidity %	0.43	0.30 - 0.50	12.15	12.49	97.28	94.59	24.34
Ascorbic acid (mg/100 g)	23.35	10.42 - 41.01	36.44	36.56	99.67	99.38	74.84
Lycopene (mg/100 g)	3.93	1.87 - 4.84	21.41	21.42	99.95	99.95	44.10
Fruit yield per plant (kg)	1.98	1.21-2.75	18.99	19.07	99.58	99.14	38.95

Table 3. Phenotypic and genotypic correlation coefficients of sixteen characters of tomato

Characters		D50F	NFCPP	NFPC	PH	PD	ED	NFPP	FW	PT	LN	TSS	TA	AA	LYP	FYPP
D1stF*	P	0.959**	0.125	-0.197	-0.402	0.554*	0.478	-0.088	-0.196	-0.306	-0.068	-0.243	-0.138	-0.275	-0.244	-0.242
	G	0.976**	0.130	-0.223	-0.415	0.608**	0.523*	-0.110	-0.216	-0.347	-0.400	-0.285	-0.132	-0.315	-0.272	-0.278
D50F	P		0.115	-0.273	-0.358	0.552*	0.483*	-0.172	-0.243	-0.252	-0.087	-0.249	-0.098	-0.217	-0.216	-0.340
	G		0.125	-0.309	-0.374	0.616**	0.540*	-0.202	-0.271	-0.288	-0.344	-0.280	-0.086	-0.254	-0.243	-0.387
NFCPP	P			-0.442	-0.356	-0.453	0.105	0.417	-0.278	-0.330	0.171	0.197	-0.061	0.093	0.026	0.107
	G			-0.448	0.373	-0.460	0.103	0.408	-0.279	-0.340	0.343	0.224	-0.061	0.094	0.025	0.096
NFPC	P				0.298	0.193	0.006	0.623**	0.112	0.468	-0.093	-0.288	-0.145	-0.332	-0.040	0.597*
	G				0.307	0.193	0.005	0.626**	0.112	0.483*	-0.205	-0.303	-0.148	-0.333	-0.040	0.598*
PH	P					0.048	-0.100	0.056	-0.206	0.515*	-0.343	-0.269	-0.143	0.089	0.104	-0.095
	G					0.051	-0.102	0.056	-0.213	0.559*	-0.625**	-0.266	-0.149	0.101	0.109	-0.102
PD	P						0.742**	-0.193	0.150	0.358	-0.165	-0.267	0.060	-0.130	-0.102	-0.058
	G						0.741**	-0.197	0.151	0.367	-0.396	-0.286	0.065	-0.131	-0.102	-0.059
ED	P							0.116	0.056	0.234	0.045	-0.044	0.352	-0.216	-0.095	0.098
	G							0.115	0.057	0.238	0.033	-0.051	0.367	-0.219	-0.096	0.098
NFPP	P								-0.167	0.172	0.030	-0.149	-0.181	-0.286	-0.041	0.667**
	G								0.166	0.182	0.035	-0.147	-0.187	-0.290	-0.043	0.664**
FW	P									-0.009	0.398	0.046	0.089	-0.173	0.184	0.615**
	G									-0.012	0.837	0.045	0.090	-0.173	0.185	0.619**
PT	P										-0.082	0.113	0.103	0.317	0.197	0.201
	G										-0.390	0.106	0.109	0.321	0.200	0.204
LN	P											0.034	0.118	-0.212	0.017	0.379
	G											-0.164	0.304	-0.449	0.036	0.381**
TSS	P												0.380	0.273	-0.129	-0.054
	G												0.407	0.285	-0.136	-0.049
TA	P													-0.210	-0.043	-0.106
	G													-0.211	-0.045	-0.109
AA	P														0.381	-0.335
	G														0.382	-0.337
LYP	P															0.147
	G															0.149

*D1stF= Days to 1st flowering; D50F= Days to 50% flowering; NFCPP= Number of flower clusters per plant; NFPC= Number of fruits per cluster; PH=Plant height; PD= Polar diameter; ED= Equatorial diameter; NFPP= Number of fruits per plant; FW= Fruit weight; PT= Pericarp thickness; LN: Locule number; TSS=Total soluble solids; TA= Titratable acidity; AA= Ascorbic acid; LYP= Lycopene; FYPP= Fruit yield per plant

P = Phenotypic correlation coefficients; G = Genotypic correlation coefficients

* Significant at 5 % level; ** Significant at 1 % level.

Table 4. Path-coefficient analysis of the components of fruit yield per plant of tomato genotypes at genotypic level

Characters	D1stF	D50F	NFCPP	NFPC	PH	PD	ED	NFPP	FW	PT	LN	TSS	TA	AA	LYP	GCFYPP
D1stF*	**-0.29520**	0.43995	0.17929	-0.37582	-0.12986	0.05989	-0.05567	0.07155	-0.17236	0.08032	-0.01580	-0.02543	-0.01154	-0.03077	0.00344	-0.278
D50F	-0.28797	**0.45099**	0.17151	-0.52126	-0.11704	0.06073	-0.05741	0.13074	-0.21591	0.06652	-0.01357	-0.02498	-0.00750	-0.02474	0.00308	-0.387
NFCPP	-0.03846	0.05621	**1.37609**	-0.75340	-0.11677	-0.04532	-0.01100	-0.26451	-0.22216	0.07854	0.01355	0.01995	-0.00538	0.00915	-0.00032	0.096
NFPC	0.06593	-0.13971	-0.61612	**1.68270**	0.09610	0.01891	-0.00045	-0.40631	0.08852	-0.11166	-0.00810	-0.02696	-0.01299	-0.03247	0.00049	0.598*
PH	0.12249	-0.16865	-0.51338	0.51667	**0.31299**	0.00505	0.01089	-0.03619	-0.16972	-0.12936	-0.02467	-0.02369	-0.01306	0.00988	-0.00140	-0.102
PD	-0.17946	0.27804	-0.63311	0.32306	0.01605	**0.09851**	-0.07883	0.12789	0.12050	-0.08497	-0.01562	-0.02552	0.00573	-0.01280	0.00129	-0.059
ED	-0.15452	0.24347	0.14234	0.00716	-0.03206	0.07301	**-0.10635**	-0.07477	0.04570	-0.05504	0.00129	-0.00459	0.03219	-0.02134	0.00121	0.098
NFPP	0.03255	-0.09088	0.56100	1.05377	0.01746	-0.01942	-0.01226	**-0.64881**	-0.13194	-0.04204	0.00139	-0.01311	-0.01634	-0.02831	0.00054	0.664**
FW	0.06389	-0.12226	-0.38385	0.18702	-0.06670	0.01490	-0.00610	0.10748	**0.79645**	0.00279	0.03303	0.00399	0.00791	-0.01690	-0.00234	0.619**
PT	0.10251	-0.12972	-0.46727	0.81235	0.17505	0.03619	-0.02531	-0.11794	-0.00960	**-0.23129**	-0.01541	-0.00645	0.00485	0.02626	-0.00076	0.204
LN	0.11813	-0.15507	0.18237	-0.34517	-0.19565	-0.03899	-0.00347	-0.02281	0.69149	0.09028	**0.03947**	-0.00459	0.06441	-0.0369	-0.00154	0.381
TSS	0.08413	-0.12625	0.30766	-0.50851	-0.08310	-0.02818	0.00547	0.09535	0.03563	0.01673	-0.00203	**0.08923**	0.03567	0.02780	0.00173	-0.049
TA	0.03889	-0.03858	-0.08447	-0.24942	-0.04665	0.00644	-0.03907	0.12101	0.07188	-0.01280	0.02001	0.03632	**0.08762**	-0.02058	0.00056	-0.109
AA	0.09308	-0.11435	0.12897	-0.55986	0.03169	-0.01292	0.02326	0.18826	-0.13790	-0.06224	-0.01493	0.02542	-0.01848	**0.09758**	-0.00484	-0.337
LYP	0.08017	-0.10947	0.03459	-0.06507	0.03447	-0.01000	0.01015	0.02747	0.14686	-0.01380	0.00479	-0.01221	-0.00388	0.03723	**-0.01268**	0.149

*D1stF= Days to 1st flowering; D50F= Days to 50% flowering; NFCPP= Number of flower clusters per plant; NFPC= Number of fruits per cluster; PH=Plant height; PD= Polar diameter; ED= Equatorial diameter; NFPP= Number of fruits per plant; FW= Fruit weight; PT= Pericarp thickness; LN: Locule number; TSS=Total soluble solids; TA= Titratable acidity; AA= Ascorbic acid; LYP= Lycopene; GCFYPP= Genotypic correlation with fruit yield per plant; Residual effect = 0.009; Direct effects = bold diagonal

* Significant at 5 % level; ** Significant at 1 % level