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Study the direct and indirect effect of various characters on fruit yield in tomato (*Solanum lycopersicon* L.)

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Abstract
A field experiment entitled "Study the direct and indirect effect of various characters on fruit yield in tomato (*Solanum lycopersicon* L.)" was conducted at the experimental field, AKS University, Satna during rabi season 2015-16. Fifteen genotypes of tomato were involved with this investigation and therefore, with a view to assess the genetic parameters and degree of mutual association in respect of direct and indirect effects of fruit yield characters *viz.*, plant height (cm), number of primary branches per plant, days to first flowering, days to 50 % flowering, days to first fruit set, number of flowers per cluster, number of fruits per cluster, fruit length (cm), fruit diameter (cm), average fruit weight (g), number of fruits per plant and fruit yield per plant (kg). Significant variations were obtained among the genotypes for all the characters under investigation. The variety H-88-78-1 recorded the maximum plant height (cm) at 120 DAT, number of flowers per cluster and fruit length. Maximum number of primary branches per plant at 120 DAT and maximum number of fruits per plant were recorded in EC-528372. Maximum average fruit weight were obtained in Kashi Vishesh. Minimum days to first flowering was found in DARL-16. A minimum days to 50% flowering and days to first fruit set were observed in Azad T-5. Further it was also noticed that maximum fruit yield per plant was recorded in H-88-78-1. However, lowest yield per plant was recorded in VRT- 101 – A. Path coefficient analysis revealed appreciable amount of direct positive effect of fruit length on fruit yield per plant.

Keywords: Tomato (*Lycopersicon esculentum* L.), direct and indirect effect of fruit yield.

1. Introduction

Tomato (*Solanum lycopersicon* L.) is one of the most widely grown vegetable in the world and ranked first in preserved and processed vegetables. It is said to be native of Western South America (Rick, 1976) [6] and belongs to family solanaceae. The genus Solanum consists of annual or short lived perennial herbaceous plants. Tomato is a typical day neutral plant and is mainly self-pollinated but a certain percentage of cross-pollination also occurs (Prajapati *et al.* 2015) [5]. It is a warm season crop, reasonably resistance to heat and drought and grows under wide range of soil and climatic conditions. Tomato fruits are consumed as raw or cooked besides large quantity of tomato are used to make soup, ketchup, sauce, salad, chutneys, paste and powder etc. India is next only to china in area and production of vegetable. The total cultivated area of tomato in India is about 879.6 thousand hectares with a production of 18227.0 thousand metric tonnes and average productivity is 20.7 metric tonnes per hectare. Major tomato growing states in India are Bihar, Karnataka, Orisa, Maharastara and Andhra Pradesh. In Madhya Pradesh, it is grown in 62.59 thousand hectare of land with the annual production of 1845.0 thousand metric tonnes and productivity of 29.5 metric tonnes per hectare (Anonymous 2014) [2]. The development of an effective plant breeding programme is depending upon the assessment of polygenic variation, selection of elite genotypes, choice of parents and breeding procedure. Crop improvement depends upon the magnitude of genetic

variability and the extent to which desirable characters are heritable. Genetic variability for yield and yield components is essential in the base population for successful crop improvement. Yield and yield components are quantitative characters and are poly genetically inherited which are greatly influenced by environment. The phenotype of a character is the resultant of interaction between genotypes and environment. Partitioning of observed variability into heritable and non-heritable components is essential to get a true indication of the genetic variation of the traits. Phenotypic and genotypic coefficients of variation (PCV and GCV) are useful in detecting the amount of variability present in the available genotypes. Heritability and genetic advance help in determining the influence of environment in the expression of the characters and the extent to which the improvement is possible after selection (Robinson *et al*. 1949) [7]. The total variability can be partitioned into heritable and non-heritable components with the help of genetic parameters like phenotypic and genotypic coefficient of variation, heritability and genetic advance. Heritable variation can be effectively studied in conjunction with genetic advance. High heritability alone is not enough to make efficient selection in segregation, unless the information is accompanied for substantial amount of genetic advance (Adhi Shankar *et al.* 2013) [1].

Material and Methods

The experimental material for the present investigation comprised of 15 genotypes of Tomato (*solanum lycopersicon* L.) was used on the basis of their genetic variability. The name of genotypes of their availability are referred as under - Arka Vikas, Kashi Vishesh, Kashi Hemant, Kashi Sharad, Kashi Amrit, Azad T-5, Palam Pink, Super Bug, DARL-16, EC-528372, EC-620421, VRT-101-A H-88-78-1, VRT-32 and Pusa Ruby etc.

Observations under study five plants were randomly selected in each replication for each treatment and were tagged. Further observations were recorded on these plants during the experiments.

(A) Morphological Characters

(I) Plant height (cm): The plant height was measured from ground level to tip of the plant, which was expressed in centimeters and mean was computed. Height of the plant was recorded at 30, 60, 90 and 120 days after transplanting.

(II) Number of primary branches per plant: Number of primary branches per plant was counted at 60, 90 and 120 days after transplanting.

(B) Phenological characters

(I) Days to first flowering: The numbers of days were counted from the date of transplanting to first flowering and finally average number of days were recorded.

(II) Days to 50 % flowering: The average numbers of days were counted from the date of transplanting to 50% of flowering.

(III) Days to first fruit set: The average numbers of days were counted from the date of transplanting to first fruit set.

(IV) Number of flowers per cluster: Number of flower was counted on each cluster, 5 clusters were taken for the purpose on each selected plant.

(V) Number of fruits per cluster: Five clusters in each plant were taken at random and number of fruits in each cluster were counted. Then the average number of fruits per cluster was worked out.

(C) Yield characters

(I) Fruit length (cm): The length of fruit was measured with the help of vernier calipers and then average length was recorded of the plants.

(II) Fruit diameter (cm): The diameter of fruit was measured with the help of vernier calipers and than average was worked out.

(**III) Average fruit weight (g):** The weight of five fruits was recorded separately with help of weighing balance and average was worked out for each treatment.

(IV) Number of fruits per plant: The total number of marketable fruits harvested from the selected five plants was counted in each picking and the average number of fruits per plant was calculated.

(V) Fruit yield per plant (kg): Picking of fruits was done from the observational plants separately throughout the harvesting period. It was totaled and then average yield per plant was worked out for each genotypes.

Result and Discussion

The results obtained from the present investigation entitled "To study the direct and indirect effect of various characters on fruit yield in tomato (*Solanum lycopersicon* L.)" are presented under the following heads;

Path coefficient analysis: To measure the direct as well as indirect association of one variable through another on the end product path coefficients were calculated at genotypic and phenotypic levels for all the yield attributing traits. The observed correlation coefficients of fruit yield with its contributing traits were partitioned into direct and indirect effects. In the present investigation, important characters *viz.*, fruit yield per plant have been used as dependable variables with other traits. Since the values of genotypic path are more reliable in predicting the correct idea about the direct and indirect effects of the component traits, only this has been discussed as below. The estimates of path coefficient were furnished in the Table 01. In general the genotypic direct as well as indirect effects were slightly higher in magnitude as compared to corresponding phenotypic direct and indirect effects. The results obtained from genotypic direct and indirect effects are presented as under.

(I) Direct effect: Path coefficient analysis of different characters contributing towards fruit yield per plant showed that fruit length (2.071) had highest positive direct effect followed by number of flowers per cluster (0.226), number of primary branches per plant at 120 DAT (0.159), days to 50 percent flowering (0.062). Whereas, number of fruits per cluster (-1.694) had the highest negative direct effect on fruit yield per plant followed by days to first fruit set (-0.539), fruit diameter (-0.429), days to 1st flowering (-0.154), number of fruits per plant (-0.089), plant height 120 DAT (-0.038) and average fruit weight (-0.030).

(II) Indirect effect

(i) Plant height (cm): Plant height at 120 DAT imparted highest positive indirect effect on fruit yield per plant via fruit length (1.817), followed by number of flowers per cluster (0.206), number of primary branches per plant at 120 DAT (0.095), average fruit weight (0.007). However, indirect effect was visible to be highest negative via number of fruits per cluster (-1.413), fruit diameter (-0.219), days to first flowering (-0.117), number of fruits per plant (-0.027), days to first fruit set (-0.019) and days to 50% flowering (-0.005).

(ii) Number of primary branches per plant: Number of branches per plant was recorded to have highest positive indirect effect on fruit yield per plant through, fruit length (1.187), followed by number of flowers per cluster (0.174), days to first fruit set (0.022), average fruit weight (0.014). However, it was expressed high negative indirect effect via number of fruits per cluster (-1.215), days to first flowering (-0.091), fruit diameter (-0.079), number of fruits per plant (-0.060) and plant height at 120 DAT (-0.023).

(iii) Days to first flowering: Days to first flowering revealed high values of positive indirect effect on fruit yield per plant through fruit length (1.370), followed by number of flowers per cluster (0.164), number of primary branches per plant at 120 DAT (0.094), days to first fruit set (0.023), average fruit weight (0.009). Therefore, the remaining characters showed high negative indirect effect *i.e.* number of fruits per cluster (-1.090), fruit diameter (-0.108), number of fruits per plant (-0.050), days to 50 % flowering (-0.039) and plant height at 120 DAT (-0.029).

(iv) Days to 50 percent flowering: Days to 50 percent flowering expressed a positive indirect effect on fruit yield per plant through, number of fruits per cluster (0.147), followed by fruit diameter (0.125), days to first flowering (0.096), number of fruits per plant (0.015) and plant height 120 DAT (0.003). Rest of the characters showed negative indirect effect viz., days to first fruit set (-0.583), fruit length (-0.273), number of flowers per cluster (-0.103), number of primary branches per plant at 120 DAT (-0.021) and average fruit weight (-0.010).

Table 1: Path coefficients showing direct and indirect effects of different characters on fruit yield per plant (kg/ha) in tomato.

Characters		Plant height 120 DAT	No of primary branches per plant 120 DAT	Days to first flowering	Days to 50% flowering	Days to 1st fruit set	Number of flower per cluster	Number of fruits per cluster	Fruit length (cm)	Fruit diameter (cm)	Average fruit weight (g)	Number of fruits per plant
Plant height 120 DAT	G	-0.038	0.095	-0.117	-0.005	-0.019	0.206	-1.413	1.817	-0.219	0.007	-0.027
	P	0.577	0.104	-0.114	0.000	-0.006	0.814	-1.289	0.248	-0.096	-0.013	-0.004
No of primary branches/plant 120 DAT	G	-0.023	0.159	-0.091	-0.008	0.022	0.174	-1.215	1.187	-0.079	0.014	-0.060
	P	0.334	0.180	-0.084	0.000	-0.003	0.645	-1.033	0.164	-0.036	-0.024	-0.008
Days to first flowering	G	-0.029	0.094	-0.154	-0.039	0.023	0.164	-1.090	1.370	-0.108	0.009	-0.050
	P	0.432	0.099	-0.153	0.000	-0.004	0.613	-0.953	0.187	-0.051	-0.014	-0.007
Days to 50% flowering	G	0.003	-0.021	0.096	0.062	-0.583	-0.103	0.147	-0.273	0.125	-0.010	0.015
	P	-0.108	-0.014	0.036	-0.001	0.055	-0.240	0.241	-0.043	0.026	0.003	0.001
Days to 1st fruit set	G	-0.001	-0.007	0.006	0.068	-0.539	-0.023	0.042	0.548	-0.106	-0.010	0.006
	P	-0.040	-0.006	0.007	-0.001	0.082	-0.157	0.144	0.053	-0.029	0.012	0.001
Number of flower per cluster	G	-0.035	0.123	-0.112	-0.028	0.055	0.226	-1.614	1.805	-0.201	0.012	-0.042
	P	0.482	0.119	-0.096	0.000	-0.013	0.974	-1.402	0.264	-0.092	-0.017	-0.005
Number of fruits per cluster	G	-0.032	0.114	-0.099	-0.005	0.013	0.215	-1.694	1.541	-0.209	0.011	-0.029
	P	0.470	0.118	-0.092	0.000	-0.007	0.863	-1.583	0.230	-0.094	-0.018	-0.004
fruit length (cm)	G	-0.033	0.091	-0.102	-0.008	-0.143	0.197	-1.260	2.071	-0.265	0.001	-0.029
	P	0.423	0.087	-0.084	0.000	0.013	0.758	-1.074	0.339	-0.111	-0.002	-0.004
fruit diameter (cm)	G	-0.019	0.029	-0.039	-0.018	-0.134	0.106	-0.826	1.282	-0.429	-0.013	0.026
	P	0.308	0.036	-0.043	0.000	0.013	0.498	-0.822	0.209	-0.180	0.022	0.004
average fruit weight (g)	G	0.009	-0.073	0.044	0.020	-0.180	-0.093	0.608	-0.097	-0.182	-0.030	0.054
	P	-0.131	-0.046	0.029	0.000	-0.001	-0.255	0.416	-0.009	-0.038	-0.013	0.002
number of fruits per plant	G	-0.012	0.109	-0.086	-0.011	0.037	0.107	-0.562	0.669	0.125	0.018	-0.089
	P	0.154	0.063	-0.056	0.000	0.000	0.321	-0.374	0.070	0.025	0.007	-0.004

Residual effect genotypic = - 0.473
Residual effect phenotypic = - 0.321

(v) Days to first fruit set: Days to first fruit set expressed a positive indirect effect on fruit yield per plant through, fruit length (0.548), followed by days to 50 percent flowering (0.068) and number of fruits per cluster (0.042).Rest of the characters showed negative indirect effect *viz.*, fruit diameter (-0.106), number of flowers per cluster (-0.023) average fruit weight (-0.010), number of primary branches per plant at 120 DAT (-0.007) and plant height (cm) at 120 DAT (-0.001).

(vi) Number of flowers per cluster: Number of flowers per cluster expressed a positive indirect effect on fruit yield per plant through, fruit length (1.805), followed by number of primary branches per plant at 120 DAT (0.123), days to first fruit set (0.055) and average fruit weight (0.012). However, remaining characters showed high negative indirect effect via number of fruits per cluster (-1.614), fruit diameter (-0.201), days to first flowering (-0.112), number of fruits per plant (0.042), plant height (cm) 120 DAT (-0.035) and days to 50 per cent flowering (-0.028).

(vii) Number of fruits per cluster: Highest positive indirect effect on number of fruits per cluster on fruit yield per plant was recorded through, fruit length (1.541), followed by number of flowers per cluster (0.215), number of primary branches per plant at 120 DAT (0.114). However, rest of the characters showed fruit diameter (-0.209), days to first flowering (-0.099).

(viii) Length of fruit: Length of fruit revealed high values of positive indirect effect on fruit yield per plant through number of flowers per cluster (0.197), followed by number of primary branches per plant at 120 DAT (0.091). The remaining characters showed high negative indirect effect i.e. number of fruits per cluster (-1.260), fruit diameter (-0.265), days to first fruit set (-0.143), days to first flowering (-0.102).

(ix) Fruit diameter (cm): Diameter of fruit exhibited significant positive indirect effect via. Fruit length (1.282), followed by number of flowers per cluster (0.106). Highest negative indirect effect was observed through, number of fruits per cluster (-0.826) and days to first fruit set (-0.134).

(x) Average fruit weight (g): Average fruit weight exhibited highest positive indirect effect on fruit yield per plant through, number of fruits per cluster (0.608), followed by number of fruits per plant (0.054). However, rest of the characters showed negative indirect effect *viz.*, fruit diameter (-0.182), days to first fruit set (-0.180) and fruit length (-0.097).

(xi) Number of fruits per plant: Number of fruits per plant exhibited positive indirect effect via Fruit length (0.669), followed by fruit diameter (0.125), number of primary branches per plant at 120 DAT (0.109), number of flowers per cluster (0.107). Highest negative indirect effect was observed through number of fruits per cluster (-0.562), days to first flowering (-0.086).

Summary

The present investigation is summarized as follows. Mean squares due to genotypes were highly significantly for all the characters, indicating the presence of genetic diversity in the existing material. The mean performance of the genotypes revealed a wide range of variability for all the traits. The variation was highest for plant height at 120 DAT, Followed by average fruit weight, days to first fruit set, days to 50% flowering, plant height at 90 DAT, days to first fruit set, plant height 60 DAT, number of fruits per plant and plant height at 30 DAT. The present study revealed that the phenotypic coefficient of variation was higher than the corresponding genotypic coefficient of variation for all the traits which might be due to interaction of the genotypes with the environment to some degree or other explaining environmental factor influencing the expression of these characters. High phenotypic and genotypic coefficient of variation was observed for average fruit weight, followed by plant height at 120 DAT, number of fruits per plant, days to first flowering, plant height at 90 DAT, days to first fruit set, number of primary branches per plant at 90 DAT, number of primary branches per plant at 120 DAT and plant height at 60 DAT. The high values of GCV suggested greater phenotypic and genotypic variability among the genotypes and responsiveness of the attributes for making further improvement by selection. However, low estimates of PCV and GCV was noted characters like plant height at 30 DAT, days to 50% flowering, number of flowers per cluster, number of primary branches per plant at 60 DAT, fruit length, fruit diameter and fruit yield per plant. Which indicated that there is limited scope for improvement. Very high heritability coupled with high genetic advance for traits like average fruit weight, followed by number of primary branches per plant at 90 DAT, number of fruits per plants. Suggested that the preponderance of additive genes. It also indicated higher response for selection of high yielding genotypes as these characters are governed by additive gene actions. High heritability supplemented with moderate genetic advances as percentage of mean were manifested by plant height 90 DAT, plant height 60, 120 DAT, plant height 30 DAT, number of flower per cluster and days to first flowering. Which might be attributed to additive gene action conditioning their expression and phenotypic selection for their amenability can be brought about. moderate heritability coupled with low genetic advance as percentage of mean was observed for days to first fruit set. Revealed that the predominance of non-additive gene action in the expression of these characters. Low estimates of heritability coupled with low genetic advances as percentage of mean were displayed by days to 50% flowering, indicated that these character was highly influenced by environmental effects and consequently its selection would be ineffective. The genotypic correlation coefficients were higher their corresponding phenotypic one in magnitude that indicating there by strong inherent. The phenotypic expression of association between different traits studied correlation was lessened possibly due to multiple influences of environmental components. In view of their correspondence, selection on phenotypic basis would be effective. Plant height expressed significant and positive correlation with number of fruits per cluster, number of fruits per plant, days to first flowering, fruit length, fruit diameter, number of primary branches per plant 120 DAT. Significant and negative association of this character was recorded with average fruit weight and days to 50% flowering.

Discussion

The experimental findings of the present investigation entitled **"**Study the direct and indirect effect of various characters on fruit yield in tomato (*Solanum lycopersicon* L.)" have been discussed on the following heads in the light of the available literature.

Path coefficient analysis: Correlation coefficients are the indication of simple association between variables. In a biological system, however the relationship may exist in a very complex form. It is therefore, essential to study the relationship among variable in a comprehensive way. Path coefficient analysis is a power full tool, which enable portioning of the given relationships in its further components. In other words, it takes into account not only the relationship of component characters with the dependent character, but simultaneously takes care of its relationship with other component also. Thus, it helps in understanding the causal system in a better way because it enables portioning the total correlations coefficient into direct and indirect effects of various characters.

(i) Direct effect: Path coefficient analysis of different characters contributing towards fruit yield per plant showed that fruit length had highest positive direct effect followed by number of flowers per cluster, number of primary branches per plant at 120 DAT, days to 50 percent flowering. The results are in propinquity with Mohanty *et al.* (2002) for number of fruits per plant, Mahapatra (2013) and Sinha (2014) for length of fruit and number of fruits per cluster. Whereas, number of fruits per cluster had the highest negative direct effect on fruit yield per plant followed by days to first fruit set, fruit diameter, days to first flowering, number of fruits per plant, plant height at 120 DAT, Average fruit weight.

(ii) Indirect effect: Plant height at 120 DAT imparted highest positive indirect effect on fruit yield per plant via fruit length, number of flowers per cluster. However, indirect effect was visible to be highest negative via number of fruits per cluster, fruit diameter, days to first flowering. Number of primary branches per plant was recorded to have highest positive indirect effect on fruit yield per plant through, fruit length, number of flowers per cluster, it was expressed high negative indirect effect via number of fruits per cluster. Days to first flowering revealed high value of positive indirect effect on fruit yield per plant through fruit length, number of flowers per cluster. Therefore, the remaining characters showed high negative indirect effect *i.e.* number of fruits per cluster, fruit diameter. Days to 50 percent flowering expressed a positive indirect effect on fruit yield per plant through, number of fruits per cluster and fruit diameter. However, rest of the characters showed negative indirect effect *viz.*, days to first fruit set, fruit length, number of flowers per cluster. Days to first fruit set revealed high values of positive indirect effect on fruit yield per plant through fruit length. While, the remaining characters showed high negative indirect effect *i.e.* fruits diameter. Number of flowers per cluster expressed a positive indirect effect on fruit yield per plant through, fruit length,

number of primary branches per plant at 120 DAT. However, the remaining characters showed high negative indirect effect via number of fruits per cluster, fruit diameter and days to first flowering. Highest positive indirect effect of number of fruits per cluster on fruit yield per plant was recorded through, fruit length, number of flowers per cluster and number of primary branches per plant 120 DAT. However, rest of the characters showed negative indirect effect *viz.*, fruit diameter. Fruit length revealed high values of positive indirect effect on fruit yield per plant through number of flowers per cluster. Fruit diameter exhibited significant positive indirect effect via. Fruit length and number of flowers per cluster. Average fruit weight manifested highest positive indirect effect on fruit yield per plant through number of fruits per cluster. Number of fruits per plant exhibited significant positive indirect effect via. Fruit length, fruit diameter, number of primary branches per plant 120 DAT and number of flowers per cluster.

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