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Character association and path coefficient analysis of yield and its contributing traits in tomato (*SolanumLycopersicon Mill.*)

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Abstract
Thirty genotypes including three check varieties (Determinate Punjab Chhuhara, Indeterminate Pusa Ruby and Indeterminate NDT-8) of tomato (*Solanum Lycopersicon Mill.*) were assessed to work out the association of different yield traits, direct and indirect effects of their various attributes on yield per plant. The most important trait fruit yield per plant had highly significant and positively correlated with marketable fruit yield per plant (0.82), number of fruits per plant (0.61), average fruit weight (0.26) and primary branches per plant (0.15). Pericarp thickness had highly significant and negatively correlated with days to 50 per cent flowering (-0.26). Number of fruit length (0.75) and locules per fruit (0.74) were highly significant and positively correlated with diameter of fruit. Number of fruits per plant was highly significant and negatively correlated with average fruit weight (-0.43). The higher direct effect showed by number of fruits per plant (0.55), followed by average fruit weight (0.49). Number of marketable fruits per plant showed highly indirect and positively effect *via* marketable fruit per plant (0.34), fruit length (0.14). While average fruit weight (-0.24) and total soluble solids (-0.15) showed negatively indirect effect *via* number of fruits per plant.

Keywords: Tomato (*Solanum Lycopersicon Mill.*), Character association, path analysis and fruit yield

Introduction
Vegetables are valuable source of carbohydrates, protein, vitamins, minerals, fat, elemental salts and crude fibers. In addition to nutritional richness, vegetables add a variety of taste, colour and texture to the diets. India is credited as the second largest producer of vegetables in the world next only to China. Because of varied agro-climatic conditions in India, a large number of vegetable crops are grown here and a great deal of research work has been conducted in the disciplines of vegetable breeding, production technology, plant protection, seed production and post harvest technology. Number of processed items are prepared on large scale for consumption as well as for export purposes. All the species of tomato are native to Western Southern America (Rick, 1976). Tomato is used as fresh vegetable and is also very important for processing purposes like soup, ketchup, sauce, concentrate, puree, juice, chutney etc. Unripe green fruits are used for preparation of pickles and chutney. Tomatoes are important source of lycopene (an antioxidant), ascorbic acid and ß-carotene and valued for their colour and flavour. It is rich source of mineral, vitamins and organic acids essential amino acid and dietary fibers. It is rich source of vitamin A and C. Tomato also contains minerals like iron, phosphorus. Tomato fruits are eaten raw or cooked. It supplies vitamin C and adds variety of colours and flavours to the food. It has many other uses; tomato seeds contain 24 per cent oil used as salad oil and in the manufacture of margarine. Tomato is known for its outstanding nutritive value, which is given as; per 100 g of edible part of tomato fruits contain- 93.1g moisture, 3.6g carbohydrate, 1.9 g protein, 0.1g fat, 0.6g minerals, 0.7g fibers, 320 I.U. vitamin A, 31mg vitamin C (Ascorbic acid), 36 mg phosphorus, 15 mg magnesium, 45.8 mg sodium, 38 mg chlorine, 114 mg potassium, 1.8 mg iron, and 192 mg. b-carotene etc. Tomato is also rich in medicinal value. The pulp and juice are digestible, a promoter of gastric secretion and blood purifier. It is said to be useful against cancer of the mouth and sour mouth, etc. It is one of the best vegetables which keep our stomach and intestine in good order. It is one of the most popular and widely cultivated vegetable throughout the world and ranking second in importance after potato in many countries including India (Anonymous, 2013-14). The total area of world in tomato under cultivation is 4.58 m ha and total production is 150.51 million tonnes with 32.8 tonnes per hectare productivity. In India, total area is 0.88 million hectare and production is 18.23 million tonnes with 20.7 tonnes per hectare productivity,

which is very low as compared to average productivity of world. Tomato (*Solanum Lycopersicon* Mill.), a member of the family Solanaceaeis a herbaceous, annual to perennial and sexually propagated cropwith bisexual flowers, having diploid chromosome number 2n=2x=24. Growth habit range from strongly determinate (bushy type) to indeterminate types fruits bearing of different shape and size. It is one of the most widely cultivated vegetable crops all over the world.

In India, Andhra Pradesh is the highest producer of tomatoes with a yearly production of 5962.21 tons. It contributed around 35% of total tomato production in India. However, the total demand for tomatoes in Andhra Pradesh is only 7% of India's demand. This shows that 80% of the produce in Andhra Pradesh has to be either exported to other states or it should be processed and sold as finished goods all over India. Concentrated hubs of tomato production in Andhra Pradesh are Madanapalle, Kurnool, and Adilabad. Karnataka is the second largest producer of tomatoes in India. Major tomato producing regions of Karnataka are Kolar, Chintamani, and rural Bangalore. As the two neighbouring states Karnataka and Andhra Pradesh happen to be major producers, there is a conflict interest between farmers and Government. Maharashtra is also one of the major producers of tomatoes in India. In Maharashtra Nashik, Sangamner are the major tomato producing regions. Tomatoes from Nasik are supplied to Orissa, Gujarat, and even to the northern states of Punjab if required.

Study of correlation between different quantitative characters pro- vides an idea of association that could be effectively exploited to formulate selection strategies for improving yield components. For any effective selection programme, it would be desirable to consider the relative magnitude of association of various characters with yield. The path coefficient technique developed by Wright (1921) helps in estimating direct and indirect contribution of various components in building up the total correlation towards yield. On the basis of these studies the quantum importance of individual characters is marked to facilitate the selection programme for better gains. Commercial F_1 hybrids are common in tomato and selection of new parents for higher heterosis is a continuous process.

Materials and Methods

The study was designed to work out the status of association of different yield traits and direct and indirect effects of these different traits on yield per plant among 30 tomato (*Solanum Lycopersicon* Mill.) genotypes at field experiment under present investigation was conducted during *Rabi* 2014-15 at the Main Experiment Station, Vegetable Science, N. D. University of Agriculture and Technology, Narendra Nagar (Kumarganj), Faizabad (U.P.) India. The experimental materials of studies comprised of 30 tomato **(***Solanum Lycopersicon* Mill.) genotypes including three check varieties *viz*., Determinate Punjab Chhuhara, Indeterminate Pusa Ruby, and Indeterminate NDT-8). The experiment was laid out in Randomized Complete Block Design, with distance of 60 cm row to row and 50 cm plant to plant. Observation were recorded on days to 50 per cent flowering, plant height (cm), number of primary branches per plant, number of fruits per plant, average fruit weight (g), diameter of fruit (cm), marketable fruits per plant, pericarp thickness (mm), number of locules per fruit, total soluble solids (TSS), fruit length (cm) and fruit yield per plant (g). Standard statistical techniques such as correlation between different characters and path coefficient analysis, the correlations between different characters at genotypic (g) and phenotypic (p) levels were worked out between characters as suggested by Searle (1965). Path coefficient analysis was done according to the formula given by Dewey and Lu (1959).

Results and Discussions

The correlation coefficient at phenotypic and genotypic level was computed for twelve characters for thirty genotypes and their significance was tested at 5 % and 1 % probability level of significance. The result is given in Table 1 and 2. In general genotypic correlations were higher than the phenotypic once for all the characters except few exception. The most important trait, fruit yield per plant had exhibited highly significant and positive phenotypic correlation coefficient with marketable fruit yield per plant. The most important trait fruit yield per plant had highly significant and positively correlated with marketable fruit yield per plant (0.82), number of fruits per plant (0.61), average fruit weight (0.26) and primary branches per plant (0.15). Pericarp thickness had highly significant and negatively correlated with days to 50 per cent flowering (-0.26). Number of fruit length (0.75) and locules per fruit (0.74) were highly significant and positively correlated with diameter of fruit. Number of fruits per plant was highly significant and negatively correlated with average fruit weight (-0.43). Marketable fruit yield was highly significant and positively correlated with fruits per plant (0.61) while negatively correlated with total soluble solids (-0.36). Number of marketable fruits per plant was highly significant and negatively correlated with total soluble solids (-0.36). Number of locules per fruit was highly significant and positively correlated with fruit length (0.56). Total soluble solids was highly significant and negatively correlated with fruit yield per plant (-0.38). The available literature has also indicated positive correlation between fruit yield per plant and number of fruits per plant, number of primary branches per plant, plant height, pericarp thickness, average fruit weight and diameter of fruit in tomato **(**Maurya *et al*. 2011, Madhurina and Paul 2012). As a result of pericarp thickness had highly significant and negatively correlated with days to 50 per cent flowering (-0.26). Number of primary branches per plant (0.31) was highly significant and positively correlated with plant height. Number of fruits per plant was highly significant and negatively correlated with fruit yield per plant (-0.38). Diameter of fruit was highly significant and positively correlated with fruit length (0.75) and no. of locules per fruit (0.74). Number of marketable fruits per plant was highly significant and positively correlated with number of fruit yield per plant (0.82). Total soluble solids was highly significant and negatively correlated with number of fruits per plant (-0.27), number of marketable fruits per plant (-0.36), number of primary branches per plant (-0.12) while positively correlated with no. of locules per fruit (0.28). Fruit length has highly significant and positively correlated with no. of locules per fruit (0.56). (Maurya *et al*. 2011, Madhurina and Paul 2012). Thus on the basis of above discussion it can be concluded that selection for average fruit weight would be effective for yield improvement. Emphasis for selection for this trait in desired direction had also been suggested by earlier workers (Narolia *et al*. 2012).

The path coefficient analysis was carried out from phenotypic and genotypic correlation coefficient of yield with the two resolve direct and indirect effect of characters on fruit yield per plant. The direct and indirect effect of different characters on fruit yield per plant at phenotypic and genotypic level has

presented in Table 3 and 4. The higher magnitude of number of fruits per plant (0.55), followed by average fruit weight (0.49), marketable fruit yield (0.40), pericarp thickness (0.09), locules per plant (0.07), plant height (0.04) and diameter of fruit (0.04) showed substantially low direct effect. The negative direct effect on fruit yield per plant was showed by primary branches per plant (-0.13), total soluble solids (-0.11), fruit length (-0.08) and days to 50 per cent flowering (-0.04). Number of marketable fruits per plant showed highly indirect and positively effect *via* marketable fruit per plant (0.34), fruit length (0.14). While average fruit weight (-0.24) and total soluble solids (-0.15) showed negatively indirect effect *via* number of fruits per plant. Path coefficient analysis is a tool to partition the observed correlation coefficient into direct and indirect effects of yield component on yield to provide clearer picture of character associations for formulating effective selection strategy. Path analysis differ from simple correlation in that it points out the causes and their relative importance whereas; the latter measures simply the mutual association ignoring the causation. In present study, the path coefficient analysis was carried out at phenotypic as well as genotypic level. High positive direct effect was exerted by number of fruit per plant and average fruit weight on fruit yield per plant. This indicates that direct selection for number of fruits per plant, average fruit weight and marketable fruit per plant in desired direction would be very effective for yield improvement, (Narolia *et al*. 2012). Thus, the above discussion reveals the fact that important direct and indirect components exhibited substantial positive effect *via* some characters along with considerable negative effect *via* some other traits. The occurrence of negative as well as positive direct and indirect effects by yield components on fruit yield *via* one or other characters, simultaneously presents a complex situation where a compromise is required to attain a proper balance of different yield components for determining the ideotype for high fruit yield in tomato. The character mentioned above, merit due to consideration at the time of formulating selection strategy aimed at developing high yielding varieties in tomato.

Table 1: Estimates of phenotypic correlation coefficients among twelve characters in tomato

Characters	Days to 50% flowering	Plant height (cm)	Primary branches /plant	No. of fruits/ plant	Average fruit weight (g)	Diameter of fruit (cm)	No. of marketable fruits/plant	Pericarp thickness (mm)	No. of locules /fruit	Total soluble solids (TSS)	Fruit length (cm)	Fruit yield /plant (kg)
Days to 50% flowering	1.00	0.16	-0.11	-0.10	0.25**	-0.21	-0.01	-0.26**	-0.14	-0.02	-0.08	0.02
Plant height (cm)			0.31**	0.27**	-0.08	0.01	0.13	-0.16	0.08	0.09	-0.10	0.15
Primary branches per plant				0.16	0.15	0.25	0.14	0.20	0.23	-0.12	0.08	0.15
Number of fruits per plant					-0.43**	-0.17	0.61**	0.10	-0.06	-0.27**	-0.14	0.61**
Average fruit weight (g)						0.18	0.09	-0.01	0.13	-0.00	0.18	0.26**
Diameter of fruit (cm)							-0.04	-0.09	0.74**	0.22	0.75**	-0.04
Number of marketable fruits per plant								0.11	-0.03	-0.36**	-0.01	0.82**
Pericarp thickness (mm)									-0.28**	-0.04	0.00	0.13
Number of locules per fruit										0.28**	0.56**	-0.00
Total soluble solids (TSS)											0.16	-0.38**
Fruit length (cm)												-0.03

* ,** Significant at 5% and 1% probability level, respectively

Table 2: Estimates of genotypic correlation coefficients among twelve characters in tomato

Characters	Days to 50% flowering	Plant height (cm)	Primary branches /plant	No. of fruits/ plant	Average fruit weight (g)	Diameter of fruit (cm)	No. of marketable fruits/plant	Pericarp thickness (mm)	No. of locules /fruit	Total soluble solids (TSS)	Fruit length (cm)	Fruit yield /plant (kg)
Days to 50% flowering	1.00	0.20	-0.19	-0.22	0.28	-0.26	-0.30	-0.43	-0.08	-0.06	-0.04	-0.27
Plant height (cm)			0.35	0.36	-0.17	0.02	0.18	-0.18	0.12	0.15	-0.09	0.25
Primary branches per plant				0.18	0.11	0.28	0.09	0.22	0.28	-0.08	0.14	0.12
Number of fruits per plant					-0.73	-0.25	0.86	0.11	-0.07	-0.36	-0.21	0.93
Average fruit weight (g)						0.39	-0.18	-0.14	0.10	0.17	0.55	-0.41
Diameter of fruit (cm)							-0.07	-0.11	0.85	0.30	0.80	-0.11
Number of								0.12	-0.08	-0.54	0.08	1.19

marketable fruits per plant												
Pericarp thickness (mm)									-0.38	-0.03	0.03	0.12
Number of locules per fruit										0.32	0.73	-0.13
Total soluble solids (TSS)											0.16	-0.55
Fruit length (cm)												0.12

*, ** Significant at 5% and 1% probability level, respectively

Table 3: Direct and indirect effects of eleven characters on fruit yield/ plant (g) at phenotypic level in tomato

Characters	Days to 50% flowering	Plant height (cm)	Primary branches /plant	No. of fruits /plant	Average fruit weight (g)	Diameter of fruit (cm)	No. of marketable fruits /plant	Pericarp thickness mm)	No. of locules /fruit	Total soluble solids (TSS)	Fruit length (cm)	Correlation with fruit yield / plant (kg)
Days to 50% flowering	**-0.01**	0.00	0.01	-0.06	0.12	-0.00	-0.00	-0.02	-0.01	0.00	0.00	**0.02**
Plant height (cm)	-0.00	**0.04**	-0.04	0.14	-0.03	0.00	0.05	-0.01	0.00	-0.01	0.00	**0.15**
Primary branches per plant	0.00	0.01	**-0.13**	0.09	0.07	0.01	0.05	0.01	0.01	0.01	-0.00	**0.15**
Number of fruits per plant	0.00	0.01	-0.02	**0.55**	-0.21	-0.00	0.24	0.00	-0.00	0.03	0.01	**0.61**
Average fruit weight (g)	-0.00	-0.00	-0.02	-0.24	**0.49**	0.00	0.03	-0.00	0.01	0.00	-0.01	**0.26**
Diameter of fruit (cm)	0.00	0.00	-0.03	-0.09	0.09	**0.04**	-0.02	-0.00	0.05	-0.02	-0.06	**-0.04**
Number of marketable fruits per plant	0.00	0.00	-0.01	0.34	0.04	-0.00	**0.40**	0.01	-0.00	0.04	0.00	**0.82**
Pericarp thickness (mm)	0.00	-0.00	-0.02	0.05	-0.00	-0.00	0.04	**0.09**	-0.02	0.00	-0.00	**0.13**
Number of locules per fruit	0.00	0.00	-0.03	-0.03	0.06	0.03	-0.01	-0.02	**0.07**	-0.03	-0.04	**-0.00**
Total soluble solids (TSS)	0.00	0.00	0.01	-0.15	-0.00	0.01	-0.14	-0.00	0.02	**-0.11**	-0.01	**-0.38**
Fruit length (cm)	0.00	-0.00	-0.01	-0.08	0.09	0.03	-0.00	0.00	0.04	-0.01	**-0.08**	**-0.03**

RESIDUAL EFFECT = 0.3832

Table-4: Direct and indirect effects of eleven characters on fruit yield/ plant (g) at genotypic level in tomato

Characters	Days to 50% flowering	Plant height (cm)	Primary branches /plant	No. of fruit /plant	Average fruit weight (g)	Diameter of fruit (cm)	No. of marketable fruits /plant	Pericarp thickness mm)	No. of locules /fruit	Total soluble solids (TSS)	Fruit length (cm)	Correlation with fruit yield/plant (kg)
Days to 50% flowering	**-0.24**	0.05	0.08	-0.16	0.20	0.12	-0.13	-0.16	-0.06	0.02	0.01	**-0.27**
Plant height (cm)	-0.05	**0.25**	-0.16	0.26	-0.12	-0.01	0.08	-0.07	0.09	-0.05	0.02	**0.25**
Primary branches per plant	0.04	0.09	**-0.44**	0.13	0.08	-0.13	0.04	0.08	0.22	0.02	-0.03	**0.12**
Number of fruits per plant	0.05	0.09	-0.08	**0.74**	-0.52	0.11	0.38	0.04	-0.05	0.11	0.05	**0.93**
Average fruit weight (g)	-0.06	-0.04	-0.05	-0.54	**0.71**	-0.18	-0.08	-0.05	0.08	-0.05	-0.13	**-0.41**
Diameter of fruit (cm)	0.06	0.00	-0.12	-0.18	0.28	**-0.46**	-0.03	-0.04	0.67	-0.09	-0.19	**-0.11**
Number of marketable fruits per plant	0.07	0.04	-0.04	0.64	-0.13	0.03	**0.44**	0.04	-0.07	0.17	-0.01	**1.19**
Pericarp thickness (mm)	0.10	-0.04	-0.10	0.08	-0.10	0.05	0.05	**0.37**	-0.30	0.01	-0.00	**0.12**
Number of locules per fruit	0.02	0.03	-0.13	-0.05	0.07	-0.39	-0.03	-0.14	**0.79**	-0.10	-0.17	**-0.13**
Total soluble solids (TSS)	0.01	0.03	0.03	-0.26	0.12	-0.13	-0.24	-0.01	0.26	**-0.32**	-0.03	**-0.55**
Fruit length (cm)	0.01	-0.02	-0.06	-0.15	0.39	-0.37	0.03	0.01	0.57	-0.05	**-0.24**	**0.12**

R SQUARE = 1.1396 RESIDUAL EFFECT =SQRT (0.1396)

Table 5: Qualitative traits of tomato

S.No.	Characters Genotypes	Plant habit (determinate/ Indeterminate)	Leaf characters (Cut/potato leaf)	Stem characters (Hairy/Non hairy)	Stem colour (Green/Blue)	Fruit shape (Oblate/ Globes/ Squae/ Pear/ Cylindrical)
1.	NDT- 519	Determinate	Cut leaf	Hairy	Blue	Square
2.	NDT- 521	Determinate	Potato leaf	Hairy	Green	Globe
3.	NDT- 522	Determinate	Cut leaf	Non hairy	Green	Oblate
4.	NDT-525	Determinate	Cut leaf	Hairy	Green	Oblate
5.	NDT-526	Determinate	Cut leaf	Hairy	Green	Globe
6.	NDT-527	Determinate	Cut leaf	Hairy	Green	Globe

7.	NDT -529	Determinate	Cut leaf	Hairy	Blue	Oblate
8.	NDT-530	Determinate	Cut leaf	Hairy	Blue	Pear
9.	NDT-532	Determinate	Cut leaf	Hairy	Green	Square
10.	NDT-533	Determinate	Potato leaf	Hairy	Green	Pear
11.	NDT- 535	Determinate	Cut leaf	Non hairy	Green	Globe
12.	NDT-536	Determinate	Cut leaf	Hairy	Green	Globe
13.	NDT-537	Determinate	Cut leaf	Hairy	Green	Pear
14.	NDT- 38	Determinate	Cut leaf	Hairy	Green	Square
15.	NDT-540	Determinate	Cut leaf	Hairy	Green	Square
16.	Punjab Chhuhara (C)	Determinate	Cut leaf	Non hairy	Green	Globe
17.	NDT-8	Determinate	Cut leaf	Hairy	Green	Cylindrical
18.	NDT-514	Indeterminate	Cut leaf	Hairy	Blue	Oblate
19.	NDT-515	Indeterminate	Cut leaf	Non hairy	Green	Square
20.	NDT-516	Indeterminate	Cut leaf	Hairy	Green	Oblate
21.	NDT-517	Indeterminate	Potato leaf	Non hairy	Blue	Oblate
22.	NDT-518	Indeterminate	Cut leaf	Hairy	Green	Globe
23.	NDT-520	Indeterminate	Cut leaf	Hairy	Green	Oblate
24.	NDT-523	Indeterminate	Cut leaf	Hairy	Green	Oblate
25.	NDT- 524	Indeterminate	Cut leaf	Non hairy	Blue	Square
26.	NDT- 528	Indeterminate	Cut leaf	Hairy	Green	Square
27.	NDT-531	Indeterminate	Cut leaf	Hairy	Blue	Oblate
28.	NDT-534	Indeterminate	Potato leaf	Hairy	Blue	Cylindrical
29.	NDT-539	Indeterminate	Cut leaf	Non hairy	Blue	Pear
30	Pusa Ruby(C)	Indeterminate	Cut leaf	Hairy	Blue	Oblate

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