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Correlation and path analysis of fruit yield and yield attributing traits in tomato (*Lycopersicum esculentum* Mill.)

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Abstract
Present study was conducted using twenty three tomato genotypes in Randomized Complete Block Design with three replications at Agriculture farm, Palli-Siksha-Bhavana (Institution of Agriculture) Visva-Bharati University, Sriniketan, West Bengal during winter *(Rabi*) season of 2016-17 to evaluate association of fruit yield and yield attributing trait in tomato (*Lycopersicum esculentum* Mill). In order to find out the degree and direction of relationship of the yield contributing characters with yield and inter relationship between them, correlation analysis was carried out for all traits under investigation. Correlation analysis showed phenotypic and genotypic correlation for most of the character pairs were in same direction and genotypic estimates were higher than the phenotypic one, indicating inherent association between the characters. Average yield per plant showed highest positive association flower per plant (0.9512) and lowest positive association with plant height (0.2427). Highest negative association was found with no of secondary branch per plant (-0.0592) and lowest negative association with days to fifty percent flowering (-0.6553). The path coefficient analysis facilitates the partitioning of the correlation coefficients into different components of direct and indirect effects. Flower per plant exihibited highest positive direct effect (1.0383) on average yield per plant and days to fifty per cent flowering showed lowest positive direct effect (0.0159) on average yield per plant. The traits *viz,* number of secondary branches, full flowering, plant height, fruits per plant was shown to have positive direct effect over the yield per plant.

Keywords: Attributing traits, *Lycopersicum esculentum* Mill

Introduction
Tomato (*Lycopersicon esculentum* Mill.) is one the important vegetable crops all over the world and second most consumed vegetable after potato. Apart from other horticultural crops, tomato is used both as row and cocked. The cultivated tomato (*Lycopersicon esculentum* Mill.) is generally known to include 12 species and a number of subspecies which are diploid (2n = 2x = 24. The crop is having the yellow colored flower which leads to self-pollination but some amount of natural crossing also occur through insect and animals but pollination is hindered in hot dry weather. India ranks 2nd after China in tomato production India shares about 11.0% of global tomato production. Major tomato producing states are Bihar, Karnataka, Uttar Pradesh, Orissa, Andhra Pradesh, Maharashtra, and Madhya Pradesh & Assam. Worldwide, tomato breeding focuses mainly on heterotic combinations and thereby the designing of hybrid cultivars. The amount of genetic variability existed among different tomato genotypes offers a comprehensive idea to develop different improved verities as, greater the diversity in the genetic resource more is the genetic potential and larger are the chances for selection to get desired plant types. (Susic *et al*., 2002) [19]. So, it is necessary to conceive the knowledge of total amount phenotypic and genotypic variation for different quantitative traits in order to choose proper breeding technique to achieve different heterotic combination of tomato genotypes for improvement. It is well documented that, yield is a complex character which is influenced by other yield attributing traits. Therefore, it is mandatory to have knowledge about the association among different yield attributing traits so indirect selection based on their correlation of yield would be helpful.

Materials and Methods
The present study has been carried out at some point during winter *(Rabi*) season of 2016-17 at the block-A, plot no-5 west at Agriculture farm, Palli-Siksha-Bhavana (Institution of Agriculture) Visva-Bharati University, Sriniketan, West Bengal. The farm is located at 29° 39/ North latitude & 87° 42/ East longitude and at an average altitude of 58.90m above the mean sea level. The Agriculture Farm is pointed at the heart of the sub-humid, subtropical belt

in the Western part of the South Bengal. The soil of experimental field was loamy sand in texture, well drained with low level of Organic carbon, available nitrogen & potassium (k_2o) content & medium in available phosphorus (p_2o_5).The soil is slightly acidic in nature ($_P$H- 5.65) in reaction. Seeds of twenty three genotypes which are given below in the table included different tomato genotypes (Table.1). All twenty three tomato genotypes are collected from department of Genetics and plant breeding and crop physiology, Palli-Siksha-Bhavana (Institute of Agriculture) Visva-Bharati, Sriniketan, West Bengal. The experimental design was randomized complete block design with three replications. Seedlings were raised in outdoor nursery beds in the field. The seeds of all twenty-three lines in last week of September after sowing beds are sprinkled with water regularly. The beds were kept until the seedling emerges from bed. Seed beds are cover with transparent polythene to protect seedlings from frost and storm. Seedlings are ready to transplant nearby last week of October 2016.Observation were taken on the following characters Days to 1st flowering, days to 50%flowering, Days to full flowering, number of secondary branches, number of primary branches, Plant height, Flowers per plant, Fruits per plant, Average fruit weight per plant, Average yield per plant.

Table 1: Listed name of genotypes.

S. No	GENOTYPE	S. No	GENOTYPE
1	ARKAALOK	13	PARUL LOCAL
2	BCT-7	14	FLORADADE
3	NDT-7	15	FAB-2
4	PKM-1	16	GOLCHAMELI
5	PUNJAB CHUARA	17	ANTHOCYANIN LOCAL
6	PURULIA LOCAL	18	BIHALI
7	PUSA RUBY	19	ARKA MEGHALI
8	PATHARKUCHI	20	PANT T3
9	PURULIA-1	21	CIDTH-1
10	S-22	22	BCT-53
11	BCT(YEALLOW FRUIT)	23	RHR-33-1
12	CHERRY TOMATO		

Result and Discussion

Yield is the resultant of combined effect of several component characters and environment. Understanding the interaction of characters among themselves and with environment has been of great use in plant breeding. Correlation studies provide information on the nature and extent of association between only two pairs of characters. From this, it would be possible to bring about genetic up gradation in one character by selection of the other pair. Obviously, the knowledge about character associations will surely help in identifying the characters to select for higher yield with a view to determine the extent and nature of relationship prevailing among yield contributing characters. Hence, an attempt has been made to study the character association in the tomato accessions at both the levels. It is necessary to know the inter relationship of the attributing characters with fruit yield to abet the effective selection process and therefore, correlation coefficients among the characters was computed.

Correlation analysis and the association of different characters with fruit yield have been presented in Table 2. Days to first flowering, fifty percent flowering, days to full flowering, number of secondary branches were found to be negatively correlated with fruit yield per plant (-0.0721, -0.6553, -0.4999, - 0.0592) whereas number of primary branch, flowers per plant, plant height, fruits per plant, average fruit weight per plant was observed to be positively correlated with yield per plant (0.5128, 0.9512, 0.2427, 0.6728 0.3675,) at genotypic level. Highest negative association with yield was found for days to fifty percent flowering (-0.6553,) followed by number of secondary branches per plant (-0.0592). Highest positive association with yield was found for flowers per plant (0.9512) and fruits per plant (0.6728). Negative correlation for the traits for traits, via, days to first flowering, fifty percent flowering, full flowering, and number of secondary branches with yield per plant was found. It may suggested that genotypes with early flowering and lesser no of secondary branches would help in getting higher yield as early flowering promoted more fruit yield. Positive correlation was found for character, viz. number of primary branches, flowers per plant, plant height, fruits per plant, average fruit weight with yield per plant which suggested that selection of the genotypes having more number of fruits and flowers along with taller height and fruit weight would be rewarding in increasing the harvest. In this present study of tomato the level of genotypic correlations were higher than the phenotypic correlations which suggested highly heritable nature of different character under study. Flower per plant was found to be highly positively correlated with yield per plant for both genotypic and phenotypic level. Therefore, selection for any of these highly associated characters with fruit yield per plant would indirectly help in the selection of plants with high yield. Hence genotype with high number of fruits would indicate towards higher yield similar result was found by Nadeem *et al.* (2013 [13], PURULIA LOCAL and PARUL LOCAL respectively. Number of primary branches were positively correlated with yield per plant as well as positively correlated with number of flowers per plant, number of fruits per plant, number of secondary branches, days to first flowering, average fruit weight but negatively correlated with days to fifty percent flowering at both genotypic and phenotypic level as well as negatively but non significantly correlated with days to full flowering. Above findings suggested that, screening of germplasm with higher number of primary branches may help in improving fruit yield per plant. These results were in agreement with the findings of Reddy *et al.* (2013) [16], Nadeem *et al.* (2013) [13], Khapte and jansirani (2014) [8], Phom *et al.* (2015) [14]. No of secondary branches was found to be negatively correlated with yield per plant and positively correlated with days to fifty percent flowering, first flowering and full flowering, it may be stated that selection of genotypes having lesser number of secondary branches would increase fruit yield per plant with similar agreement by Wali and kabura (2008) [20]. Such genotypes were FLORADAE, FAB-

2, and PUNJAB CHUARA for the present study. Plant height was found to be positively associated with yield per plant both at genotypic and phenotypic level and also positively correlated with days to 1st flowering and full flowering, number of primary branches, secondary branches, flowers per plant, fruits per plant, average fruit weight per plant. The above observations suggested towards selection of the genotypes having tall height to increase in fruit yield per plant. Similar finding was appreciated by Mayavel *et al*. (2005) [11], Prashanth *et al.* (2008), Kaushik *et al*. 2011, Reddy *et al*. (2013) [16], Monamodi *et al.* (2013) [12], in their prospective study of tomato. Such genotypes were PURULIA-1, PKM-1, and ARKA ALOK for our case. Positive correlation was found for fruits per plant with fruit yield per plant. These findings indicated that, screening of genotypes with more number of fruits per plant would result in increase of fruit yield per plant and similar observation was found by Dar *et al.* (2011) [3] Nadeem *et al.* (2013) [13], Paul *et al*. (2014) [15], in their investigation over tomato. Suggested genotypes were PARUL LOCAL, PKM-1 for the present investigation. Average fruit weight found strongly positively correlated with fruit yield per plant while non-significant association was observed with 1st flowering, 50% flowering, full flowering and plant height. Based on findings it may be suggested that, selection of genotypes with more amount of fruit weight would improve fruit yield per plant and similarity was confirmed by Prashanth *et al.* (2008), Rani *et al.* (2010), Dar ***et*** *al.* (2011) [17, 3], Kumar and Singh 2016, in their correlation studies of tomato. Such genotypes were NDT-7, PATHARKUCHI in this experiment.

Path analysis was introduced by Wright (1921) and was illustrated by Dewey and Lu (1959) from the correlation studies we cannot get perfect idea about the character which is indirectly effected the yield so hence path coefficient studies help us to differentiation between correlation coefficients into direct and indirect contribution of various characters to yield. These help the breeder to identify the important component for future crop improvement program. Path coeffiecnt analysis provides better illustration of cause and effect relationship between different pair of components characters and the ultimate characters. In path analysis at genotypic level the component traits presented diagonally direct effect of the character towards their correlation with yield per plant in the current study, while all other off diagonal component shows effect via other component which is indirect effect of the character towards their correlation with yield per plant.

Path analysis offers the idea about the actual effects of the yield attributing traits towards the yield. Yield, the dependent character is always the target of improvement dependent over many independent traits through direct and/or indirect effects along with some undefined factors therefore even if a character is shown to be significantly correlated with yield may not be worthy for improvement due to the indirect effects of that character through other characters. Hence it is rational to split the total correlation into direct and indirect effects which are efficiently computed by path coefficient analysis. The path analysis was practiced under the present investigation and the data related to direct and indirect effect have been presented in Table 3 and 4. The residual effect also has been shown here which would help to judge the undefined factors beyond the traits under study.

Among the characters studied here, six were shown to have positive direct effect on yield per plant at the genotypic level. These characters were days to 50% flowering (0.0159), to full flowering (0.1392), number of secondary branches (0.0321), flowers per plant (1.0383), plant height (0.2972), fruits per plant (0.1123). Whereas, negative direct effect on yield per plant was observed for characters via days to 1st flowering (-0.0357), number of primary branches (-0.1071) and average fruit weight (-0.0176). But phenotypically negative direct effect for yield per plant negative direct effect over yield per plant was found for character, viz. Days to 1st flowering, fifty percent flowering and no of primary and secondary branches (-0.0073, -0.0084, -0.0722, -0.0018).Highest value for positive and negative direct effect at genotypic level was observed for flowers per plant (1.0383) and number of primary branches (-0.1071) per plant respectively. Phenotypically it was recorded for no of flowers per plant (0.9534) and number of primary branches (-0.0722) per plant. All above mentioned traits were found to be major contributors for yield per plant. The traits *viz*, days to 50% flowering, number of secondary branches, full flowering, plant height, fruits per plant was shown to have positive direct effect over the yield per plant. This information was in accordance with Islam *et al*. 2010, Kumar and Dudi 2011, Monamodi *et al*.2013 [6, 7, 12]. Negative direct effect for yield per plant was found for the traits like, days to 1st flowering, number of primary branches, average fruit weight and similar findings was observed by Hyder *et al*. (2007), Islam *et al*. (2010) [6], and Hasan *et al*. (2016) [5]. The above observations suggested for the selection of the genotypes with early days to 50% flowering, more number of secondary branches, early days to full flowering, high plant height, highest number of fruits per plant, late in days to 1st flowering, less no of secondary branches and lower fruit weight are major contributor towards yield per plant hence direct selection for above traits will increase the yield of fruit per plant. In the cases of phenotypic indirect effects, five character were found to have negative indirect effects, viz. fifty percent flowering, full flowering and number of primary and secondary branches, plant height (-0.0037, -0.0035, -0.0005, -0.0010, -0.0008) where as flower per plant, fruits per plant and average fruit weight were observed to be positively indirectly related (0.0010, 0.0009, 0.0012).The characters to have genotypically negative indirect were fifty percent flowering, full flowering and number of primary and secondary branches, plant height (-0.0214, -0.0201, -0.0030, - 0.0050) where as flower per plant, fruits per plant and average fruit weight were shown to have positive indirect effect. (0.0050, 0.0045, 0.0061). Highest negative and positive indirect effect for phenotypic level was recorded for days to 50% flowering (-0.037) and average fruit weight (0.0012), whereas at the genotypic level similar observation was found for days to 50% flowering (-0.0214) and average fruit weight (0.0061) respectively. In case of indirect effect, five characters was shown to have negative indirect effect genotypically with fifty percent flowering, full flowering and number of primary and secondary branches and plant height. Whereas flower per plant, fruits per plant and average fruit weight were found to have positive indirect effect over yield per plant accordance confirmed by Veershetty (2004), Singh (2005), Rani *et al*. (2010), Atugwu and Uguru (2012). Hence indirect selection these above mention traits will complement in improving yield per plant indirectly.

Table 2: Correlation study among different characters at genotypic level.

CHARACTER	D.F.F(1)	D.F.F(2)	D.F.F(3)	N.P.B	N.S.B	F.P.P(1)	P.H	F.P.P(1)	A.F.W.P.P	A.Y.P.P
D.F.F(1)(G)	1	0.5995	0.5619	0.0827	0.1408	-0.1393	0.1212	-0.1262	-0.1714	-0.0721
D.F.F(2)(G)		1	0.8475	-0.5754	0.0505	-0.7238	-0.0233	-0.7013	-0.3456	-0.6553
D.F.F(3)(G)			1	-0.3184	0.1199	-0.5936	0.0871	-0.738	-0.1574	-0.4999
N.P.B(G)				1	0.7216	0.5117	0.2335	0.4921	0.1564	0.5128
N.S.B (G)					1	-0.0765	0.1845	-0.0154	0.0105	-0.0592
F.P.P(1)(G)						1	-0.0412	0.703	0.4186	0.9512
P.H(G)							1	-0.0148	-0.0927	0.2427
F.P.P(2)(G)								1	0.14	0.6728
A.F.W.P.P (G)									1	0.3675
A.Y.P.P(G)										1

D.F.F (1)=Days to 1st flowering, D.F.F(2)=days to 50%flowering,D.F.F(3)=Days to full flowering, N.S.B=NO of secondary branches, N.P.B=No of primary branches, P.H=Plant height, F.P.P(1)=Flowers per plant, F.P.P(2)=Fruits per plant, A.F.W.P.P=Average fruit weight per plant, A.Y.P.P=Average yield per plant.

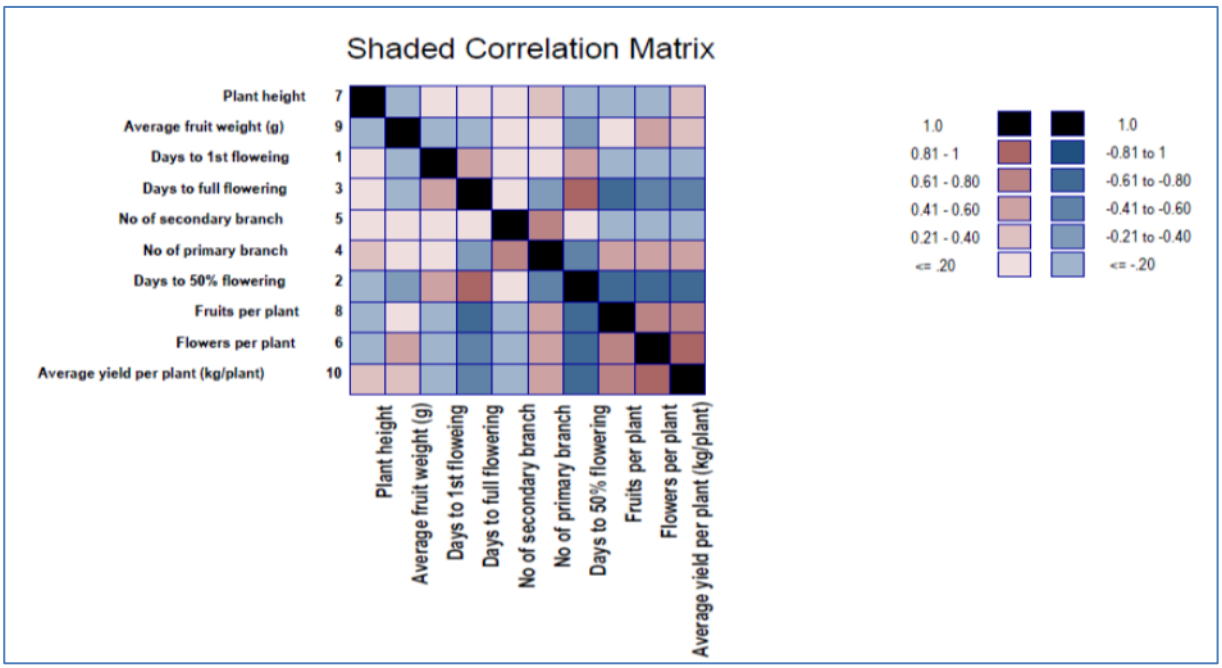

Fig 1: shaded correlation matrix for all character under study at the genotypic level.

Where black shed presents the neutral values, where deep to light blue sheds comparatively presents high to low positive correlation values where deep to light purple shades represents negatively high to low values for all character under study.

Table 3: Genotypic path matrix for direct and indirect effect.

	Days to 1st flowering	Days to 50% flowering	Days to full flowering	Number of primary branches	Number of secondary branches	Flowers per plant	Plant height (cm)	Fruits per plant	Average fruit weight per plant (g)
Days to 1st flowering	-0.0357	-0.0214	-0.0201	-0.003	-0.005	0.005	-0.0043	0.0045	0.0061
Days to 50% flowering	0.0095	0.0159	0.0135	-0.0092	0.0008	-0.0115	-0.0004	-0.0112	-0.0055
Days to full flowering	0.0782	0.118	0.1392	-0.0443	0.0167	-0.0826	0.0121	-0.1027	-0.0219
Number of primary branches	-0.0089	0.0616	0.0341	-0.1071	-0.0773	-0.0548	-0.025	-0.0527	-0.0167
Number of second ary branches	0.0045	0.0016	0.0038	0.0232	0.0321	-0.0025	0.0059	-0.0005	0.0003
Flowers per Plant	-0.1446	-0.7515	-0.6163	0.5313	-0.0794	1.0383	-0.0428	0.7299	0.4346
Plant height (cm)	0.036	-0.0069	0.0259	0.0694	0.0548	-0.0122	0.2972	-0.0044	-0.0275
Fruits perplant	-0.0142	-0.0787	-0.0829	0.0553	-0.0017	0.0789	-0.0017	0.1123	0.0157
Average fruit weight Per plant(g)	0.003	0.0061	0.0028	-0.0027	-0.0002	-0.0074	0.0016	-0.0025	-0.0176
	Correlation of yield with different character under study								
Average yield per (kg/pla	-0.0721	-0.6553	-0.4999	0.5128	-0.0592	0.9512	0.2427	0.6728	0.3675
Partial R^2	0.0026	-0.0104	-0.0696	-0.0549	-0.0019	0.9876	0.0721	0.0755	-0.0065

Table 4: Phenoptypic Direct and Indirect effect.

Character	Days to 1st flowering	Days to 50% flowering	Days to full flowering	Number of primary branches	Number of secondary branches	Flowers per plant	Plant height (cm)	Fruits per plant (g)	Average fruit weight per plant(kg/plant)
Days to 1st flowering	-0.0073	-0.0037	-0.0035	-0.0005	-0.0010	0.0010	-0.0008	0.0009	0.0012
Days to 50% flowering	-0.0044	-0.0084	-0.0054	0.0033	-0.0003	0.0054	-0.0003	0.0051	0.0025
Days to full flowering	0.0577	0.0752	0.1184	-0.0226	0.0085	-0.0613	0.0023	-0.0781	-0.0150
Number of primary branches	-0.0052	0.0286	0.0138	-0.0722	-0.0406	-0.0311	-0.0098	-0.0302	-0.0089
Number of second ary branches	-0.0002	-0.0001	-0.0001	-0.0010	-0.0018	0.0001	-0.0003	0.0000	0.0000
Flowers per Plant	-0.1314	-0.6056	-0.4933	0.4108	-0.0763	0.9534	-0.0346	0.6448	0.3801
Plant height (cm)	0.0343	0.0108	0.0062	0.0426	0.0625	-0.0114	0.3146	-0.0038	-0.0277
Fruits perplant	-0.0133	-0.0659	-0.0722	0.0459	-0.0018	0.0741	-0.0013	0.1095	0.0118
Average fruit Weight Per plant (g)	-0.0002	-0.0003	-0.0001	0.0001	0.0000	0.0005	-0.0001	0.0001	0.0012
	Correlation of yield with different character under study								
Average yield per	-0.0699	-0.5696	-0.4364	0.4065	-0.0507	0.9306	0.2698	0.6483	0.3452
Partial R^2	0.0005	0.0048	-0.0517	-0.0293	0.0001	0.8872	0.0849	0.0710	0.0004

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