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Genetic variability, character associations and path coefficient studies in tomato (*Solanum lycopersicum* L.) grown under terai region of West Bengal

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Abstract
The present study was carried out at the Instructional Farm, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India during 2017-2018. The material for the present study comprised of 37 genotypes of tomato. The experiment was laid out in a randomized block design (RBD) with three replications for each treatment. Quantitative character were recorded such as plant height (cm), Number of primary branch, Days to 1st flower, fruit weight (g), equatorial diameter (cm), polar diameter (cm), pericarp thickness (mm), locule number, fruit yield plant^{-1} (kg). On the basis of Analysis of variance, significant differences were observed among the genotypes for all the characters under study. The high (> 30%) Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) were observed for yield per plant (i.e., 57.31% and 58.14%, respectively) followed by fruit weight (i.e., 35.27% and 35.49%, respectively). The presence of high GCV for fruit yield per plant and fruit weight suggested the possibility of improving and fixing these characters through employing selection breeding. high heritability (>60%) coupled with high genetic advance as per cent of mean (>20%) were evident for all the characters under study indicated possibility of improvement of those traits through selection due to existence of additive gene effect. From combined study of correlation and path analysis suggested the characters *viz.*, polar diameter, number of primary branches and equatorial diameter found to be most important selection criteria in crop improvement of tomato.

Keywords: Variability, correlation, path analysis, tomato, yield

Introduction
Tomato (*Solanum lycopersicum* L.) belongs to a family Solanaceae, one of the important warm season self-pollinated vegetable that grown both for fresh and processing market (Das *et al*., 2011; Nwosu *et al*., 2014) [1, 2]. It is a native to Peru – Ecuador-Bolivia region (Rick, 1969) [3] and third popular widely grown and consumed vegetable in the world after potato and sweet potato. In India, tomato occupies an area of 0.87 million hectare with a production of 17.50 million ton and productivity of 20.11 tons per hectare (FAO, 2012) [4]. It is a rich source of vitamins, minerals and organic acids those imparts considerable amounts of antioxidant property in human body (Tomlekova *et al*., 2007; Glogovac *et al*., 2010) [5, 6] that alleviate chronic diseases such as cancer and coronary heart disease (Canene-Adams *et al*., 2005; Omoni and Aluko, 2005; Kun *et al*., 2006) [7,8,9]. Being a self pollinated crop, it has a tremendous potential for heterosis breeding and it is used in different breeding programme for genetic studies. Potent variability can be expected in tomato with respect to plant stature, fruit shape, size, quantity and quality (Bhardwaj and Sharma, 2005) [10]. In order to meet the demands of alarming increasing population of the world, plant breeders exerting great toil to improve genetic potential of yield and quality traits of tomato crop. Thus for improving the productivity of tomato primary concern should be on development of elite genotype by employing selection among and/or within the population through the utilization of existing genetic variability. Yield is attributed as complex polygenetically controlled character, closely associated with direct effect of other individually contributing characters and their complex interactions among themselves for ultimate manifestation of yield.

Hence, it is often misleading by employing direct selection based only on yield. Therefore knowledge about inter-relationship between yield attributing characters towards the yield is essential to bring a rational improvement in the desirable traits. Information regarding nature and magnitude of genetic variation in quantitative traits and their interrelationships in the available germplasm are the important pre-requisites for a systematic breeding program (Firas *et al*., 2012) [11]. The magnitude of variability present in germplasm can be detected by phenotypic and genotypic coefficients of variation. Heritable variation can be effectively studied in conjunction with genetic advance. Although, high heritability alone is not enough to make efficient selection in segregating generation and therefore needs to be accompanied by a substantial amount of genetic advance (Narolia *et.al*.,2012) [12]. The influence of environment in expression of characters and the extent to which improvement is possible after selection can be determined by heritability and genetic advance (Mohamed *et.al* 2012**)** [13]**.** Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for yield improvement. But, it is not adequate to examine traits interrelationship leading to yield. Under such circumstances, path coefficient analysis serves an additional informative tool (Islam et.al., 1991 and McGiffen *et.al*., 1994) [14, 15]. Path analysis splits the correlation coefficients into direct and indirect effects of a set of dependent variables on the independent variables which help in selecting elite genotypes. Thus the study has been framed based on above background. Keeping all this information in purview present experiment was laid out to estimate the genetic variability and determine the character association with yield in tomato.

Materials and Methods

Field experiments were carried out at the Instructional Farm, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar,West Bengal, India during 2017-2018. The material for the present study comprised of 37 genotypes of tomato viz., Patharkutchi, Alisa Craig, CLN 2011, CLN 2016, CLN 2165, CLN 2116-B, CLN 2005-D, CLN 21141-1, 213-H-1, BCT 15, BCT 20, BCT 27, BCT 46, BCT 27-1, BCT36/CONLCR-6, BERIKA,, BCT 21, BCT 37, BCT 107, BCT 17/RHR 32, BCT 281/C2203060, CONLCR-8, TTL-2, CIDH-1, H-88, BCT 115HG/DG, AC AFT (these all 27 genotypes were collected from BCKV,Mohanpur, Nadia, W.B.), NIMPITH LOCAL, COOCHBEHAR LOCAL (these 2 genotypes were collected from UBKV, Pundibari, CoochBehar, W.B), ARKA ASISH, ARKA ALOK, ARKA ABHA,ARKA AHUTI, ARKA MEGHALI, ARKA VIKASH, ARKA SAURABH (these 7 genotypes were collected from IIHR, Bangalore) and PUSA RUBY (From BAU, Sabour, Bihar). The experiment was laid out in a randomized block design (RBD) with three replications for each treatment. Standard crop management practices and plant protection measures were taken from time to time. Ten randomly selected plants from each replication were taken to record the quantitative observations at standard recommended stages. Quantitative character were recorded such as plant height (cm), Number of primary branch, Days to 1st flower, fruit weight (g), equatorial diameter (cm), polar diameter (cm), pericarp thickness (mm), locule number, fruit yield plant^{-1} (kg).Genotypic co-efficient of variation and Phenotype co-efficient of variation were computed as suggested by Burton (1952) [16]**,** heritability in broad sense by Hanson *et al*., 1956 [17], and the expected genetic advance based on Johnson *et al*., 1955 [18]. The correlation coefficients at genotypic and phenotypic levels were calculated as per the method given by Johnson *et al.* (1955) [18]. The path coefficient analysis was done as per Dewey and Lu (1959) [19]**.**

Result and discussion

Variability, Heritability and Genetic Advance: The results obtained under the present investigation are presented in Table 1 to 4. On the basis of Analysis of variance, significant differences were observed among the genotypes for all the characters under study (Table 1) that justified the significance of present research work; also exhibited the possibility of selection for genetic improvement of desirable types and isolation of promising superior genotypes. Similar observations in tomato were also reported by Pradeep kumar *et al*. (2001), Mohamed *et al.* (2012) and Narolia *et al.* (2012) [20, 13, 12]. Variability study (Table 2) exhibited that the phenotypic coefficient of variation was slightly higher than that of genotypic coefficient of variation for all the characters as well as differences among the magnitude of these two component was very less, indicated preponderance of genetic architecture in manifestation these characters and there by less influence of environmental factors; argued for stability in expression of characters. The high (> 30%) Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) were observed for yield per plant (i.e., 57.31% and 58.14%, respectively) followed by fruit weight (i.e., 35.27% and 35.49%, respectively). While, it was moderate for Locule number (i.e., 29.66% and 29.89%, respectively), Number of primary branches (i.e., 28.39% and 28.49%, respectively), plant height (i.e., 25.62% and 26.62%, respectively) pericarp thickness (i.e., 25.36% and 25.51%, respectively) and polar diameter (i.e., 20.18% and 20.39%, respectively). Whereas, very low GCV and PCV components were recorded for Days to first flower (i.e., 19.03% and 19.04%, respectively) and Equatorial diameter (i.e., 11.85% and 11.92%, respectively). The presence of high GCV for fruit yield per plant and fruit weight suggested the possibility of improving and fixing these characters through employing selection breeding. These results were corroborated with the findings of Das *et.al*. (1998) [21] and Mohamed *et al.* (2012) [13]**.** Whereas, low magnitude for days to first flower and equatorial diameter indicated the narrow genetic base; hence, suggested for enhancement of variability either through introduction or hybridising divergent genotypes in order to get transgressive segregants.

High heritability (> 60%) observed for all the characters under study *viz.* plant height, Number of primary branches, Days to first flower, fruit weight, polar diameter, equatorial diameter, pericarp thickness, Locule number and Yield per plant which indicated that there was less influence of environmental factors in manifestation of traits. This findings were in agreement with the findings of Das *et al.* (1998) [21], Singh *et al.* (2001) [22] and Singh *et al.* (1999) [23] for locule number, fruit weight; Reddy and Reddy (1922) [24], Pujari *et al*. (1995) [25], Sahu and Mishra (1995) [26], Padmini and Vadivel (1997) [27], Phookan *et al*. (1998) [28], Bharti *et al*. (2002) [29] and Mohanty *et al*. (2002,2003) [30, 31] for fruit yield /plant, fruit weight; Das *et al*. (1998) [21] for pericarp thickness. High heritability suggested the major role of genetic constitution in the expression of characters and such traits are considered to be dependable from breeding point of view. However, heretibility used in conjunction with genetic advance provides better information for selecting the best individuals than the heritability alone (Johnson *et al*., 1995).

Hence, high heritability (>60%) coupled with high genetic advance as per cent of mean (>20%) were evident for all the characters under study indicated possibility of improvement of those traits through selection due to existence of additive gene effect. The result obtained was in agreement with the findings of Singh (2009) [32] for plant height; Ara *et al.* (2009) [33] for Number of primary branches; Golani *et al.* (2007) [34] for Number of locules per fruit**,** Patil *et al*. (1996) [35] for Pericarp thickness; Mehta and Asati (2008) [36] for fruit weight and fruit yield per plant.

Character association: The result on correlation coefficients revealed that both the magnitude for genotypic and phenotypic correlations followed more or less similar trend of character association but the genotypic correlation is generally higher than the phenotypic correlations indicating that the phenotypic expression of correlation is reduced under the influence of environment (Table 3).

It was observed that yield per plant was positively and significantly correlated with Number of primary branches (G = 0.438 and P = 0.432) and Polar diameter (G = 0.430 and P = 0.428). Similar findings having positive and significant correlation of yield per plant with Number of primary branches was also reported by Chabbi et.al (2018) [37] and Khapte and Jansirani (2014) [38]. Similarly positive and significant correlation of yield per plant with polar diameter was also observed by Prasantha *et al.* (2008) [39]. Yield per plant was significantly but negatively correlated with days to first flowering (-0.462 and -0.454) suggested that delayed in flowering reflected with low yield might be due to reduction in net fruiting span and the result was corroborated with the finding of Khapte and Jansirani (2014) [38]**.** However, yield related traits *viz.,* fruit weight, polar diameter, equatorial diameter and pericarp thickness were insignificant but positively correlated with the yield per plant, suggested that simultaneous selection in each generation might be helpful to enhance the yield related traits in subsequent selection progeny.

Path coefficient analysis: Path coefficient analysis revealed that plant height (Table 4) had high direct effect (0.349) on yield, but have negative correlation with the yield (-0.207). It showed low indirect effect via pericarp thickness (0.14) and locule number (0.13); but had negative indirect effect via number of primary branches, days to first flowers, fruit weight, polar diameter and equatorial diameter. Number of primary branches showed low direct positive effect on yield (0.138) along with highly significant and positive correlation with the yield (0.432). Verma and Sarnaik (2000) [40] observed that number of Primary branches per plant showed positive direct effect on yield. It showed high positive indirect effect via polar diameter (0.381) as well as negligible positive indirect effect via days to first flowers (0.056) and equatorial diameter (0.080); but had negative indirect effect via plant height, fruit weight, pericarp thickness and locule number. Days to first flower showed high negative direct effect on yield (-0.581) along with highly significant and negative correlation with the yield (-0.454). It exhibited high positive indirect effect via plant height (0.198) along with negligible positive indirect effect via polar diameter, equatorial diameter, pericarp thickness and locule number with negative indirect via number of primary branches and fruit weight. Fruit weight exhibited high direct negative effect on yield (-0.691) along with high and positive correlation with the yield (0.197). It showed high positive indirect effect via polar diameter (0.528), equatorial diameter (0.432); negligible positive indirect effect via plant height, Number of primary branches, locule number, but negative indirect effect via days to first flower and pericarp thickness. Polar diameter indicated high direct positive effect on yield (0.808) along with highly significant and positive correlation with the yield (0.428). It showed moderate positive indirect effect via equatorial diameter (0.236) and negligible positive indirect effect via Number of primary branches (0.065) as well as negative indirect effect via plant height, days to first flower, fruit weight, pericarp thickness and locule number. Equatorial diameter indicated high direct positive effect on yield (0.511) along with moderate and positive correlation with the yield (0.244). It showed high positive indirect effect via polar diameter (0.374) and negligible positive indirect effect via Number of primary branches (0.022) and Locule number (0.048); negative indirect effect via plant height, days to first flower, fruit weight and pericarp thickness. Pericarp thickness indicated low negative direct effect on yield (-0.081) along with moderate and positive correlation with the yield (0.258). It showed high positive indirect effect via polar diameter (0.602), low positive indirect effect via equatorial diameter (0.192) and negligible indirect effect via number of primary branches (0.027); negative indirect effect via plant height, days to first flower, fruit weight and Locule number. Locule number exhibited low positive direct effect on yield (0.189) along with low and negative correlation with the yield (-0.126). It showed low positive indirect effect via equatorial diameter (0.130), Locule number (0.189) and negligible positive indirect effect via plant height (0.025), Pericarp thickness (0.028); negative indirect effect via number of primary branches, days to first flower, fruit weight and polar diameter. However, based on the higher magnitude for the direct effect coupled with correlation with yield at desired direction characters *viz.,* polar diameter, number of primary branches and equatorial diameter could be subjected to direct selection for yield improvement in tomato. The magnitude of residual effect with 0.166 at genotypic level indicated 83.4% contribution of selected characters for yield. Hence, indicating inclusion of the maximum fruit yield influencing characters of tomato in the present analysis.

Conclusions

From the above discussion it could be concluded that there were sufficient variability among the genotypes for all the characters under study that justified the incorporation of local genotype in the present experiment and expression of characters was less influenced by the environment. Higher magnitude for genotypic as well as phenotypic coefficient of variation for fruit yield per plant and fruit weight suggested effectiveness of selection breeding in fixation and improvement of these characters. High heritability coupled with high genetic advance as per cent of mean for all the characters under study was evident for existence of additive gene effect, suggested significance of selection breeding for improvement of these characters. From combined study of correlation and path analysis suggested the characters *viz.,* polar diameter, number of primary branches and equatorial diameter found to be most important selection criteria in crop improvement of tomato.

Table 1: Analysis of variance for various characters under study Genotypes

Sources of variation	d.f	PH	NPB	DFF	FW	PD	ED	PT	LN	YP
Replication	2	5.18	15.23	17.14	3242.08	5.49	3.85	11.48	2.51	3.04
Genotypes	36	1004.15**	6.98**	135.71**	2089.22**	2.85**	1.04**	6.55**	3.12**	4.10**
Error	72	0.01	0.02	0.03	9.01	0.02	0.01	0.03	0.02	0.04

**Significant at 1 per cent level, d.f- degree of freedom, PH- Plant height, NPB- Number of primary branches, DFF- days to first flower, FW- Fruit weight, PD- Polar diameter(cm), ED- Equatorial diameter(cm), PT- Pericarp thickness (mm), LN- Locule number, YP- Yield per plant (kg)

Table 2: Variability studies in tomato genotypes

Characters	Mean	Range		GCV (%)	PCV (%)	Heritability (h^2%)	Genetic Advance (% of mean)
		Max.	Min.				
Plant height (cm)	68.72	115.41	43.18	25.62	26.62	99.67	54.84
Number of primary branches	5.37	9.62	3.66	28.39	28.49	99.27	58.26
Days to 1st flower	35.34	44.76	22.89	19.03	19.04	99.93	39.19
Fruit wt.(g)	74.66	132.46	28.04	35.27	35.49	98.72	72.19
Polar diameter (cm)	4.81	6.47	3.15	20.18	20.39	98.01	41.11
Equatorial diameter (cm)	4.95	5.95	3.74	11.85	11.92	98.79	24.26
Pericarp thickness (mm)	5.82	9.13	3.46	25.36	25.51	98.82	51.93
Locule number	3.43	5.28	2.00	29.66	29.89	98.50	60.64
Yield/plant (kg)	2.03	5.53	0.48	57.31	58.14	97.17	116.38

Table 3: Genotypic and Phenotypic correlation coefficients among 09 quantitative traits in tomato accessions

		PH	NPB	DFF	FW	PD	ED	PT	LN	YP
PH	G		-0.081	0.567**	0.054	-0.165	-0.147	-0.177	0.073	-0.210
	P		-0.081	0.567**	0.054	-0.164	-0.146	-0.176	0.072	-0.207
NPB	G			-0.097	0.221	0.471**	0.157	0.199	-0.109	0.438**
	P			-0.097	0.220	0.467**	0.156	0.196	-0.109	0.432**
DFF	G				0.221	0.059	0.061	0.019	0.057	-0.462**
	P				0.220	0.059	0.060	0.018	0.057	-0.454**
FW	G					0.654**	0.846**	0.481**	0.189	0.187
	P					0.647**	0.835**	0.471**	0.185	0.197
PD	G						0.463**	0.746**	-0.398*	0.430**
	P						0.453**	0.731**	-0.394*	0.428**
ED	G							0.376*	0.255	0.254
	P							0.375*	0.251	0.244
PT	G								-0.347*	0.271
	P								-0.343*	0.258
LN	G									-0.128
	P									-0.126

G – Genotypic correlation coefficient, P – Phenotypic correlation coefficient, PH- Plant height, NPB- Number of primary branches, DFF- days to first flower, FW- Fruit weight, PD- Polar diameter(cm), ED- Equatorial diameter(cm), PT- Pericarp thickness (mm), LN- Locule number, YP- Yield per plant (kg).

Table 4: Path coefficient analysis showing direct and indirect effects of different characters on yield per plant.

Characters	PH	NPB	DFF	FW	PD	ED	PT	LN	GCY
PH	0.349	-0.011	-0.329	-0.037	-0.133	-0.075	0.014	0.013	-0.207
NPB	-0.028	0.138	0.056	-0.152	0.381	0.080	-0.016	-0.021	0.432**
DFF	0.198	-0.013	-0.581	-0.153	0.048	0.031	0.002	0.011	-0.454**
FW	0.018	0.031	-0.128	-0.691	0.528	0.432	-0.038	0.036	0.197
PD	-0.057	0.065	-0.034	-0.451	0.808	0.236	-0.060	-0.075	0.428**
ED	-0.051	0.022	-0.035	-0.584	0.374	0.511	-0.030	0.048	0.244
PT	-0.061	0.027	-0.011	-0.332	0.602	0.192	-0.081	-0.065	0.258
LN	0.025	-0.015	-0.033	-0.131	-0.321	0.130	0.028	0.189	-0.126

RESIDUAL EFFECT= 0.166; * and ** Significant at 5% level and 1% level respectively
PH- Plant height, NPB- Number of primary branches, DFF- days to first flower, FW- Fruit weight, PD- Polar diameter(cm), ED- Equatorial diameter(cm), PT- Pericarp thickness (mm), LN- Locule number, GCY- Genotypic correlation with yield

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