North American Academic Research

Variability of Tomato (*Lycopersicon esculentum* L.) Genotypes for Higher Yield and Yield Contributing Traits

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ABSTRACT

Experiments were conducted with 25 tomato (*Lycopersicon esculentum* L.) genotypes to study the field performance and genetic variability for yield and yield contributing characters in the field laboratory of Department of Genetics and Plant Breeding, Bangladesh Agricultural University, Mymensingh. The design was laid out following Randomized Complete Block Design (RCBD) with three replications. The duration of the experiment was started from October 2016 to April 2017. The analysis of variances showed a high degree of variation existed among the genotypes of the studied traits. The experiment showed the highest plant height and the minimum days required for flowering was World Champion (101.2cm). The highest number of primary branches (9.76 cm) and the highest number of fruits (30.48) recorded in Joint Hybrid. Early maturity found in genotype Binatomato-9 (110 days) and the highest yield obtained from Binatomato-8 (606.80g). Genetic analysis of yield contributing traits showed higher PCV than GCV that indicated the presence of environmental influence on varietal performance. In path coefficient analysis positive direct effects were found in the number of primary branches followed by days to 50% flowering, days to fruit maturity, number of fruits per plant and fruit diameter. Genotypes were classified into five clusters by Ward's method where high yield, maximum days to fruit maturity and maximum days to first flowering were found in cluster IV, the highest plant height was found in cluster I, the highest fruit diameter was found in cluster III, minimum days to fruit maturity was found in cluster IV. In principal component analysis, the main four principal components accounted for around 78.02% of total variability. Based on the present findings, World Champion, Joint Hybrid and Binatomato-8 may be considered as the superior genotypes among twenty-five tomato genotypes.

Keywords

Tomato, Genetic Diversity, Heritability, Genetic Advance, Correlation coefficient, Path co-efficient

Introduction

Tomato (*Lycopersicon esculentum* L.) is one of the most important vegetables and cultivated world widely. As a processing crop, it ranks first among the vegetables and a major source of vitamins and minerals [1]. Tomato is a self-pollinated crop which belongs to the *Solanaceae* family with containing 24 chromosomes. It was first domesticated in Mexico. Nowadays, tomato is grown in practically every country in the world in outdoor fields, greenhouses and net houses and commercially, it has great importance. Tomato is considered a tender warm season crop but is actually a perennial plant, although it is cultivated as an annual. It requires a relatively long growing season and moderately high temperature (20-28°C). It ensures that the optimum fruit setting is at night temperature and the optimum range is 15°-20°C. In Bangladesh, it is also a popular vegetable and occupying an area of about 14338 ha, with a total production of about 97565 metric tons and average yield of 6.8 metric tons per ha. The yield is remarkably poor in comparison to the world average of 27.8 metric tons per ha (Anonymous, 1997). Tomato contains a number of nutritive elements almost double compared to apple [2]. Tomatoes are a good source of vitamins A, C and E and minerals that are very good for the body and protect the body against diseases [3]. The tomato is composed mainly of water (approximately 90%), soluble and insoluble solids (5-7%), citric and other organic acids, and vitamins and minerals [4]. Because of its nutritional value, it is considered as "poor man's orange" in some countries [5]. Ripe tomatoes have a high content of the antioxidant lycopene, which plays a possible role in the prevention of certain forms of cancer [6]. Tomatoes help wash out the toxins and other contaminants from the body and act as a gentle stimulant for kidneys. Tomatoes are also rich in Vitamin A. Regular consumption of tomatoes can prevent short sightedness, night blindness, and other eye diseases. Tomato is also effective in curing morning sickness, excessive gas formation in the intestine, gastrointestinal diseases, indigestion, etc. Tomato is also helpful in preventing joint pain problems and respiratory disorders [7]. Several decades ago, it was common fora single tomato variety to serve multiple purposes and markets. To develop new varieties that thrive under the pressures and challenges of specific conditions, and to incorporate traits most important to each market, it is vital that breeding work use the same cultural practices and environmental conditions. Intense breeding programs worldwide have resulted in tomato being the second most important vegetable in production in the world [8]. Genetic variation in wild species has been the source of traits for crop improvement in quality and disease and insect resistance in modern breeding programs [9]. In order to develop desired tomato cultivars, it is important to catalogue the genetic diversity within the germplasm [10]. Morphological traits have been used to estimate genetic diversity and cultivar development since they provide a simple way of quantifying genetic variation [11].

Selection of suitable parent with desirable character is important for getting higher yield in effective breeding programme. In present study, 25 genotypes were used for determining genetic variability by correlation coefficient, path coefficient, cluster analysis and principal component analyses. In this study, we will be able to identify some suitable genotypes which can be used for the further tomato breeding

programme. The present research work was therefore, designed to address the following objectives: To study the field performance of tomato for yield and yield contributing characters, to select the suitable tomato genotypes for breeding programme and to determine the relationship between yield and yield contributing characters.

Materials and Methods

Experiments were conducted with twenty five tomato *(Lycopersicon esculentum* L.) genotypes to study the field performance and genetic variability for yield and yield contributing characters in the field laboratory of Department of Genetics and Plant Breeding, Bangladesh Agricultural University, Mymensingh. The design was laid out following Randomized Complete Block Design (RCBD) with three replications. The duration of the experiment was started from October 2016 to April 2017. This study involved 25 varieties Binatomato-2, Binatomato-3, Binatomato-8, Binatomato-9, Binatomato-11, Burpi Big, Big Cherry, Combel 28 F.R, Cl-3d-143-0-13, Feridal, Florida 1, Hekuri, Homeastid, Joint Hybrid, Marglobe-1, Marglobe-2, Tm-2, Tm-131, Tm-134, Tm-219, V1057583, Walter, WP-10, World Champion, 193. The indigenous exotic tomato lines and variety were collected from Field laboratory, Genetics and Plant breeding department, Bangladesh Agricultural University, Mymensingh. The experiment was laid out in Randomized Block Design at a spacing of 90 cm × 45 cm in the plots with 3 replications. The standard agronomic practices were followed to maintain healthy crop stand. In this experiment following parameters of tomato i) Plant height, ii) No. of primary branches per plant, iii) Days to first flowering, iv) Days to 50% flowering, v) No. of fruit cluster per plant, vi) No. of fruits per plant, vii) Days to fruit maturity, viii) Fruit diameter, ix) Fruit yield per plant were recorded for the study. For experimental purpose data were collected for the 9 characters with three replications for each genotype and five plants from each replication were randomly selected. Observations were taken from randomly selected plants plants for each character for using statistical analysis. Data on various yield and yield attributing characters were recorded in the field conditions. Analysis of variance was performed using the plant breeding statistical program (Uttzzal, MSTATc and PLABSTAT, Version 2N, 2007). The replicates were considered as random variables. Multiple mean comparisons were made with Fisher's least significant difference (LSD) procedure using stat graphics Plus for Windows 7.0 (Statistical Graphics Crop. Rockville, USA). Genotypic and phenotypic variances were estimated according to the formula given by Johnson et al 1955 [12]. Heritability in broad sense was calculated according to the formula suggested by Johnson et al 1995 and Hanson 1956 [13, 14]. Genotypic and phenotypic coefficient of variations were estimated according to Singh and Chaudhury 1985 and Burton 1952 [15, 16]. Estimation of genetic advance was done following formula given by Allard 1960 and Johnson et al 1955 [17, 12]. Genetic advance in percent of mean was calculated by the formula of Comstock and Robinson 1952 [18]. The phenotypic and genotypic correlation was estimated by the formula given by Miller et al 1991 [19]. Direct and indirect path co-efficient were calculated as described by Lynch

and Walsh 1998 [20]. Clustering was done by Tocher method [21]. The principal component analysis was done by the method given by Holland 2008 [22].

Results and Discussion

The result of the analysis of variance showed highly significant (0.1% level) variation among different genotypes for yield and yield contributing traits (viz. plant height, number of primary branches, days to first flowering, days to 50% flowering, number of fruit clusters per plant, days to first fruit maturity, number of fruits per plant, fruit diameter, yield per plant) studied (Table 1). The table 2 showed the mean performance of genotypes on different morphological traits related to yield of tomato germplasm. The highest plant height (101.2 cm) was observed in World Champion was statistically significant and different from all other genotypes and the lowest value (43.08 cm) was recorded in Walter. The maximum number of primary branches bear by genotype Joint Hybrid and Feridal (9.76) and lowest number of primary branches bear in Tm-131 (6.05). The maximum days required for flowering was Binatomato-9 (41) and minimum days required for flowering was World Champion (31.67). The genotype WP-10 required maximum number of days (47.33) to 50% flowering and genotype whereas World champion required minimum number of days (37.33) to 50% flowering. The maximum number of fruit cluster bear in Cl-3d-143-0-13 (7.10) and the minimum number of fruit cluster bear in WP-10 (3.22). The experiment showed the maximum days required for fruit maturity in genotype Combel 28 F.R (119.70) and the minimum days required in genotype Binatomato-9 (110). The highest number of fruits (30.48) recorded in Joint hybrid and the lowest number of

Table 1. Analysis of variance for different morphological plant characters of tomato germplasm

Characters	d.f	PH (cm)	PB (no.)	DFF (days)	50%F (days)	FC (no.)	FM (days)	FP (no.)	FD (cm)	YP (g)
Replication	2	1.18	0.597	2.33	3.29	0.624	13.69	2.26	0.469	91.08
Genotypes	24	546.25**	3.113**	21.94**	21.70**	2.716**	28.92**	64.31**	12.976**	33951.18**
Error	48	13.54	0.31	2.73	4.72	0.313	12.72	1.85	0.824	136.94

Here, ** indicates significant at 0.01 probability level.

PH = Plant height; PB = Number of primary branches per plant; DFF = Days to first flowering; 50% F = Days to 50% flowering; FC = Number of fruit cluster per plant; DFM = Days to fruit maturity; FP = Number of fruits per plant; FD = Fruit diameter; YP = Yield per plant.

Table 2. Mean performance of genotypes on different morphological traits related to yield of tomato germplasm

G	PH (cm)	PB (no.)	DFF (days)	50%F (days)	FC (no.)	FM (days)	FP (no.)	FD (cm)	YP (g)
G1	81.36b	9.14abcd	40.67ab	45.00abcd	4.55fgh	111.70def	13.72ijk	13.02cdef	191.70gh
G2	63.57d	9.11abcd	35.33efg	41.67cdefg	6.25abc	111.70def	17.59defg	12.97cdef	376.40b
G3	49.41ijklm	8.53cdef	34.33fgh	38.00gh	5.83bcd	111.00ef	18.42def	15.90a	253.10e
G4	101.2a	9.73ab	31.67h	37.33h	6.46ab	110.70ef	19.07cde	15.04ab	307.10c
G5	51.89hijkl	7.61fgh	40.67ab	47.33a	3.22i	110.30ef	9.27n	13.14cdef	249.70e
G6	45.53lm	6.05i	40.67ab	45.00abcd	5.27cdefg	113.70abcdef	16.53efgh	9.50g	175.80h
G7	49.73ijklm	9.20abcd	34.33fgh	39.00efgh	5.26cdefg	113.30abcdef	18.93cde	12.70cdef	321.60c
G8	52.27hijkl	7.31gh	40.33abc	45.00abcd	4.73efgh	111.30def	18.33def	12.31def	225.60f
G9	43.08m	7.35gh	38.67abcd	43.67abcd	3.83hi	116.30abcdef	14.17hijk	7.90h	175.30h
G10	54.68fghij	9.00abcd	39.67abc	45.33abcd	5.77bcde	119.70a	12.47klm	12.87cdef	135.10ij
G11	60.53def	7.82efgh	38.33abcde	43.67abcd	4.42gh	111.70def	9.64n	15.00ab	209.70fg
G12	64.07d	9.76a	37.67bcde	43.00bcde	6.40ab	111.70def	19.47bcd	13.60bcde	251.30e
G13	43.67m	8.66bcdef	35.67defg	41.67defg	4.61fgh	112.30cdef	15.65ghi	13.45bcdef	257.20e
G14	62.50de	9.16abcd	39.67abc	45.33abcd	5.75bcde	114.70abcdef	21.00bc	13.70bcd	280.00d
G15	53.45ghijk	9.10abcd	40.33abc	44.33abcd	4.33gh	119.30ab	14.58hijk	11.85ef	100.00kl
G16	61.10def	9.76a	39.67abc	45.33abcd	6.63ab	110.30ef	30.48a	12.10def	255.80e
G17	55.87efghi	9.40abc	37.33cdef	42.67bcdef	5.06defg	115.70abcdef	21.73b	13.38bcdef	136.60ij
G18	57.55defgh	6.86hi	36.33defg	42.67bcdef	5.58bcdef	112.70bcdef	13.64ijk	14.17bc	201.70g
G19	47.53klm	7.41gh	38.67abcd	43.33abcd	4.91defgh	111.70def	10.17mn	12.37def	95.67l
G20	55.12fghi	8.70abcde	40.67ab	45.00abcd	4.55fgh	119.00abc	12.73jkl	13.44bcdef	606.80a
G21	51.32hijkl	6.80hi	40.67ab	45.33abcd	4.66fgh	111.00ef	10.64mn	8.73gh	153.60i
G22	72.33c	8.33cdefg	40.33abc	46.00abc	6.25abc	114.30abcdef	15.17ghij	11.73f	154.70i
G23	59.67defg	7.76efgh	41.00a	46.33ab	4.63fgh	110.00f	12.56klm	11.77f	178.00h
G24	81.70b	8.29defg	40.33abc	44.67abcd	4.56fgh	117.30abcde	16.12fghi	7.67h	117.30jk
G25	47.95jklm	8.20defg	33.67gh	38.67fgh	7.10a	118.30abcd	17.57defg	13.53bcdef	195.80gh
LSD$_{0.05}$	6.04	0.914	2.72	3.56	0.919	5.86	2.23	1.49	19.21
Mean	58.68	8.36	38.27	43.41	5.23	113.59	15.99	12.47	224.22
SE (±)	2.70	0.20	0.54	0.54	0.19	0.62	0.93	0.42	21.28
SD	13.49	1.02	2.70	2.69	0.95	3.11	4.63	2.08	106.38
Min	43.08	6.05	31.67	37.33	3.22	110.00	9.28	7.67	95.67
Max	101.20	9.77	41.00	47.33	7.10	119.67	30.48	15.90	606.83
LS	**	**	**	**	**	**	**	**	**
CV%	6.27	6.66	4.32	5.01	10.70	3.14	8.50	7.28	5.22

Here, * and ** indicate significant at 5% and 1% level of probability, respectability.

G = Genotypes, G$_1$ = Marglobe-1, G$_2$ = 193, G$_3$ = Hekuri, G$_4$ = World Champion, G$_5$ = WP-10, G$_6$ = Tm-131, G$_7$ = Tm-134, G$_8$ = V1057583, G$_9$ = Walter, G$_{10}$ = Combel 28 F.R, G$_{11}$ = Binatomato-3, G$_{12}$ =Feridal, G$_{13}$ = Binatomato-11, G$_{14}$ = Burpi Big, G$_{15}$ = Big Cherry, G$_{16}$ = Joint Hybrid, G$_{17}$ = Florida 1, G$_{18}$ = Tm-219, G$_{19}$ = Homeastid, G$_{20}$ = Binatomato-8, G$_{21}$ = Tm-2, G$_{22}$ = Binatomato-2, G$_{23}$ = Binatomato-9, G$_{24}$ = Marglobe 2, G$_{25}$ = Cl-3d-143-0-13. PH = Plant height; PB = Number of primary branches per plant; DFF = Days to first flowering; 50% F = Days to 50% flowering; FC = Number of fruit cluster per plant; DFM = Days to fruit maturity; FP = Number of fruits per plant; FD = Fruit diameter; YP = Yield per plant, SD=Standard Deviation, Min=Minimum Max=Maximum LS=Level of significance

fruits in the genotype WP-10 (9.27cm). The highest fruit diameter was measured in Hekuri (15.90 cm) and the lowest diameter was in Walter and Marglobe 2 (7.90 and 7.67, respectively). The highest yield 606.80g per plant was obtained from Binatomato-8 and the lowest yield 95.67g per plant was obtained from Homeastid.

Estimation of Genetic Variability, Heritability and Genetic Advances

The mean sum of squares, PV(δ^2p), GV(δ^2g), GCV, PCV, h2$_b$, GA and (GA %) for yield and yield attributing traits of tomato are presented in Table 3. Analysis of PCV and GCV a clear concept can be established for the actual strength of variability. It is shown that the values for PCV for all of the traits studied were higher than those of their corresponding GCV: Plant height (PCV = 23.56, GCV = 22.71); Number of primary branches per plant (PCV = 13.34, GCV = 11.56); Days to First flowering (PCV = 7.90, GCV = 6.61); Days to 50% flowering (PCV = 7.42, GCV = 5.48); Number of fruit cluster per plant (PCV = 20.19, GCV = 17.12); Days to fruit maturity (PCV = 3.75, GCV = 2.05); Number of fruits per plant (PCV = 29.78, GCV = 28.54); Fruit diameter (PV = 17.70, GV = 16.14); Yield per plant (PCV = 47.64, GCV = 47.35). The higher PCV and GCV for all traits showed that there were environmental influences on the phenotypic expression of all the genotypes. Among all the traits, yield per plant showed highest (47.64% and 47.35%) and days to fruit maturity showed lowest (3.75% and 2.05%) PCV and GCV values respectively. So the selection on the phenotypic value can be effective for the improvement of the traits.

Table 3. Estimation of some genetic parameters in respect of 25 genotypes of tomato germplasm

Characters	PV (δ^2p)	GV (δ^2g)	PCV (%)	GCV (%)	h2$_b$ (%)	GA	GA (%)
PH (cm)	191.11	177.57	23.56	22.71	92.92	26.46	45.09
PB (no.)	1.24	0.93	13.34	11.56	75.09	1.73	20.63
DFF (days)	9.14	6.40	7.90	6.61	70.06	4.36	11.40
50%F (days)	10.38	5.66	7.42	5.48	54.50	3.62	8.33
FC (no.)	1.11	0.80	20.19	17.12	71.90	1.56	29.90
FM (days)	18.12	5.40	3.75	2.05	29.80	2.61	2.30
FP (no.)	22.67	20.82	29.78	28.54	91.85	9.01	56.35
FD (cm)	4.87	4.05	17.70	16.14	83.10	3.78	30.30
YP (g)	11408.35	11271.41	47.64	47.35	98.80	217.39	96.95

Here, PV (δ^2p) = Phenotypic variance; GV (δ^2g) = Genotypic variance; PCV (%) = Phenotypic coefficient of variation; GCV (%) = Genotypic coefficient of variation; h2$_b$ (%) = Heritability; GA = Genetic advance; GA (%) = Percentage genetic advance; PH = Plant height; PB = Number of primary branches per plant; DFF = Days to first flowering; 50%F = Days to 50% flowering; FC = Number of fruit cluster per plant; DFM = Days to fruit maturity; FP = Number of fruits per plant; FD = Fruit diameter; YP = Yield per plant.

Similar findings were reported earlier by Mohamed et al 2012, Kaushik et al 2011, and Dar and Sharma 2011 [23, 24, 25]. The low difference between phenotypic and genotypic coefficient of variations indicated a slight environmental influence on the expression of this character which is also supported by Mallik 1985

who found higher PCV than GCV for plant height [26]. Only by PCV or GCV cannot possible to determine the amount of variation which is heritable. Previous studies showed a high heritability and GA help to effectively select a particular trait [27]. The heritability along with GA is helped breeders to select plants based on phenotypic performance and predict the most suitable conditions for improvement in yield. According to the present study the high heritability was observed in plant height (92.92) and yield per plant (98.80) and the low heritability was shown in days to fruit maturity (29.80). High GA was observed in yield per plant (217.39) and low value found in the number of fruit clusters per plant (1.56). In yield per plant and in plant height showed high heritability and high GA. Therefore traits with high heritability with low GA can be improved by hybridization followed by progeny selection. High heritability with low GA showed in Plant height ($h2_b$ = 92.92, GA = 26.46); Number of primary branches per plant ($h2_b$ = 75.09, GA = 1.73); Days to first flowering ($h2_b$ = 70.06, GA = 4.36); Days to 50% flowering ($h2_b$ = 54.50, GA = 3.62); Number of fruit cluster per plant ($h2_b$ = 71.90; GA = 1.56); Days to fruit maturity ($h2_b$ = 29.80, GA = 2.61); Number of fruits per plant ($h2_b$ = 91.85, GA = 9.01); Fruit diameter ($h2_b$ = 83.10, GA = 3.78); Yield per plant ($h2_b$ = 98.80, GA = 217.39). The findings of present investigation reveal that high heritability accompanied by estimates of GA or GA% for most of the traits measured, that indicates the selection of genotype based on phenotypic levels would be useful for the improvement of these traits. High heritability with low GA and GA% of various yield-contributing traits has been reported by other researchers in tomato [28, 29, 25, 30, 31, 23, 32]. Mehta and Asati 2008 reported that the highest GCV and PCV (17.3%) and (16.83%) with high heritability (96.50%) and genetic advance as percentage of mean (34.08%) for plant height [28]. Meena and Bahadur 2014b also obtained high heritability for plant height which also supports our findings [29]. These findings were in agreement with Dar and Sharma 2011 and Golani et al 2007 [25, 30]. Mohamed et al 2012 also found that GCV and PCV (16.41%) and (17.91%) respectively in the case of number of primary branches with high heritability (80%) and high GA% (31.04%) [23]. Kaushik et al 2011 reported higher PCV (2.25%) than GCV (1.87%) for days to first flowering with high heritability (69.20%) but low GA% (3.2%), which is also observed in present investigation [24]. Mohanty 2002 also found that the range of days to 50% flowering was 51.33 to 53.67 days and low heritability and low GA%, which is in support of the present results [31]. Meitei et al 2014 reported high heritability but low GA and high GA% in the number of primary branches, fruit cluster per plant and also found higher, number of fruit per plant, fruit and diameter which are similar to our experiment results [32]. Kaushik et al 2011 found similar results for days to first flowering where the higher PCV (2.25%) than GCV (1.87%) with high heritability (69.20%) but low GA% (3.2%) [24]. Findings of Meena and Bahadur 2014b and Mohanty 2002, who also found that the range of days to 50% flowering was high heritability with low GA and low GA% [29, 31]. Pujari et al 1995 obtained high heritability (90.00%), high GA% (72.10%) with low genetic gain (0.83) for fruit yield per plant [33]. The same result was also found by Ghosh et al 1995 [34]. Vinod et al 2013 reported high heritability (94%), high

GA% (30.10%) with low GA (0.96) for this trait in tomato [35]. Therefore traits with high heritability with low GA can be improved by hybridization followed by progeny selection.

Table 4. Coefficients of phenotypic and genotypic correlation among different yield components of tomato genotypes

Characters	Correlation	PB (no.)	DFF (days)	50%F (days)	FC (no.)	FM (days)	FP (no.)	FD (cm)	YP (g)
PH (cm)	r_p	0.453*	-0.121	-0.088	0.274	-0.152	0.168	0.129	0.065
	r_g	0.462*	-0.122	-0.094	0.279	-0.168	0.174	0.136	0.065
PB (no.)	r_p		-0.332	-0.302	0.417*	0.118	0.557**	0.439*	0.297
	r_g		-0.318	-0.277	0.435*	0.168	0.565**	0.463*	0.304
DFF (days)	r_p			0.959**	-0.523**	0.126	-0.287	-0.524**	-0.223
	r_g			0.859**	-0.540**	-0.094	-0.283	-0.587**	-0.229
50%F (days)	r_p				-0.481*	0.047	-0.279	-0.454*	-0.194
	r_g				-0.492*	-0.258	-0.265	-0.538**	-0.205
FC (no.)	r_p					-0.011	0.610**	0.352	0.114
	r_g					0.018	0.613**	0.352	0.118
FM (days)	r_p						-0.079	-0.229	-0.030
	r_g						-0.064	-0.353	-0.036
FP (no.)	r_p							0.125	0.153
	r_g							0.121	0.152
FD (cm)	r_p								0.377
	r_g								0.380

Here, * and ** indicate significant at 5% and 1% level of probability, respectability.

PH = Plant height; PB = Number of primary branches per plant; DFF = Days to first flowering; 50% F = Days to 50% flowering; FC = Number of fruit cluster per plant; DFM = Days to fruit maturity; FP = Number of fruits per plant; FD = Fruit diameter; YP = Yield per plant.

Correlation Coefficient

A comprehensive study of correlation coefficient among the genotypes is important because it suggests which one or both traits will be beneficial to select for an effective breeding program. A crop breeding program aim is not only increasing the yield but also of its associate components that have direct or indirect impact on yield. The correlation coefficient analysis helps to measure the mutual relationship between various plant characters and determines the component characters on which selection can be based for improvement in crop yield. For this reason, genotypic and phenotypic correlation studies were conducted with nine characters where yield per plant showed positive insignificant relation with plant height, number of primary branches per plant, number of fruit clusters per plant, and fruit diameter (Table 4). The study of correlation coefficient was found positive and significant along with the plant height and number of primary branches (r_p=0.453 and r_g= 0.462). Sharma and Singh 2012 [36] obtained positive insignificant association with plant height, number of fruits per plant. Similar results were also obtained by Golani et al 2007 and Manna and Paul 2012 [30, 37]. In the present study also showed positive and significant relation between number of primary branches with number of fruit cluster per plant (r_p=0.417 and r_g=0.435), number of fruits

per plant (r_P=0.557 and r_g=0.565) and fruit diameter (r_P=0.439 and r_g=0.463). De Souza et al 2012 obtained positive insignificant association with fruit diameter, which supports the present results [38]. Days to first flowering showed positive and negative significant relationship with days to 50% flowering (r_P= 0.959and r_g=0.859), number of fruit cluster per plant (r_P= -0.523 and r_g= -0.540), and fruit diameter (r_P=-0.524 and r_g= -0.587). Days to 50% flowering showed a negative significant relationship with number of fruit clusters per plant (r_P= -0.481 and r_g= -0.492), and fruit diameter (r_P= -0.454 and r_g= -0.538). Singh et al 1997 reported negative association between yield and days to flowering. Similar results were also obtained by Mallik 1985, Singh et al 1997 and Raijadhav et al 1996 [26, 39, 40]. But Islam et al 2015 observed positive significant association between yield and fruit diameter, which is contradictory with the present research finding [27]. Number of fruit clusters per plant showed a positive significant relationship with number of fruits per plant (r_P= 0.610 and r_g= 0.613). Reddy et al 2013 also observed positive association between number of fruit clusters and fruit yield per plant [41]. Similar findings were also reported by Kumar and Dudi 2011 for fruit cluster [42]. The results indicated that yield per plant was positively and negatively associated with most of the traits. The traits which are shown negative correlation of yield with the quality traits indicating that simultaneous improvement of yield and yield contributing traits was not possible. On the other hand the traits which do not show any positive or negative significant relationship can be discarded to reduce the number of traits to characterize. A correlation studies give an idea about the positive and negative associations of different characters with yield and yield components that have direct or indirect impact on yield. The result of the correlation can be used as a basis for character discard if similar research is conducted in the future.

Path Coefficient Analysis

The path coefficient analysis shows the detailed relationship among yield and yield contributing characters by dividing them into direct and indirect effects on yield. Path coefficient analysis revealed that number of primary branches per plant (**0.111**), days to 50% flowering (**0.125**), days to fruit maturity (**0.062**), number of fruits per plant (**0.143**) and fruit diameter (**0.348**) had direct positive effect on yield which indicated as the main contributors for yield (Table 5). Similar findings were also reported by Hasan et al 2016 that in 30 tomato genotypes individual fruit weight (0.704), days to first flowering (0.590), number of fruit cluster (0.259), number of fruits per plant (0.192), days to first harvest (0.107) were positively correlated with yield

Table 5. Phenotypic Path coefficient analysis showing direct and indirect effects of different characters on of tomato germplasm (boled number means direct effect)

Characters	PH (cm)	PB (no.)	DFF (days)	50%F (days)	FC (no.)	FM (days)	FP (no.)	FD (cm)	YP (g)
PH (cm)	**-0.0079**	0.050	0.022	-0.011	-0.048	-0.009	0.024	0.045	0.065
PB (no.)	-0.0036	**0.111**	0.061	-0.038	-0.073	0.007	0.080	0.153	0.297
DFF (days)	0.0010	-0.037	**-0.183**	0.120	0.091	0.008	-0.041	-0.182	-0.223
50%F (days)	0.0007	-0.033	-0.176	**0.125**	0.084	0.0029	-0.040	-0.158	-0.194
FC (no.)	-0.0022	0.046	0.096	-0.060	**-0.174**	-0.0007	0.087	0.123	0.114
FM (days)	0.0012	0.013	-0.023	0.0059	0.0019	**0.062**	-0.011	-0.080	-0.030
FP (no.)	-0.0013	0.062	0.053	-0.035	-0.106	-0.005	**0.143**	0.044	0.153
FD (cm)	-0.0010	0.049	0.096	-0.057	-0.061	-0.014	0.018	**0.348**	0.377

Here, PH = Plant height; PB = Number of primary branches per plant; DFF = Days to first flowering; 50% F = Days to 50% flowering; FC = Number of fruit cluster per plant; DFM = Days to fruit maturity; FP = Number of fruits per plant; FD = Fruit diameter; YP = Yield per plant.

per plant [43]. Singh et al 2004 also found that in 92 tomato genotypes individual fruit weight and plant height had a positive direct effect on yield [44]. The same results were found by Alam et al 1988, Islam and Khan 1991 and Mohanty 2002 [45, 46, 31]. It was reported that average fruit weight had a high positive direct effect on yield per plant followed by number of fruits per plant [47]. However, it was also observed that plant height (**-0.0079**), days to first flowering (**-0.183**), number of fruit clusters per plant (**-0.174**) and had direct negative effects on yield (Table 5). These results are in agreement with other studies [41, 48, 49]. Hasan et al 2016 found days to 50% flowering (-0.792), number of primary branches (-0.169), fruit diameter (-0.055), plant height (-0.038), dry matter (%) (-0.038) and TSS (-0.038) had direct negative effect on yield [41]. Islam et al 2010 also reported direct negative effect on plant height and days to first flowering on yield [46]. The same results were also found by Matin 2001 [47]. The above information revealed that highly significant positive correlation with highest positive direct effect was observed in individual primary branches per plant, days to 50% flowering, days to fruit maturity, number of fruits per plant and fruit diameter can be considered as selection criteria for improvement in tomato.

Characterization of Individual Clusters

Table 6 showed different variations of individual cluster mean for all 25 genotypes for nine characters. In case of plant height the cluster I showed the highest value (68.70 cm) and the cluster V showed lowest value (55.12 cm). Whereas, no. of primary branches showed a variation in the clusters, the cluster II showed highest value and cluster IV showed lowest value, the cluster I, III & IV showed intermediate value. In the

case of days to first flowering, cluster V showed maximum number of days (40.67 days) and cluster II showed minimum days (33.93 days) required for flowering. In days to 50% flowering, cluster I showed maximum days (45.07 days) and cluster III showed minimum number days (38.93 days) and cluster II, IV & V showed intermediate days for 50% flowering. In the case of the number of fruit clusters per plant, cluster II showed the highest value (6.02) and the lowest value showed in cluster V (4.55). Whereas in case of days

Table 6: Cluster mean of yield and yield components of 25 tomato genotypes

Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V
PH (cm)	68.70	61.42	58.39	52.15	55.12
PB (no.)	8.77	9.45	8.87	7.22	8.70
DFF (days)	40.27	37.93	33.93	39.48	40.67
50%F (days)	45.07	43.60	38.93	44.70	45.00
FC (no.)	5.10	6.02	5.86	4.59	4.55
FM (days)	116.47	112.80	113.13	112.07	119.00
FP (no.)	14.41	22.05	17.93	12.77	12.73
FD (cm)	11.43	13.15	14.12	11.66	13.44
YP (g)	139.75	260.03	266.95	184.99	606.83

Here, Cluster I = G1, G10, G15 G22 and G24 ; Cluster II =G2, G12, G14, G16 and G17; Cluster III = G3, G4, G7, G13 and G25; Cluster IV = G5, G6, G8, G9, G11, G18, G19, G21 and G23 and Cluster V = G20

Where, G1 = Marglobe-1, G2 = 193, G3 = Hekuri, G4 = World Champion, G5 = WP-10, G6 = Tm-131, G7 = Tm-134, G8 = V1057583, G9 = Walter, G10 = Combel 28 F.R, G11 = Binatomato-3, G12 =Feridal, G13 = Binatomato-11, G14 = Burpi Big, G15 = Big Cherry, G16 = Joint Hybrid, G17 = Florida 1, G18 = Tm-219, G19 = Homeastid, G20 = Binatomato-8, G21 = Tm-2, G22 = Binatomato-2, G23 = Binatomato-9, G24 = Marglobe 2, G25 = Cl-3d-143-0-13. PH = Plant height; PB = Number of primary branches per plant; DFF = Days to first flowering; 50% F = Days to 50% flowering; FC = Number of fruit cluster per plant; DFM = Days to fruit maturity; FP = Number of fruits per plant; FD = Fruit diameter; YP = Yield per plant.

to fruit maturity, the cluster V showed maximum days (119.00 days) and the cluster IV showed minimum days (112.07 days) for the fruit maturity. In the case of the number of fruits per plant, the highest value showed in cluster II (22.05) and cluster V showed lowest value (12.73) and cluster I, III & IV showed intermediate values. In fruit diameter, cluster III showed the highest value (14.12 cm) and the lowest value showed in cluster I (11.43cm). With regard to yield per plant, the maximum yield is shown in cluster V (606.83 g) and the lowest yield shown in cluster I (139.75 g) and the intermediate value shown in cluster II, III & IV respectively.

Dendrogram

Dendrogram was conducted using Ward's method, where 25 genotypes were grouped into five clusters (figure 1). V (1, 10, 15, 22 and 24) were grouped in cluster I; V (2, 12, 14, 16 and 17) in cluster II while V (3, 4, 7, 13 and 25) in cluster III; V (5, 6, 8, 9, 11, 18, 19, 21 and 23) were in cluster IV and V (20) in cluster V. Reddy et al 2013 worked on 19 tomato genotypes and found five clusters by cluster analysis [41]. Henareh et al 2015 classified 97 tomato genotypes into five clusters as I, II, III, IV and V by Ward's method [50]. Both of the above findings are very close to the present findings. In regards to plant height, cluster I showed high values (68.70), cluster IV showed low values (52.15) and cluster II, III & V showed intermediate values. Cluster II showed highest value (9.45) for the primary branches and cluster IV showed lowest value (7.22). Cluster III showed both lowest values (33.93 & 38.93) in respect to days to first flowering and days to 50% flowering. Cluster II showed highest no. of fruit clusters per plant (6.02) and the lowest value (4.55) found in cluster V. In days to fruit maturity, cluster V showed maximum days (119.00) and cluster IV showed minimum days (112.07). Cluster II showed highest value (22.05) for no. of fruit per plant, otherwise cluster V showed lowest value (12.73). For the fruit diameter, cluster3 showed maximum value (14.12cm) and the minimum no. found in cluster I (11.43). In regards with the yield per plant, maximum values (606.83) found from cluster V and the minimum values obtained from cluster I (139.75), cluster II, III, IV showed intermediate values.
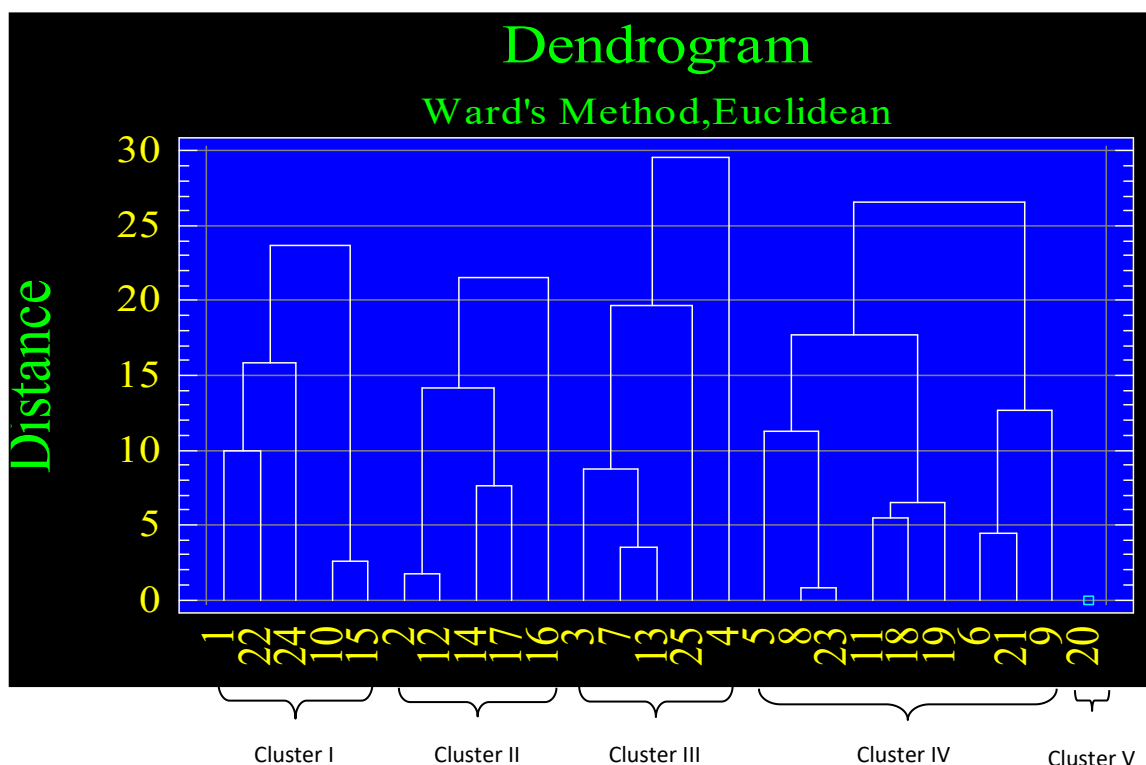

Fig. 2: Dendrogram based on summarized data on differentiation among 25 Genotypes according to Wards method

Principal Component Analysis

In the present findings, all the selected traits are considered for principal component analysis, by which three main components were found that explained 78.02% of total variance (Table 7). The present findings are almost similar with the Henareh et al 2015 results that three main components in tomato accounted for 71.06% of total variability [50]. The first principal component accounted for more than 38% of total variance, whereby days to first flowering, days to 50% flowering and days to first fruit maturity were the variables that contributed most negatively. And the plant height, number of primary branches per plant, number of fruit clusters per plant, number of fruits per plant, fruit diameter and yield per plant was positively contributed. The second principal component accounted for more than 15% of total variance. Variables are negatively associated with fruit diameter and yield per plant. The third principal component accounted for more than 12% of total variance which is negatively related with days to fruit maturity and number of fruit per plant. The four principal components also accounted for 11% of total variance that except plant height, no of fruit cluster per plant and no. of fruit per plant was negatively contributed.

Table 7. Eigen value, % variance and (%) cumulative total variance, principal components (PCs) for morphological traits of 25 of tomato genotypes under field condition

Characters	Eigen Value	% Variance	CV (%)	PC1	PC2	PC3	PC4
PH (cm)	3.49	38.74	38.74	0.1993	0.4517	-0.3900	-0.2047
PB (no.)	1.36	15.10	53.83	0.3727	0.4298	-0.0530	0.2505
DFF (days)	1.13	12.56	66.39	-0.4426	0.3866	-0.1691	0.1151
50%F (days)	1.05	11.62	78.02	-0.4212	0.3881	-0.2497	0.0978
FC (no.)	0.813	9.04	87.05	0.4003	0.1787	0.2376	-0.2320
FM (days)	0.550	6.11	93.16	-0.0729	0.2086	0.6704	0.5331
FP (no.)	0.439	4.88	98.04	0.3273	0.4081	0.1816	-0.1640
FD (cm)	0.143	1.58	99.62	0.3588	-0.2546	-0.3259	0.2188
YP (g)	0.034	0.379	100	0.2160	-0.0661	-0.3302	0.6780

Here, PH = Plant height; PB = Number of primary branches per plant; DFF = Days to first flowering; 50% F = Days to 50% flowering; FC = Number of fruit cluster per plant; DFM = Days to fruit maturity; FP = Number of fruits per plant; FD = Fruit diameter; YP = Yield per plant.

Conclusion

The findings suggested that the selection of genotypes having the plant height and number of fruit clusters per plant were important characters related to the fruit yield per plant than other traits.Genetic analysis of

yield contributing traits showed higher PCV than GCV that indicated the presence of environmental influence on varietal performance. In path coefficient analysis positive direct effects were found in the number of primary branches followed by days to 50% flowering, days to fruit maturity, number of fruits per plant and fruit diameter. Based on our research findings, World Champion, Joint Hybrid and Binatomato-8 may be considered as the superior genotypes among twenty-five tomato genotypes. Using these genotypes could be beneficial for future breeding programs targeting yield and quality improvement because these genotypes have the suggested characteristics.

References

1. Shanmugavelu RG. Production Technology of Vegetables Crops. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi. 1989; 229.

2. Barman SC. Real Adoption Impact Measure of Tomato Technologies on Production at Farmers' Level in Bangladesh. Bangladesh Journal of Scientific and Industrial Research. 2007; 42(1):15-28.

3. Taylor JH. Text of lectures delivered at the national workshop on fruit and vegetable seedlings production held at NIHORT. 1987; 9-13.

4. Pedro AMK, Ferreira MMC. Simultaneously calibrating solids, sugars and acidity of tomato products using PLS2 and NIR spectroscopy. Analytica Chimica Acta. 2007; 595: 221-227.

5. Saleem MY, Asghar M, Iqbal Q, Rahman A, Akram M. Diallel analysis of yield and some yield components in tomato (*Solanum lycopersicum* L.). Pakistan Journal of Botany. 2013; 45:1247-1250.

6. Agarwal S, Rao A. Tomato lycopene and its role in human health and chronic diseases. Canadian Medical Association Journal. 2000; 163(6):739-744.

7. Friedman M. Anticarcinogenic, Cardioprotective, and Other Health Benefits of Tomato Compounds Lycopene, α-Tomatine, and Tomatidine in Pure Form and in Fresh and Processed Tomatoes. Journal of Agricultural Food Chemistry. 2013; 61:9534-9550.

8. FAOSTAT (2014): World Production (Tonnes) of Tomatoes in 2013.

9. Rick CM, Chetelat RT. Utilization of related wild species for tomato improvement. Acta Horticulturae. 1995; 412:21-38.

10. Islam FMA, Beebe S, Munoz M, Tohme J, Redden RJ, Basford KE (2004): Using molecular markers to assess the effect of introgression on quantitative attributes of common bean in the Andean gene pool. Theory of Applied Genetics. 2004; 108: 243-252.

11. Fufa H, Baenziger PS, Beecher BS, Dweikat I, Graybosch RA, Eskridge KM. Comparison of phenotypic and molecular marker-based classifications of hard red winter wheat cultivars. Euphytica. 2005; 145:133-146.

12. Johnson HW, Robinson H, Comstock R. Estimates of genetic and environmental variability in soybeans. Agronomy Journal. 1955; 47:314-318.

13. Johnson HW, Robinson FPF, Comstock RE. Estimation of genetic and environmental variability in soybean. Journal of Agronomy. 1995; 47:314-318.

14. Hanson G, Robinson HF, Comstock RE. Biometrical studies on yield in segregating population of Korean Lesoedeza. Journal of Agronomy. 1956; 49:268-274.

15. Singh RK, Choudhury BD. Biometrical method in quantitative genetic analysis. Kalyani Publishers, Ludhiana, NEW Delhi, India. 1985; 318.

16. Burton GM. Quantitative inheritance in grasses. Proceedings of 5th International Grassland. 1952; 1: 277-283.

17. Allard RW. Principals of Plant breeding. John Wiley and Sons. Inc, New York. 1960; 30-35.

18. Comstock RE, Robinson HF. Estimation of average dominance of genes in heterosis. Iowa State College Press, Ames. 1952; 494-516.

19. Miller JC, Miller L, Paterson AH, Pineda O, Roeder MS, Wing RA, Wu W, Young N. High density molecular linkage maps of the tomato and potato genomes. Genetics. 1991; 132:1141-1160.

20. Lynch M, Walsh B. Genetics and Analysis of Quantitative Traits. Sinauer Associates Inc. Sunderland, Massachusetts. 1998; 823-831.

21. Rao CR. Advanced statistical methods in biometric research. John Willey and Sons, Inc, New York. 1952; 4:34-36.

22. Holland SM. Principal component analysis. Department of Geology, University of Georgia, Athens, GA. 2008; 30:602-2501.

23. Mohamed S, Ali E, Mohamed T. Study of heritability and genetic variability among different plant and fruit characters of tomato (*Solanum lycopersicon* L.). International Journal of Scientific & Technology Research. 2012; 1:55-58.

24. Kaushik SK, Tomar DS, Dixit AK. Genetics of fruit yield and its contributing characters in toimato (*Solanum lycopersicon*). Journal of Agricultural Biotechnology and Sustainable Development. 2011; 3:209-213.

25. Dar RA, Sharma JP. Genetic variability studies of yield and quality traits in tomato (*Solanum lycopersicon* L.). International Journal of Plant Breeding and Genetics. 2011; 5: 168-174.

26. Mallik AK. Study on genetic parameters and character association of tomato. Department of Genetics and Plant Breeding, Bangladesh Agricultural University, Mymensingh. MS thesis. 1985.

27. Islam MA, Raffi SA, Hossain MA, Hasan AK. Analysis of genetic variability, heritability and genetic advance for yield and yield associated traits in some promising advanced lines of rice. Progressive Agriculture. 2015; 26:26-31.

28. Mehta N, Asati B. Genetic relationship of growth and development traits with fruit yield in tomato (*Lycopersicon esculentum* Mill). Karnataka Journal of Agricultural Sciences. 2008; 21.

29. Meena OP, Bahadur V. Assesment of genetic variability, heritability and genetic advance among tomato (*Solanum lycopersicum* L.) germplasm. Agricultural Science Digest. 2014b; 27:185-192.

30. Golani I, Mehta D, Purohit V, Pandya H, Kanazariya M. Genetic variability, correlation and path coefficient studies in tomato. Indian Journal of Agricultural Research. 2007; 41: 2610-2621.

31. Mohanty BK. Studies on variability, heritability, interrelationship and path analysis in tomato. Annals of Agricultural Research. 2002; 23:65-69.

32. Meitei KM, Bora G, Singh SJ, Sinha AK. Morphology based genetic variability analysis and identification of important characters for tomato (*Solanum lycopersicum* L.) crop improvement. Journal of the American Society for Horticultural Science. 2014; 86:114-119.

33. Pujari CV, Wagh RS, Kale RN. Genetic variability and heritability in tomato. Maharastra Journal of Agricultural University. 1995; 20:15-17.

34. Ghosh PK, Symal MM, Rai N, Joshi AK. Improvement of hybrid tomatoes. Advanced Plant Science. 1995; 2:207-2013.

35. Vinod KR, Nandan KR, Srivastava SK, Sharma R, Kumar A. Genetic parameters and correlation study for yield and quality traits in tomato (*Solanum lycopersicum* L.). Plant Archives. 2013; 13:463-467.

36. Sharma B, Singh JP. Correlation and path coefficient analysis for quantitative and qualitative traits for fruit yield and seed yield in tomato genotypes. Indian Journal of Horticulture. 2012; 69: 540-544.

37. Manna M, Paul A. Studies on genetic variability and characters association of fruit quality parameters in tomato. Horticulture Flora Research Spectrum. 2012; 1:110-116.

38. De Souza LM, Melo PCT, Luders RR, Melo AM. Correlations between yield and fruit quality characteristics of fresh market tomatoes. Horticultura Brasileira. 2012; 30:627-631.

39. Singh DN, Saha A, Parida AK. Genetic variability and correlation studies in tomato (*Lycopersicon esculentum* Mill.). Environment and Ecology. 1997; 15(1):177-181.

40. Raijadhav SB, Choudhan KG, Kale PN. Correlation studies in Tomato. Journal of Maharashtra Agricultural University. 1996; 21(2):252-253.

41. Reddy BR, Reddy DS, Begum H. Correlation and path analysis studies for yield and quality traits in tomato (*Solanum lycopersicum* L.) IOSR Journal of Agriculture and Veterinary Science. 2013; 4:56-59.

42. Kumar M, Dudi BS. Study of correlation for yield and quality characters in tomato (*Lycopersicon esculentum* Mill.). Electronic Journal of Plant Breeding. 2011; 2:453-460.

43. Hasan MM, Bari Al, Hossain MA. Genetic Variability and Traits Association Analysis of Tomato (*Lycopersicon esculentum* L.) Genotypes for Yield and Quality Attributes. Universal Journal of Plant Science. 2016; 4(3):23-34.

44. Singh JK, Singh JP, Jain SK, Aradhana J. Correlation and path coefficient analysis in tomato. Progressive Agriculture. 2004; 36(1):82-86.

45. Alam MS, Ahmed QN, Ali MM. Correlation and Path coefficient analysis for some characters in tomato. Bangladesh Journal of Plant Breeding and Genetics. 1988; (1-2):42-46.

46. Islam M, Khan S. Variability and character association in tomato (*Lycopersicon esculentum* Mill.). Bangladesh Journal of Plant Breeding and Genetics. 1991; 23:13-18.

47. Khapte PS, Jansirani P. Correlation and path coefficient analysis in tomato (*Solanum lycopersicum* L.). Electronic Journal of Plant Breeding. 2014; 5(2): 300-304.

48. Islam BMR, Ivy NA, Rasul MG, Zakaria M. Character association and path analysis of exotic tomato (*Solanum lycopersicum* L.) genotypes. Bangladesh Journal of Plant Breeding and Genetics. 2010: 23 13-18.

49. Matin MA. Studies on variability, interrelationship of agro-morphological and some quantitative characters of tomato. Department of Genetics and Plant Breeding, Bangladesh Agricultural University, Mymensingh. MS Thesis. 2001.

50. Henareh M, Dursun A, Mandoulakani BA. Genetic diversity in tomato landraces collected from Turkey and Iran revealed by morphological characters. Acta scientiarum Polonorum. Hortorum cultus. 2015; 14(2):87-96.