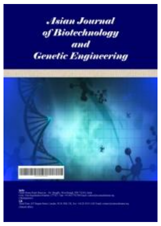

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Variability, Correlation and Path Coefficient Analysis: Principle Tools to Explore Genotypes of Brinjal (*Solanum melongena* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Authors MHUR, FM and SP planned the experiment and lead the research. Authors SS and MHUR designed and carried out the research. Author MEH performed the statistical analysis. Authors SS and MEH carried out the research on the field. Author SS collected the data. Authors SS, SP, MHUR and MEH wrote the manuscript. Authors SS, MEH and SRC managed the literature searches. All authors provided critical feedback and helped shape the research, analysis and manuscript.

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ABSTRACT

To lessen the pressure on staple crops and to combat hidden hunger, vegetable production is the key to success. Massive studies should be conducted regarding genotype selection to gain the desired yield to overcome these global problems. Brinjal is gaining popularity not only as a vegetable crop but also for its medicinal value. Despite this, the yield and nutritional potentials of brinjal genotypes remain underexploited in many parts of the world. In this study, brinjal genotypes were explored through genetic variability, correlation, and path coefficient analysis to combine yield along with yield contributing variables. Ten quantitative characters of twelve genotypes in a

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completely randomized design were investigated in this research work at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, from October 2013 to March 2014. In this study, PCV was found slightly higher than the GCV, which suggested the influence of the environment on the variability of these traits. Characters with a lower difference in GCV and PCV value could be improved by following phenotypic selection. Broad-sense heritability, coupled with moderate to low genetic advance was recorded in fruit length, average fruit weight, plant height and days to maturity. These traits were proposing the predominance of additive gene action. Days to first flowering, secondary branches per plant, fruit length and fruit diameter exhibited positive genotypic correlation with fruit yield per plant. In the case of path analysis, secondary branches per plant proposed maximum direct effect on the yield on both genotypic and phenotypic level followed by average fruit weight and fruit length. To explore interrelations among brinjal genotypes for gaining optimum yield variability, correlation and path coefficient analysis act as prime tools for which this study was conducted.

Keywords: Correlation; genetic advance; heritability; path coefficient; variability; brinjal/eggplant.

1. INTRODUCTION

Brinjal is a globally popular vegetable crop, especially for the vegetarians. It is also highly beneficial for the regulation of blood sugar levels and helps to control the absorption of glucose. Brinjal was reported as one of the vegetables with the highest antioxidant activity [1]. The world population is expecting to exceed 8 billion by 2030 [2]. To meet world hunger, emphasis should be given on enhancing vegetable production along with staple crops,-especially in Asia, Africa and sub-tropical area. Vegetable genetic resources have enormous significance to plant breeders as a reservoir of genetic variation [3]. Nowadays, plant breeders are tried to develop potential cultivars which help to get the desired yield. Knowledge of genetic information is the prerequisite to achieve effective utilization and conservation of brinjal genetic resources.

Genetic variability and relatedness are the crucial tools for analysis of genotypes. Use of traditional varieties with low variability is one of the chief constraints in achieving higher yield potentiality in brinjal. Moreover, better knowledge of genetic variability could help to sustain long term selection gain [4]. Assessment of genetic variation is also a vital criterion for initiating fruitful breeding program as it provides a basis for tailoring desirable genotypes [5]. Until the collected germplasm is adequately investigated, and its traits are explored, it has no practical significance [6]. Besides, heritability is the heritable portion of the phenotypic variance. It is an efficient indicator of the transmission of characters from parents to offspring [7]. For plant breeders, selection of elite genotypes from the diverse genetic population could be easily achieved through heritability. Heritability suggests plant breeders about the proportion of improvement of their populations through the genetic study of plants. In the selected plants, improvement in the mean genotypic value over the parental population is termed as genetic advance. It helps to measure the genetic gain under selection. Enhancement of yield and quality of brinjal is attributed by the simultaneous choice of desirable character combination of genotypes existing in nature [8]. The fundamental objective of most crop improvement programs is to expand crop yield. But yield is a complex character which is controlled by the association of different traits. Thus, knowledge on the association of yield attributes and their direct and indirect effects on grain yield is rudimentary to find out guidelines for genotype selection. Correlation coefficient analysis is a convenient approach to measure the degree and extent of the relationship among yield and yield relating variables which influence selection procedure in the field experiment [9]. Besides, path coefficient analysis is a statistical procedure aimed to determine the extent of the interrelationship of yield attributing traits and their direct and indirect effects on yield. For having such nutritional and economic potentiality, nowadays focuses of researchers are concentrated on both morpho-genetic and molecular level of brinjal throughout the world with the intention of future utilization and conservation. The previous studies regarding crop yield suggested that plant variability, correlation and path coefficient have pronounced impact relating to yield and yield contributing characters of germplasms. Therefore, the present study was conducted to explore the relationship between brinjal genotypes, along with different morphological variables.

2. MATERIALS AND METHODS

The pot experiments were conducted at the Sher-e-Bangla Agricultural University, Dhaka from between October to March of 2013 and 2014. Twelve elite genotypes of brinjal from the Plant Genetic Resource Center (PGRC) of Bangladesh Agricultural Research Institute (BARI) were used. Among them, nine varieties were named as SM-1, SM-2, SM-3, SM-4, SM-5, SM-6, SM-7, SM-8 and SM-9 with three local varieties named Singnath, Islampuri and BARI Begun 6 where SM was *Solanum melongena*. The experimental site is located at an altitude of 8.6m above sea level. The area contains a subtropical climate with plenty of sunshine. Soil is shallow Red Brown Terrace soil with a pH level of 6.0-6.6.

A Completely Randomized Design (CRD) with three replications was followed in this study Thirty-six crates (10L) were used in this experiment for growing brinjal germplasms. Before sowing, seeds were treated with Bavistin (Carbendazim 50% DF) for 5 minutes. 25 days old seedlings were transplanted from the nursery to the pots, where pots were prepared with loamy soils. The rate of applied manures and fertilizers were: cow dung (1.5 t ha^{-1}), urea (375 kg ha^{-1}), TSP (150 kg ha^{-1}) and MOP (250 kg ha^{-1}). The total cow dung, TSP and MOP were applied in the soil preparation of the pot. Urea and MOP were applied at two equal instalments as a top dressing. The first instalment was given after 21 days of transplanting and 2^{nd} was given after flowering. The plants were irrigated to avoid drought or water shortage. During the cropping period, in order to prevent disease infestation, 'Ripcord 10EC' was used for five times at an interval of 7 days. Neem powder (*Azadirachta indica*) mixed with water at 5.0% (w/w) and ashes were sprayed on leaves to prevent pest infestation. Data were collected on the following three growth parameters: plant height (PH), primary branches per plant (PBP), secondary branches per plant (SBP) and seven floral and yield parameters: days to first flowering (DFF), days to maturity (DM), fruits per plant (FPP), fruit length (FL), fruit diameter (FD), average fruit weight (AFW) and fruit yield per plant (FYP). Genotypic and phenotypic variances were estimated [10,11]. Genotypic and phenotypic coefficient of variations were calculated as per Burton and De vane [12]. Broad-sense heritability was estimated as given by Johnson, et al. [13]. The expected genetic advance for different characters under selection was estimated using the formula suggested by Johnson, et al. [13]. Genotypic and phenotypic correlation coefficients of yield and yield attributed traits were determined as per Singh and Choudhury, 1985 [14]. The direct and indirect effects of different characters on yields were calculated through the procedure of Dewey and Lu (10). Residual effect (R^2) was calculated as given by Singh and Choudhury [14].

3. RESULTS AND DISCUSSION

The analysis of variance revealed significant variations among the tested genotypes for all the studied characters except primary branches per plant (Table 1). The genotypic coefficient of variation indicating the variability of studied character influenced by genetic factors. Along with that, the impact of the environment on tested genotypes is largely influenced by the magnitude of the differences among the genotypic and phenotypic coefficient of variation.

The higher difference between GCV and PCV is the indicator of significant environmental impact on the studied trait. In this study (Table 2), days to maturity exhibited the lower difference between the genotypic and phenotypic coefficient of variance. As well as fruit length, plant height, primary branches per plant, secondary branches per plant and average fruit weight were also showing the relatively lower difference. Similar results were reported by Banerjee, et al. [15], Kumar et al. [16], Muniappan, et al. [17], Patel et al. [18]. Hence, these traits are highly recommended for selection as being less influenced by the environment on the variability of these traits. The phenotypic coefficient of variation was slightly higher than genotypic one for all traits, which pointed out the lesser effect of environment on the phenotypic expression of characters. Hence, these characters could be improved by further phenotypic selection. The greater difference among genotypic and phenotypic coefficient of variation was observed in days to first flowering, fruit per plant, fruit length, fruit diameter and average fruit weight. This specified that it might be endorsed to non-additive gene effects controlling the expression and selection would not be profitable. Top of that, higher genotypic and phenotypic coefficient of variation were detected in fruit per plant, secondary branches per plant, fruit length and fruit diameter which indicating the higher impact of the environment on these traits. Expression of traits if depends on the environment are not reliable descriptors for morphological characterization [19].

Estimation of heritability is classified as low (<50%), moderate (50-70%) and high (>70%). On the other hand, Genetic advance is classified as low (<20%), moderate (20-50%) and high (>50%) which was suggested by Johnson et al., [13]. According to this classification, high heritability was found in all characters especially in fruit length (98.48%), with contrast to primary and secondary branches per plant. Primary branches per plant were directed to low heritability (21.72%), where secondary branches per plant were pointed to moderate heritability (60.32%) (Table 2). High heritability is the indicator of rewarding selection to achieve the desired yield for brinjal germplasms as these characters have less influence on the environment. An identical result was found for every trait in brinjal by Chauhan et al. [20], Dhaka and Soni [21], Sabeena et al. [22], except in primary branches per plant.

Genetic advance is the enhancement over base population which can be gained through selection [15]. High heritability would not be always associated with high genetic advance. Aiming at this, Johnson et al. [13] also stated about this correlation of high heritability combining with genetic advance. They described the effect of genetic advance, which was attributed by genetic variability, amount of environmental masking effect on genetic expression and intensity of selection. They also recommended that genetic advance would be the key factor for predicting effects of selection. High heritability with high genetic advance is the result of additive gene action. In this study, all characters were exhibiting moderate to low genetic advance. Among these traits, average fruit weight was associated with both high heritability (98.29%) and highest genetic advance (40.42). A similar result has been reported by Patel et al. [18]. Hence, selection based on this genotype would be more helpful for crop enhancement.

The existing relationships between traits are generally determined by the genotypic and phenotypic correlations and based on their performance superior traits are selected for further advancement. The genotypic correlation is the genetic portion of phenotypic correlation, which is heritable in nature and therefore used to orient breeding program [7]. Alternatively, phenotypic correlation measures the degree of association of two variables and is determined by genetic and environmental factors. In this study, days to first flowering (0.03), secondary branches per plant (0.33), fruit length (0.02) and fruit diameter (0.19) exhibited positive genotypic correlation with fruit yield per plant (Table 3). A similar trend has been reported by Das et al. [23], Nalini et al. [24], Shinde et al. [25], Muniappan et al. [17]. In contrast, plant height (-0.89), days to maturity (-0.65), primary branches per plant (-0.12), fruit per plant (-0.23) and average fruit weight (-0.12) were showed d negative correlation relating to yield. This similar trend was reported by Das et al. [23]. Likewise, positive phenotypic correlation with yield was found among all traits apart from days to maturity (-0.61), primary branches per plant (-0.12) and average fruit weight (-0.12).

Both genotypic and phenotypic significant positive correlation with yield was observed in secondary branches per plant, which is 0.33 and 0.25 respectively. The highly significant positive correlation was also observed between plant height and primary branches per plant, which indicated if plant height increased primary branches per plant also increased. A similar result was observed between days to first flowering and average fruit weight, days to maturity and average fruit weight, primary branches per plant and secondary branches per plant and fruit length and fruit diameter as well as average fruit weight. Conversely, a highly significant negative association was perceived in plant height with fruit diameter and average fruit weight. In the same way, fruit per plant indicated a significant negative correlation with fruit diameter.

Path coefficient analysis is employed to measure the direct and indirect effect of variables on yield. Yield is dependent not only by the interrelationship of associated traits but also changes in any character could affect the whole cause and effect relationship. In this study, (Table 4) primary branches per plant, secondary branches per plant, fruit length and average fruit weight indicated direct positive influence with yield both genotypic and phenotypically. A similar trend has been reported by Pravu, et al. [26], Sharma and Swaroop [5], Shinde et al. [25]. As well as, plant height, days to first flowering, days to maturity, fruit diameter and fruit per plant indicated a negative impact on yield at both genotypic and phenotypic level. Similar results were noted by Shinde et al. [25]. Sharma and Swaroop [5], Patel et al. [18]. This revealed that slight changes in these traits will directly affect the brinjal yield. Pravu et al. [26], stated similar findings for these traits except for plant height as it indicated a positive direct effect on yield.

Table 1. Estimates of mean, range, mean square, the genotypic and phenotypic variance for different traits of 12 brinjal genotypes

Parameters	Range	Mean	MS	CV%	σ^2_p	σ^2_g	σ^2_e
Plant height (cm)	70.86-81.45	75.78	32.70**	1.27	11.51	10.59	0.92
Days to first flowering	110.44-126.97	120.80	56.17**	1.90	22.25	16.96	5.29
Days to maturity	170.95-182.99	176.26	53.99**	0.61	18.77	17.63	1.14
Primary branches per plant	10.72-13.20	11.80	1.70	8.18	1.19	0.26	0.93
Secondary branches per plant	10.95-16.23	13.19	8.06**	9.13	3.66	2.21	1.45
Fruit per plant	13.50-23.50	18.24	40.90**	8.82	15.35	12.77	2.58
Fruit length (mm)	102.40-146.81	21.47	659.95**	1.51	222.23	218.86	3.37
Fruit diameter (mm)	60.87-88.43	71.23	149.56**	2.17	51.44	49.06	2.38
Average fruit weight (g)	236.37-291.29	268.57	1,182.17**	0.97	398.57	391.75	6.82
Fruit yield per plant (g)	418.02-980.63	793.37	92,977.98**	4.59	3187.07	30.550.89	1325.18

*** Significant at 1% level of significance*

Table 2. Estimates of the genotypic and phenotypic coefficient of variation, heritability and the genotypic advance of 12 brinjal genotypes

Parameters	PCV	GCV	ECV	Heritability (%)	Genetic advance (5%)	Genetic advance (%mean)
Plant height (cm)	5.57	4.30	1.27	91.99	6.43	8.49
Days to first flowering	5.31	3.41	1.90	76.22	7.41	6.13
Days to maturity	2.99	2.38	0.61	93.93	8.38	4.76
Primary branches per plant	12.49	4.31	8.18	21.72	0.49	4.14
Secondary branches per plant	20.39	11.26	9.13	60.32	2.38	18.02
Fruits per plant	28.42	19.60	8.82	83.17	6.71	36.82
Fruit length (mm)	13.69	12.18	1.51	98.48	30.24	24.90
Fruit diameter (mm)	12.00	9.83	2.17	95.37	14.09	19.78
Average fruit weight (g)	8.34	7.37	0.97	98.29	40.42	15.05
Fruit yield per plant (g)	26.62	22.03	4.59	95.84	352.50	44.43

Table 3. Estimates of genotypic and phenotypic correlation coefficients among different quantitative characters of brinjal genotypes

Characters		**DFF**	**DM**	**PBP**	**SBP**	**FPP**	**FL**	**FD**	**AFW**	**FYP**
Plant height (cm)	G	0.20	-0.07	0.85**	0.27	-0.26	-0.17	-0.49**	-0.38	-0.09
	p	0.19	-0.08	0.36*	0.15	-0.25	-0.18	-0.45**	-0.35*	0.09
Days to first flowering	G		0.19	0.20	0.15	0.04	-0.04	-0.20	0.46**	0.03
	p		0.20	0.05	0.22	0.03	-0.01	-0.11	0.40*	0.02
Day to maturity	G			0.12	-0.32	0.36*	0.25	-0.18	0.65**	-0.65**
	p			0.03	-0.22	0.36*	0.24	-0.17	0.63**	-0.61**
Primary branches per plant	G				0.98**	0.10	-0.14	-0.32	0.29	-0.12
	p				0.34*	-0.07	-0.08	-0.19	-0.17	-0.12
Secondary branches per plant	G					0.12	-0.40**	-0.03	-0.29	0.33*
	p					0.05	-0.29	-0.03	-0.22	0.25
Fruit per plant	G						-0.11	-0.45**	0.14	-0.30
	p						-0.09	-0.42**	0.11	0.23
Fruit length (mm)	G							0.48**	0.64**	0.02
	p							0.47**	0.63	0.02
Fruit diameter (mm)	G								0.28	0.18
	p								0.26	0.17
Average fruit weight (g)	G									-0.11
	p									-0.11

***= significant at 1%, *= significant at 5%*

Table 4. Direct and indirect effect of different quantitative traits on the yield of brinjal genotypes at the genotypic and phenotypic level

Characters		PH	DFF	DM	PBP	SBP	FPP	FL	FD	AFW	Genotypic correlation with yield
Plant height (cm)	g	-0.381	-0.068	0.073	0.012	0.133	0.139	-0.017	0.385	-0.359	-0.09
	p	-0.121	-0.013	0.074	-0.027	0.040	0.028	-0.016	0.129	-0.180	-0.09
Days to first flowering	g	-0.076	-0.340	-0.198	0.003	0.074	-0.021	-0.004	0.157	0.435	0.033
	p	-0.023	-0.068	-0.182	-0.003	0.059	-0.003	0.001	0.033	0.204	0.02
Days to maturity	g	0.027	-0.064	-1.040	0.002	-0.158	-0.193	0.025	0.141	0.614	-0.65**
	p	0.010	-0.014	-0.894	-0.003	-0.059	-0.040	0.024	0.048	0.320	-0.61**
Primary branches per	g	-0.323	-0.068	-0.124	0.014	0.493	-0.054	-0.014	0.251	-0.274	-0.12
plant	p	-0.044	-0.003	0.030	-0.075	0.093	-0.007	-0.008	0.054	-0.087	-0.11
Secondary branches	g	-0.103	-0.051	0.333	0.014	0.483	-0.054	-0.041	0.024	-0.274	0.33*
per plant	p	-0.018	-0.015	0.195	-0.026	0.272	-0.005	0.028	-0.009	-0.114	0.25
Fruit per plant	g	0.099	-0.013	-0.374	0.001	0.052	-0.536	-0.011	0.354	0.132	-0.30
	p	0.030	-0.002	-0.320	-0.005	0.013	0.112	-0.009	0.119	0.057	-0.23
Fruit length (mm)	g	0.065	0.013	-0.260	-0.002	-0.197	0.064	0.102	-0.377	0.605	0.02
	p	0.021	0.001	-0.218	-0.006	-0.078	0.010	0.097	-0.135	0.032	0.02
Fruit diameter(mm)	g	0.186	0.068	0.187	--0.004	--0.014	0.459	0.049	-0.786	0.265	0.18
	p	0.054	0.008	0.149	0.014	0.008	0.046	0.046	-0.286	0.132	0.17
Average fruit weight	g	0.144	-0.156	-0.676	-0.004	-0.143	-0.241	0.065	0.221	0.946	-0.11
(g)	p	0.043	-0.027	-0.562	0.013	-0.061	-0.013	0.061	-0.074	0.509	-0.11

*Residual effect: 0.228 and 0.447 at genotypic and phenotypic level, **= significant at 1%, *= significant at 5%*

4. CONCLUSION

According to the present study, secondary branches per plant, fruit height, and fruit diameters had more genotypic effect rather than the environmental one. Average fruit weight, fruit length, secondary branches per plant had a positive direct effect on yield which advocated for being more influential of getting the higher yield. Hence, fruit length and secondary branches per plant are the most promising characters being used as a base for selection to expand the inbred lines followed by pure line selection schemes in brinjal genotype generations.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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