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GENETIC VARIABILITY AND CORRELATION STUDIES OF MULBERRY (*MORUS ALBA* L.) GENOTYPES IN BANGLADESH

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Abstract

Morphological, phenotypical and yield attributing characteristics of 20 mulberry genotypes were evaluated. Genotypic and phenotypic variations, heritability, genetic advance and correlation co-efficient were also estimated. It was found that the phenotypic co-efficient of variation (PCV) was higher (97.68%) than genotypic co-efficient of variation (GCV, 96.99%). The broad sense heritability for these traits ranged from 98.60 (AL) to 4.69 (LLS). High heritability coupled with high genetic advance was recorded for the characters apex length (AL), leaf length (LL), leaf width (LW), leaf petiole ratio (LPR) and petiole length (PL) suggesting the higher genetic control over these traits. Significant positive correlations to leaf yield/plant were observed for the characters, namely total shoot weight (0.817), longest shoot length (0.600), total branch height (0.596) and leaves fresh weight/10 leaves (0.425). Leaf yield showed significantly positive phenotypic and genotypic correlations with all other growth traits (*viz.*, total shoot weight 0.817, length of longest shoot 0.600, total branch height 0.596 and leaves fresh weight/10 leaves 0.425) except total branch number, nodes per meter, leaf width and petiole length. High genetic advance as percentage of mean coupled with heritability was observed on AL, LL, LW, LPR, PL and 10 fresh leaves weight suggesting the prevalence of additive gene action with low environmental influence for the determination of these characters and could be effective in phenotypic selection. Analysis of variances (ANOVA) for characters such as AL, LL, LW, LPR and PL showed significant variations among the genotypes. Since mulberry is mainly cultivated for leaf yield, genotypes having higher AL, LL, LW and LPR and PL must be given importance during parent selection to evolve high yielding varieties across different seasons in mulberry.

Mulberry (*Morus* spp.) is a perennial tree cultivated as a seasonal crop by regular pruning and training for sustained supply of foliage to rear the silkworm *Bombyx mori* L., which feeds only on mulberry leaves. The plants are cultivated under both tropical and temperate climatic conditions of different regions in Bangladesh. As leaf productivity is one of the principal factors that decide the sustainability and profitability of sericulture, good quality mulberry leaf increases the cocoon productivity and quality of silk (Ashiru 2002, Doss *et al.* 2012). It is grown as small bushes and 60% of cost involved in total production of silkworm cocoon production goes to mulberry cultivation only (Das and Swami 1965). Development of high yielding superior cultivars is a major challenge and goals for the breeders. Variability assessment among the germplasms and creation of variability are two major components for any breeding programme to be successful (Murthy *et al*. 2010). They also reported quantitative characters on leaf yield that associated with many contributing traits. The extent and magnitude of genetic variability in the mulberry germplasm help in the crop improvement through conventional breeding. Genetic variability is the pre-requisite for initiation of any crop improvement programme including mulberry and selection acts upon the variability which is present in the genotypes (Saini *et al*. 2018). Prior knowledge of genetics on yield contributing traits is very essential to formulate a

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breeding strategy of mulberry. Under this circumstances the present work was undertaken to estimate the extent of genotypic and phenotypic variation, heritability, genetic advance and inter-relationship of different yield and yield contributing traits among the selected genotypes of mulberry.

Twenty mulberry genotypes *viz.*, BSRM5, BSRM16, BSRM18, BSRM19, BSRM20, BSRM24, BSRM34, BSRM39, BSRM40, BSRM45, BSRM50, BSRM54, BSRM55, BSRM56, BSRM58, BSRM59, BSRM63, BSRM64, BSRM65 and BSRM66 were collected and maintained in the Germplasm bank of Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi, Bangladesh. Data were recorded and analyzed during four cropping seasons for final yield trial (FYT) in 2017 - 2018. The plantation was made with 12 plants in each replication with 90 × 90 cm spacing under randomized block design (RBD) with three replications. Recommended cultural practices about 4-crops schedule were followed by standard methods of BSRTI (Quader *et al.* 1992). Irrigation was provided as and when required. Data from the middle 5 plants were recorded on various growth and yield attributing traits such as total branch number (TBN), total branch height (TBH), nodes/meter (N/M), internodal distance (IND), length of longest shoot (LLS), leaf length (LL), leaf width (LW), petiole length (PL), apex length (AL), 10 fresh leaves weight (FLW), leaf petiole ratio (LPR), total shoot weight (TSW), leaf yield (LY) and moisture content (MC). Total branch height (TBH) is the sum up on number of branch on a plant. Five plants were measured in cm for each genotype and was made an average. For FLW 10 leaves were harvested at random and weighed, five samples of 10 leaves of each genotype were taken. To measure the leaf, petiole ratio (LPR) leaf and petiole length were recorded in cm in five plants per genotype and the leaf petiole ratio was calculated on the basis of average lengths. Data were analyzed by one way ANOVA followed by DMRT using a commercially available statistics software package (SPSS® for Windows, V. 22.0, Chicago). Data were statistically analyzed for genotypic and phenotypic co-efficient of variance (GCV and PCV), broad sense heritability and genetic advance (GA) following the standard methods of Burton and Devane (1953) and Hanson *et al.* (1956). Genotypic, phenotypic and environmental correlations between yield and yield attributing characters were also estimated by Weber and Moorthy (1952).

Experimental findings based on the data pooled over four seasons are presented in Table 1. All the seasons selected for evaluation had significant effect on the expression of all the traits. The highest (14.42) branch per plant was recorded in BSRM56 and lowest (8.10) in BSRM59. The total branch height per plant was highest (1810.20 cm) in BSRM19 and lowest (929.00 cm) in BSRM54. Nodes per meter were recorded highest (33.55) in BSRM20 and lowest (22.90) in BSRM55. Internodal distance was recorded highest (4.63) in BSRM55 and lowest (3.03) in BSRM20. Length of longest shoot was highest (178.00 cm) in BSRM5 and lowest (107.85) in BSRM20. Leaf length was recorded highest (20.44 cm) in BSRM20 and lowest (9.04 cm) in BSRM5. Leaf width was observed highest (17.34 cm) in BSRM20 and lowest (7.05 cm) in BSRM58. Leaf petiole length was found highest (4.00 cm) in BSRM20 and lowest (2.60 cm) in BSRM50. Apex length was found highest (6.75 cm) in BSRM20 and lowest (0.70 cm) in BSRM58 (Table1). Ten fresh leaves weight per plant was observed highest (49.00 g) in BSRM64 and lowest (20.75 g) in BSRM58. Total shoot weight was observed highest (748.15 g) in BSRM5 and lowest (362.70 g) in BSRM20. Leaf petiole ratio by length was recorded highest (6.37 cm) in BSRM63 and lowest (3.47 cm) in BSRM39. Leaf yield per plant was recorded highest (1019.00 g) in BSRM 64 and lowest (602.58 g) in BSRM54. Moisture content of leaf was recorded highest (77.80%) in BSRM24, BSRM39, BSRM64 and lowest (73.50%) in BSRM56.

In accordance with the variability, maximum phenotypic variance was observed in TBH (149741.44) followed by LY (37841.82) and TSW (34136.77) indicating the maximum influence of environment on these characters and comparatively minimum range of variability and phenotypic

Table 1. Phenotypic variability of some selected growth characters in 20 mulberry (*Morus* spp.) germplasm genotypes.

Genotypes	Total branches/ per plant	Branch height/plant (cm)	Nodes/meter	Inter nodal distance (cm)	Length of longest shoot (cm)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Apex length (cm)
BSRM 5	11.30±0.86a-h	1784.70±128.9ab	24.05±0.89de	4.17±0.16a-e	178.00±10.06a	11.30±0.44h-j	8.52±0.32gh	3.15±0.14c-e	1.25±0.12ef
BSRM 16	13.37±1.01a-c	1189.50±28.09c-e	27.73±1.11b-e	3.6±0.14c-g	111.85±13.42b	10.50±0.18jk	8.50±0.10gh	2.91±0.04c-e	0.87±0.0fg
BSRM 18	13.80±1.11ab	1385.30±91.54a-e	30.38±1.85a-c	3.32±0.18e-g	123.08±17.32ab	12.20±0.20gh	9.05±0.21f-h	3.30±0.17cd	1.35±0.13e
BSRM 19	13.07±1.28 a-d	1810.20±104.99a	26.75±1.22c-e	3.76±0.17bc-g	159.93±12.00ab	14.66±0.58e	11.30±0.28d	4.00±0.29a	3.66±0.19c
BSRM 20	11.05±0.82b-h	1011.40±114.92de	33.55±2.27a	3.03±0.22g	107.85±16.45b	20.44±0.47a	17.34±0.48a	3.90±0.17ab	6.75±0.32a
BSRM 24	10.82±0.86b-h	1014.70±76.86de	28.80±1.20a-d	3.49±0.14d-g	114.55±14.99ab	13.40±0.04f	10.20±0.08e	3.05±0.04c-e	1.41±0.02e
BSRM 34	11.57±0.72a-g	1494.70±38.99a-d	26.00±0.79c-e	3.86±0.12a-g	162.99±14.61ab	11.50±0.42g-i	9.10±0.07f-h	2.79±0.13c-e	1.17±0.08ef
BSRM 39	12.17±1.34a-f	1263.00±351.23b-e	32.73±4.57ab	3.29±0.56fg	114.45±26.19ab	10.05±0.45k	8.09±0.42h	3.04±0.45c-e	1.34±0.12e
BSRM 40	10.55±1.47b-h	1294.20±237.85a-e	25.70±2.45c-e	4.00±0.38a-f	143.25±26.00ab	11.20±0.34ij	8.50±0.34gh	3.13±0.11c-e	1.24±0.12ef
BSRM 45	10.67±0.53b-h	1234.50±62.69c-e	27.38±0.93b-e	3.67±0.13c-g	134.13±10.26ab	16.33±0.18d	14.66±0.04c	4.00±0.21a	2.16±0.07d
BSRM 50	9.00±0.64f-h	1130.40±214.09de	23.70±2.15de	4.31±0.35a-d	144.15±29.06ab	11.20±0.15ij	9.00±0.22f-h	2.60±0.09f	1.20±0.11ef
BSRM 54	8.65±0.75gh	929.00±272.60e	26.03±1.97c-e	3.91±0.29a-f	112.20±27.17b	12.30±0.15g	9.60±0.26ef	3.40±0.15bc	1.45±0.12e
BSRM 55	9.80±0.81d-h	1274.90±165.34b-e	21.90±1.55e	4.63±0.32a	142.95±19.41ab	12.20±0.20gh	9.05±0.21f-h	3.30±0.17cd	1.35±0.13e
BSRM 56	14.42±1.23a	1676.30±120.48a-c	24.48±0.74c-e	4.10±0.12a-f	139.00±14.49ab	18.66±0.17b	16.00±0.46b	4.00±0.29a	4.00±0.22c
BSRM 58	12.43±1.10a-e	1506.10±69.06a-d	25.58±0.84c-e	3.92±0.13a-f	151.70±16.63ab	9.04±0.031l	7.05±0.40i	1.92±0.04g	0.70±0.09g
BSRM 59	8.10±0.49h	1119.00±52.02de	22.78±1.27de	4.43±0.25a-c	166.70±13.94ab	13.33±0.37f	11.20±0.34d	2.92±0.15c-e	1.09±0.04ef
BSRM 63	10.98±0.82b-h	1374.20±40.18a-e	22.13±0.85e	4.54±0.18ab	148.10±11.38ab	16.33±0.16d	14.88±0.39c	2.56±0.13f	6.04±0.02b
BSRM 64	10.85±0.61b-h	1238.90±92.73c-e	23.70±0.62de	4.23±0.11a-d	132.65±13.31ab	17.44±0.20c	15.33±0.15bc	3.09±0.04c-e	5.77±0.11b
BSRM 65	10.15±1.06c-h	1328.70±225.65a-e	22.08±1.37e	4.58±0.28ab	145.10±25.09ab	11.30±0.15h-j	9.25±0.32e-g	2.60±0.18f	1.10±0.06ef
BSRM 66	9.35±1.08e-h	1053.30±165.96de	24.85±2.14c-e	4.11±0.34a-f	124.50±25.05ab	11.40±0.29g-j	9.50±0.46e-g	2.70±0.18ef	1.10±0.09ef
Grand mean	11.10	1305.65	26.015	3.94	137.87	13.23	10.80	3.11	2.25
SE	0.38	55.66	0.74	0.10	4.52	0.69	0.68	0.12	0.42

BSRM = Bangladesh Sericulture Research Mulberry, SE = Standard error.

variance was recorded in IND (0.45). However, the least phenotypic variance was observed in IND followed by PL, LPR, MC and AL indicated the strong genetic control on the expression of these characters. Significant genotypic co-efficient of variance (GCV) and phenotypic co-efficient of variance (PCV) were observed for yield and different yield attributing characters. The PCV was higher than the GCV for all the characters and it ranged between 2.31 (MC) and 97.68 (AL). The maximum GCV was recorded in AL. The phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the characters and was highest in apex length (97.68), leaf width (33.01), 10 fresh leaves weight (32.50), total branch height (29.64) and was least in MC (2.31). Similar type of results was also reported by Mallikarjunappa *et al.* (2008), Roy *et al.* (2015) and Suresh *et al.* (2017).

Table 2. Phenotypic variability of some selected yield characters in 20 mulberry (*Morus* spp.) germplasm genotypes.

Genotypes	10 fresh leaves wt./plant (g)	Total shoot wt. (g)	Leaf-petiole ratio by length (cm)	Leaf yield/ plant (g)	Moisture content (%)
BSRM 5	26.50 ± 2.10e-h	748.15 ± 113.35a	3.61 ± 0.23fg	733.60 ± 93.09a	75.50 ± 0.89b-f
BSRM 16	36.13 ± 2.31b-e	562.53 ± 112.22a	3.61 ± 0.05fg	883.54 ± 107.45a	77.10 ± 0.19ab
BSRM 18	22.88 ± 1.5h	511.03 ± 83.83a	3.72 ± 0.14e-g	624.48 ± 163.48a	76.65 ± 0.78a-d
BSRM 19	24.75 ± 1.44f-h	661.98 ± 51.77a	3.67 ± 0.19e-g	772.63 ± 129.25a	74.50 ± 0.15fg
BSRM 20	28.00 ± 4.63e-h	362.70 ± 94.57a	5.26 ± 0.12bc	602.58 ± 116.23a	75.50 ± 0.21b-f
BSRM 24	37.00 ± 5.02b-e	437.15 ± 74.79a	4.40 ± 0.06d	814.90 ± 128.34a	77.80 ± 0.09a
BSRM 34	30.50 ± 1.04d-h	685.93 ± 93.02a	4.12 ± 0.04d-g	848.53 ± 152.73a	75.20 ± 0.09b-g
BSRM 39	24.50 ± 4.66gh	546.55 ± 184.97a	3.47 ± 0.38g	657.13 ± 248.36a	77.80 ± 0.31a
BSRM 40	28.13 ± 5.72e-h	570.85 ± 191.16a	3.58 ± 0.14fg	780.73 ± 246.36a	76.80 ± 0.52a-c
BSRM 45	34.25 ± 2.29c-g	538.95 ± 52.66a	4.08 ± 0.21d-g	845.30 ± 80.07a	74.70 ± 0.09e-g
BSRM 50	39.53 ± 3.17a-d	498.45 ± 169.22a	4.31 ± 0.13de	763.65 ± 194.75a	74.80 ± 0.28d-g
BSRM 54	40.25 ± 6.21a-d	520.95 ± 200.91a	3.64 ± 0.17fg	659.30 ± 270.40a	74.90 ± 0.07c-g
BSRM 55	35.75 ± 3.10b-f	561.78 ± 157.92a	3.72 ± 0.14e-g	698.70 ± 181.38a	76.65 ± 0.78a-d
BSRM 56	37.38 ± 2.91b-e	668.90 ± 118.13a	4.74 ± 0.34cd	922.50 ± 139.59a	73.50 ± 0.29g
BSRM 58	20.75 ± 0.85h	594.03 ± 75.05a	4.72 ± 0.12cd	965.85 ± 140.30a	74.50 ± 0.20fg
BSRM 59	44.95 ± 2.60a-c	554.08 ± 65.68a	4.57 ± 0.17d	761.50 ± 119.82a	76.10 ± 0.13a-f
BSRM 63	47.00 ± 1.86ab	613.53 ± 79.62a	6.37 ± 0.35a	998.34 ± 114.56a	77.60 ± 0.29a
BSRM 64	49.00 ± 2.27a	590.78 ± 104.09a	5.64 ± 0.10b	1019 ± 134.57a	77.80 ± 0.4a
BSRM 65	41.75 ± 2.69a-d	660.98± 182.73a	4.41 ± 0.31d	827.20 ± 223.57a	76.00 ± 1.83a-f
BSRM 66	42.75 ± 4.75a-c	732.95 ±194.50a	4.26 ± 0.18d-f	853.25 ± 222.28a	76.50 ± 0.46a-e
Grand mean	34.58	581.11	4.295	801.63	75.99
SE	1.89	21.29	0.17	26.83	0.29

The selection efficiency was higher when the parameters had higher heritability. Estimation of genotypic coefficient of variation and heritability gives the best information for getting desirable characters through parental selection and hybridization (Burton and Devane 1953). Difference between PCV and GCV was minimum in all characters except that in length of longest shoot, total branch height, total shoots weight suggesting higher influence of environmental factors on these characters. Heritability (h^2) was highest in apex length (98.60) followed by in leaf length (97.25), leaf width (96.99) leaf petiole ratio by length (81.62), petiole length (72.30), 10 fresh leaves weight (62.91) and leaf moisture content (57.60). Such high level of heritability may be due to the excessive additive gene effect.

Table 3. Genotypic and phenotypic correlation coefficients for growth and yield attributing traits of 20 mulberry (*Morus* spp.) genotypes.

Traits	Total branch number	Total branch height (cm)	Nodes /meter	Inter nodal distance (cm)	Length of longest shoot (cm)	10 fresh leaves wt. (g)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Apex length (cm)	Total shoot wt. (g)	Leaf petiole ratio by length (cm)	Leaf yield/ plant (g)	Moisture content (%)
Total branch number	1.000	0.275*	0.221*	–0.262*	–0.363**	–0.478**	0.105	0.056	0.198	0.139	–0.156	–0.081	–0.021	–0.020
Total branch height (cm)	0.275*	1.000	–0.261*	0.227*	0.744**	0.025	0.013	–0.020	–0.001	0.029	0.722**	0.036	0.596**	–0.142
Nodes per meter	0.221*	–0.261*	1.000	–0.975**	–0.352**	–0.465**	0.124	0.098	0.326**	0.104	–0.270*	–0.219	–0.343**	0.088
Inter nodal distance (cm)	–0.262*	0.227*	–0.975**	1.000	0.330**	0.465**	–0.127	–0.102	–0.324**	–0.085	0.255*	0.214	0.311**	–0.045
Length of longest shoot (cm)	–0.363**	0.744**	–0.352**	0.330**	1.000	0.326**	–0.065	–0.064	–0.188	-0.084	0.780**	0.125	0.600**	–0.148
10 Fresh leaves wt. (g)	–0.478**	0.025	–0.465**	0.465**	0.326**	1.000	0.215	0.279*	–0.195	0.177	0.368**	0.443**	0.425**	0.138
Leaf length (cm)	0.105	0.013	0.124	–0.127	–0.065	0.215	1.000	0.971**	0.603**	0.874**	–0.070	0.530**	0.079	–0.073
Leaf width (cm)	0.056	–0.020	0.098	–0.102	–0.064	0.279*	0.971**	1.000	0.527**	0.873**	–0.071	0.587**	0.072	–0.049
Petiole length (cm)	0.198	–0.001	0.326**	–0.324**	–0.188	–0.195	0.603**	0.527**	1.000	0.372**	–0.177	–0.335**	–0.221*	–0.091
Apex length (cm)	0.139	0.029	0.104	–0.085	–0.084	0.177	0.874**	0.873**	0.372**	1.000	–0.087	0.651**	0.077	0.063
Total shoot weight (gm)	–0.156	0.722**	–0.270*	0.255*	0.780**	0.368**	–0.070	–0.071	–0.177	–0.087	1.000	0.106	0.817**	–0.042
Leaf petiole ratio by length (cm)	–0.081	0.036	–0.219	0.214	0.125	0.443**	0.530**	0.587**	–0.335**	0.651**	0.106	1.000	0.331**	0.020
Leaf yield per plant (gm)	–0.021	0.596**	–0.343**	0.311**	0.600**	0.425**	0.079	0.072	–0.221*	0.077	0.817**	0.331**	1.000	0.038
Moisture content (%)	–0.020	–0.142	0.088	–0.045	–0.148	0.138	–0.073	–0.049	–0.091	0.063	–0.042	0.020	0.038	1.000

*, ** Correlation is significant at the 0.05 level and 0.01 level respectively.

The heritability estimates along with genetic gain is more useful than heritability alone in predicting the resultant effects of selection (Johnson *et al*. 1955). Earlier studies in mulberry also stated that quantitative traits with high h^2 and GA responded better than others to simple phenotypic selection as they contribute to additive gene action, which will aid in effective selection for obtaining genetic improvement of polygenetic traits in mulberry (Masilamani *et al*. 2000). In the present study also, high GA, as % of mean, coupled with high heritability was observed for the characters *viz*., apex length (h^2 = 98.60; GA% = 198.68); leaf width (h^2 = 96.99; GA% = 66.05); leaf length (h^2 = 97.25; GA% = 54.46); 10 fresh leaves weight (h^2 = 62.91; GA% = 42.18); leaf petiole ratio (h^2 = 81.62; GA% = 36.96) and petiole length (h^2 = 72.30; GA% = 33.65).

High genetic advance as percentage of mean coupled with heritability was observed in the characters, namely apex length, leaf length, leaf width, leaf petiole ratio by length, petiole length and 10 fresh leaves weight. This suggests the prevalence of additive gene action with low environmental influence for the determination of these characters and could be effective in phenotypic selection. Moderate genetic advance as percentage of mean coupled with high heritability noticed for the characters total branch number per plant, nodes per meter, internodal distance and leaf yield per plant indicated the presence of intra and inter allelic interactions in the expression of these characters. These result agreed well with the observation made by Goel *et al*. (1998), Tikader *et al.* (2004), Banerjee *et al.* (2007), Mallikarjunappa *et al.* (2008), Tikader and Kamble (2008), Doss *et al.* (2012), Biradar *et al.* (2015) and Suresh *et al.* (2017). Previously similar findings of high h^2 and GA% were reported for the characters *viz*., leaf yield, weight of 10 fresh leaves and SLA among 9 different species of mulberry (Doss *et al*. 2006). A high h^2 coupled with high GA% for the characters *viz*., leaf area and weight of 100 leaves (fresh) were observed among 77 mulberry germplasm accessions (Rahman *et al*. 2006).

Correlation among the 14 growths and yield attributing characters revealed substantial differences between phenotypic and genotypic correlations (Table 3). Predominantly, the magnitude of genotypic correlations was higher than their corresponding phenotypic correlations. Leaf yield had significant positive correlations with all the yield attributing characters except N/M and PL, which showed significant negative correlations. Petiole length had significant negative correlations with all important yield attributing characters with high heritability *viz*., IND, LPR, LY. Therefore, the yield attributes which are genetically controlled having high heritability and GA and also having significant positive association with leaf yield *viz*., TSW, LLS, TBH, LW and LPR and significant negative correlation of N/M and PL are worth considering for parental selection aiming developing high yielding mulberry varieties. Similar results obtained in case of leaf size and shoot lengths were highly correlated with leaf yield that agreed most of the earlier observations (Tikader and Kamble 2008 and 2009, Vijayan *et al*. 1997).

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