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Variability, heritability and genetic advance in mulberry (*Morus* spp.) for growth and yield attributes

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ABSTRACT

Genetic improvement of crop plants is brought about by manipulating the genetic makeup through systematic breeding techniques or by employing modern biotechnological tools. Application of systematic breeding technique to a large extent is decided by the knowledge on the genetic control of the traits. Keeping this in view, nine mulberry genotypes were evaluated for different growth and yield attributing traits *viz*., number of tillers (NT), plant height (PH), total shoot length (TSL), nodal distance (ND), leaf fall % (LF), number of leaves/plant (NLP), weight of 100 fresh leaves (WFL), weight of 100 dry leaves (WDL), single leaf area (LA), leaf area index (LAI), aboveground biomass (AGB), leaf harvest index (LHI) and leaf yield (LY) and estimated the magnitude of genotypic and phenotypic variation, heritability, genetic advance and correlation coefficients. The broad sense heritability for these traits ranged from 63.942 (WFL) to 13.261 (PH). High heritability coupled with high genetic advance was recorded for the characters WFL, LF, LA, WDL and LY suggesting the higher genetic control over these traits. Leaf yield showed significantly positive phenotypic and genotypic correlations with all other growth traits except PH and LF. Leaf fall had significant negative correlations with all the highly heritable yield attributes viz., ND (−0.379), WDL (−0.225), LA (−0.346), LAI (−0.233) at 1% level and AGB (−0.148), LHI (−0.122) and LY (−0.146) at 5% level. Likewise, it showed positive correlations with TSL (0.558), NLP (0.264) and PH (0.221). Since mulberry is mainly cultivated for leaf yield, genotypes having higher WFL, LA, WDL and LY and less LF must be given importance during parent selection to evolve high yielding varieties with less leaf fall across different seasons in mulberry.

Keywords: Variability; Heritability; Genetic Advance; Yield Attributes; Low Leaf Senescence

1. INTRODUCTION

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. As leaf productivity is one of principal factors that decide the sustainability and profitability of sericulture, good quality mulberry leaf increases the cocoon productivity and quality of silk [1]. Mulberry leaf quality deterioration, due to biotic and abiotic stresses, has increasingly been felt in tropical and subtropical regions where leaf yield was also less due to accelerated leaf fall during the winter months. Varieties with delayed leaf senescence can be of much use to reduce leaf fall and to provide better yield during the colder months [2]. This can make a huge difference in the availability of mulberry leaf during this highly favorable season for silkworm rearing. It is also found that some major disease of mulberry like powdery mildew caused by *Phyllactinia corylea* occur mostly during the winter month which further aggravate the problem of reduced leaf availability [3,4]. Thus, it is essential to develop varieties, which are insensitive to seasonal variations. Cold tolerance is known to be a quantitative trait mostly associated with other abiotic stress tolerance like drought and salinity [5] as delayed leaf senescence was found associated with higher drought tolerance [6]. In order to harness the natural variability in the germplasm, meticulous screening of germplasm for target traits and subsequent selection of appropriate parents, are required. Information on the heritability of characters is one of the prerequisite for proper planning of breeding programs. Therefore, in the present paper attempts were made to assess the phenotypic variability, heritability and genetic advance and inter-relationship of different yield and yield attributes in mulberry keeping the trait delayed senescence in mind.

2. MATERIALS AND METHODS

Nine mulberry genotypes viz., C-6, CT-9, CT-11, CT-15, CT-44, CT-94, CT-156, CT-185, and CT-210, developed through systematic breeding, involving 9 female, 9 male, 3 open and 2 self pollinated sources **(Table 1)**, were selected and evaluated under final yield trial (FYT) for 3 years keeping the current ruling variety "S-1635" as control. The plantation was made with 49 plants in each replication with 60 × 60 cm spacing under Randomized Block Design with 3 replications. Recommended cultural practices were followed [7] and after one year of establishment in the field, data were recorded by following a 5-crop schedule for consecutive 3 years. Data from the middle 25 plants were recorded on various yield attributing traits such as number of tillers (NT); plant height (HT), total shoot length (TSL), nodal distance (ND), leaf fall % (LF), number of leaves per plant (NLP), weight of 100 leaves (WCL), weight of 100 dry leaves (WCLD), single leaf area (SLA), leaf area index (LAI), aboveground biomass (AGB), leaf harvest index (LHI) and leaf yield (LY) were recorded. Data was statistically analyzed for genotypic (GCV) and phenotypic co-efficient of variance (PCV), broad sense heritability and genetic advance (GA) following Burton [8] and Lush [9], respectively. Genotypic, phenotypic and environmental correlations between yield and yield attributing characters were also estimated.

Table 1. Mulberry germplasm accessions utilized for crossing programme targeted to develop delayed senescent mulberry genotypes.

Parent	Acc. name	Origin	Climate	Character
	Morus indica HP	India	Tropical	Quick sprouting
	Maliha (F)	-do-	-do-	Thick leaves
	Berhampore local	-do-	-do-	Quick sprouting
	S-36	-do-	-do-	Thick leaves
Female	S-30	-do-	-do-	-do-
	Nagaland local	-do-	-do-	Cold tolerance
	Morus Multicaulis	France	Temperate	Stress tolerance
	KPG-2	India	-do-	Cold tolerance
	MR	-do-	Tropical	Thick leaves
	C-776	India	Tropical	Thick leaves
	CH-9	China	Temperate	Low senescence
	CH-12	-do-	-do-	-do-
	CH-13	-do-	-do-	-do-
Male	CH-23	-do-	-do-	-do-
	Maliha (M)	India	Tropical	Thick leaves
	Morus alba (S-1)	Burma	-do-	Thick leaves
	Thailand	Thailand	-do-	Thick leaves
	Zing	China	Temperate	Large leaf area
	English Black	France	Temperate	Stress tolerance
Open Pollinated mother plants	Tollygunge	India	Tropical	Quick Sprouting
	Kajli	-do-	-do-	-do-
Self Pollinated mother plants	S-799 (S_1)	India	Tropical	Quick Sprouting
	S-799 (S_2)	-do-	-do-	-do-

3. RESULTS AND DISCUSSION

The extent of variability present among the yield and yield attributes is presented in **Table 2**. The maximum range of variability was observed in WCL followed by WCDL, SLA, LY and LAI with 0.73, 0.65, 0.62, 0.50 and 0.47 fold, respectively, and the least was in LF (0.07 fold). The phenotypic, genotypic and environmental variances of 12 yield attributes are also presented in **Table 2**. A perusal of data indicated that the characters were greatly influenced by environment as the phenotypic variances were always greater than their genotypic variances. In accordance with the variability, maximum phenotypic variance was observed in TSL (6842.06) followed by WCL (5976.65) and SLA (1828.79) indicating the maximum influence of environment on these characters and comparatively minimum range of variability and phenotypic variance was recorded in LF (14.73) showing the genetic control of delayed senescence characteristic in the genotypes. However, the least phenotypic variance was observed in ND followed by NT, LAI, LY and AGB indicated the strong genetic control on the expression of these characters. Significant genotypic (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 0.155 (ND) to 6842.063 (TSL). The maximum GCV was in TSL, weight of 100 leaves. Single leaf area revealed the maximum influence of environment factors on its expression. The phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the characters and was highest in leaf fall % (25.126), weight of 100 leaves (20.963), LAI (20.797), leaf area (20.010) and was least in LHI (5.911).

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 [10]. Difference between PCV and GCV was minimum in all characters except that in number of tillers, plant height, TSL and NLP suggesting higher influence of environmental factors on these characters. Heritability (h^2) was highest in weight of 100 leaves (63.94) followed by in leaf fall % (53.317),

Table 2. Variance components, heritability and GA of different yield attributing characters and leaf yield in delayed senescent mulberry genotypes.

Component	NT	PH	TSL	ND	LF	NLP	WCL	WCLD	SLA	LAI	AGB	LHI	LY
	(No)	(cm)	(cm)	(cm)	(%)	(No)	(g)	(g)	(cm^2)		(mt/ha/yr)	(%)	(mt/ha/yr)
Range	7.17 to 8.36	88.86 to 102.94	557.52 to 653.08	4.35 to 5.12	9.80 to 16.75	97.37 to 118.59	293.29 to 509.25	62.81 to 103.70	178.05 to 289.67	5.27 to 7.79	63.07 to 75.69	57.25 to 64.35	32.05 to 47.94
Mean	7.844	96.703	608.599	4.605	15.276	107.827	377.798	78.214	213.719	6.332	13.248	60.498	7.935
SE	0.823	10.017	77.019	0.335	2.622	13.955	46.423	11.730	29.332	1.135	1.555	3.048	0.873
Variance													
Phenotypic	0.859	115.678	6842.063	0.155	14.732	241.146	5976.653	268.837	1828.799	1.734	3.329	12.789	1.476
Genotypic	0.182	15.340	910.159	0.043	7.855	46.403	3821.598	131.246	968.431	0.446	0.912	3.498	0.714
Error	0.677	100.338	5931.904	0.112	6.877	194.743	2155.055	137.591	860.367	1.288	2.417	9.290	0.762
Co-efficient of Variation (%)													
Phenotypic	11.819	11.122	13.591	8.547	25.126	14.402	20.463	20.963	20.010	20.797	13.771	5.911	15.310
Genotypic	5.439	4.050	4.957	4.484	18.347	6.318	16.363	14.647	14.561	10.545	7.208	3.092	10.650
Error	10.493	10.358	12.655	7.276	17.167	12.942	12.288	14.997	13.725	17.926	11.734	5.038	10.999
Heritability (broad sense)	21.180	13.261	13.302	27.523	53.317	19.243	63.942	48.820	52.955	25.709	27.395	27.356	48.386
Genetic Advance	0.344	2.496	19.256	0.190	3.581	5.229	86.508	14.008	39.630	0.592	0.875	1.712	1.029
Genetic Advance (as % of mean)	4.381	2.581	3.164	4.117	23.444	4.850	22.898	17.910	18.543	9.357	6.602	2.830	12.964

NT: No. of tillers; PH: Plant height; TSL: Total shoot length; ND: Nodal distance; LF: Leaf fall %; NLP: Total no. of leaves plant^{-1}; WCL: Fresh weight of 100 leaves; WCLD: Weight of 100 dry leaves; SLA: Single leaf area; LAI: Leaf area index; AGB: Aboveground biomass; LHI: Leaf harvest index; LY: Leaf yield.

Table 3. Correlation among the important yield attributing characters, leaf fall and leaf yield in delayed senescent mulberry genotypes.

Character	Type	TSL	ND	LF	NLP	WCL	WCLD	SLA	LAI	AGB	LHI	LY
	P	0.568**	0.245**	0.129*	0.180**	0.011	−0.025	−0.070	0.050	0.373**	−0.297**	0.162**
HT	G	0.222**	−0.502**	0.221**	0.508**	−0.282**	−0.378**	−0.322**	−0.121*	−0.119*	−0.503**	−0.218**
	E	0.621**	0.430**	0.110	0.118*	0.167**	0.107	0.024	0.091	0.499**	−0.253**	0.324**
	P		0.152**	0.303**	0.647**	0.120*	0.055	−0.059	0.357**	0.346**	−0.183**	0.218**
TSL	G		−0.094	0.558**	0.627**	0.126*	−0.006	0.010	0.372**	0.215**	−0.033	0.141*
	E		0.215**	0.243**	0.653**	0.149**	0.085	−0.096	0.359**	0.384**	−0.223**	0.272**
	P			−0.128*	−0.453**	0.397**	0.373**	0.447**	0.098	0.365**	0.247**	0.428**
ND	G			−0.379**	−0.726**	0.961**	0.986**	0.966**	0.832**	0.938**	0.907**	0.955**
	E			0.030	−0.373**	−0.013	0.020	0.133*	−0.168**	0.148*	−0.003	0.130*
	P				0.025	−0.067	−0.110	−0.182**	−0.130*	0.053	−0.111	−0.004
LF	G				0.264**	−0.145*	−0.225**	−0.346**	−0.233**	−0.148*	−0.122*	−0.146*
	E				−0.097	0.042	0.010	0.005	−0.073	0.188**	−0.110	0.142*
	P					−0.139*	−0.155**	−0.290**	0.387**	0.016	−0.300**	−0.126*
NLP	G					−0.653**	−0.735**	−0.666**	−0.321**	−0.526**	−0.741**	−0.609**
	E					0.166**	0.109	−0.126*	0.592**	0.178**	−0.169**	0.094
	P						0.898**	0.665**	0.527**	0.554**	0.317**	0.640**
WCL	G						0.992**	0.976**	0.908**	0.966**	0.914**	0.980**
	E						0.801**	0.236**	0.306**	0.292**	−0.128*	0.219**
	P							0.613**	0.467**	0.445**	0.281**	0.512**
WCLD	G							0.984**	0.872**	0.944**	0.956**	0.976**
	E							0.230**	0.256**	0.163**	−0.113	0.073
	P								0.753**	0.352**	0.272**	0.459**
SLA	G								0.918**	0.924**	0.919**	0.945**
	E								0.701**	0.000	−0.132*	−0.040
	P									0.330**	0.055	0.336**
LAI	G									0.908**	0.798**	0.893**
	E									0.121*	−0.213**	0.034
	P										0.029	0.861**
ABG	G										0.863**	0.995**
	E										−0.285**	0.815**
	P											0.471**
LHI	G											0.916**
	E											0.225**

NT: Number of tillers; PH: Plant height; TSL: Total shoot length; ND: Nodal distance; LF: Leaf fall %; NLP: Total no. of leaves plant^{-1}; WCL: Fresh weight of 100 leaves; WCLD: Weight of 100 dry leaves; SLA: Single leaf area; LAI: Leaf area index; AGB: Aboveground biomass; LHI: Leaf harvest index; LY: Leaf yield; P: Phenotypic, G: Genotypic and E: Environmental Correlation Co-efficient, respectively; * and **: significant at 5% and 1% level, respectively.

single leaf area (52.95), weight of 100 dry leaves (48.82) and leaf yield (48.38). Such high level of heritability may be due to the excessive additive gene effect.

The heritability estimates along with genetic gain is more useful than heritability alone in predicting the resultant effects of selection [11]. 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 [12]. In the present study also, high GA, as % of mean, coupled with high heritability was observed for the characters viz., leaf fall (h^2 = 53.31; GA% = 23.44); weight of 100 leaves (h^2 = 63.942; GA% = 22.89); single leaf area (h^2 = 52.95; GA% = 18.54); weight of 100 dry leaves (h^2 = 48.82; GA% = 17.91); and leaf yield (h^2 = 48.38; GA% = 12.96). This higher GA suggested the preponderance of additive gene action with low environmental influence in determining the expression of these characters and could be useful for selecting senescence delayed mulberry varieties. Similar findings of high h^2 and GA% was reported for the characters viz., leaf yield, weight of 100 leaves (both fresh and dry) and SLA among 9 different species of mulberry [13]. 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 [14]. Moderate GA% coupled with high h^2 noticed for the characters viz., ND, LAI and AGB indicated the possible control of intra and interallelic interactions in the expression of these characters.

Correlation among the 12 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, except between TSL and HT; TSL and ND; TSL and NLP; TSL and WCLD; TSL and SLA, TSL and LHI; TSL and AGB; TSL and LY; LAI and NLP and AGB and HT.

Leaf fall (%) had significant negative correlations with all important yield attributing characters with high heritabilty viz., SLA, LAI, ND and PH. Nodal distance was ranged between 4.35 to 5.12 cm and the optimum value range was 4.5 to 5.5 cm [15]. Leaf yield had significant positive correlations with all the yield attributing characters except HT and LF%, which showed significant negative correlations.

Therefore, the yield attributes, which are genetically controlled having high heritability and GA and also having significant positive association with leaf yield, viz., ND, WCL, WCLD, SLA, LAI, AGB and LHI and significant negative correlation with leaf fall (%) are worth considering for parental selection aiming to develop high yielding mulberry varieties with delayed leaf fall during the winter months.

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