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Vipul Sharma,
Department of Tree Improvement and Genetic Resources, College of Forestry Dr. Yashwant Singh Parmar University of Horticulture & Forestry Solan, Himachal Pradesh, India

Anita Kumari
Department of Tree Improvement and Genetic Resources, College of Forestry Dr. Yashwant Singh Parmar University of Horticulture & Forestry Solan, Himachal Pradesh, India

Inder Kumar Thakur
Department of Tree Improvement and Genetic Resources, College of Forestry Dr. Yashwant Singh Parmar University of Horticulture & Forestry Solan, Himachal Pradesh, India

Mrinalini Chandel
Department of Tree Improvement and Genetic Resources, College of Forestry Dr. Yashwant Singh Parmar University of Horticulture & Forestry Solan, Himachal Pradesh, India

Avinash Kumar Bhatia
College of Horticulture and Forestry, Neri, Hamirpur Dr. Yashwant Singh Parmar University of Horticulture & Forestry Solan, Himachal Pradesh, India

Akash Kumar
Department of Floriculture and Landscape Architecture, College of Horticulture, Dr. Yashwant Singh Parmar University of Horticulture & Forestry Solan, Himachal Pradesh, India

Corresponding Author:
Vipul Sharma,
Department of Tree Improvement and Genetic Resources, College of Forestry Dr. Yashwant Singh Parmar University of Horticulture & Forestry Solan, Himachal Pradesh, India

Variations in morphometric characteristics of white mulberry (*Morus alba* L.)

Vipul Sharma, Anita Kumari, Inder Kumar Thakur, Mrinalini Chandel, Avinash Kumar Bhatia and Akash Kumar

Abstract
High estimates of heritability were recorded for leaf area, lamina length and green leaf yield. Significant and positive correlations were found among basal diameter, lamina width, lamina length, petiole length and leaf area. Petiole length and crown area also exhibited significant and positive correlation with green leaf yield. Best performance was shown by clones Tr10, S146 and Mandaley with respect to various morphometric traits.

Keywords: morphometric characteristics of white mulberry (*Morus alba* L.)

Introduction
White mulberry (*Morus alba* L.) is a fast-growing small to medium sized tree which grows 10–20 m tall. It belongs to family Moraceae. It is native to northern China however it is widely cultivated elsewhere (India, United States, Mexico, Australia, Kyrgyzstan, Argentina, etc.). Indian gene centre is rich in *Morus* species. *Morus alba* is cultivated especially in northern India from Jammu and Kashmir to Assam. In some areas it is found wild. In the Himalayas it ascends up to an elevation of about 1200 m. In the hills it is mostly confined to stream beds or such other places where sufficient moisture is available for its growth. It does not grow on dry slopes or shallow soils where moisture becomes a limiting factor.

The species is widely cultivated in Jammu and Kashmir, Haryana, Punjab, Uttar Pradesh, Karnataka, Tamil Nadu, West Bengal, Kerala and to a lesser extent in Madhya Pradesh, Bihar, Orissa, Assam, Manipur, Andhra Pradesh (Ghosh, 1977) [6]. Wild relatives of genus *Morus* are reported to occur in India in tropical and sub-tropical Himalayan belt. It grows on soils ranging from sandy loam to clay loam however, alluvial and deep loamy soil with sufficient moisture supply supports its best growth. The tree cannot tolerate alkalinity and grows best on soils with pH ranging between 6.0-7.5. The soil texture and depth are the important factors affecting its growth. The old leaves are shed in November-December and trees are leafless during winter season. The new leaves on the tree appear in March-April depending upon the climate of the locality. The flowering takes place in March-April and the fruits ripen from April to June (Brandis, 1906) [2].

White mulberry is a multipurpose agroforestry tree species having high ecological and economic importance in terms of production of fodder, timber, silk and fuel. It is an important crop for silkworm (*Bombyx mori* L.) feed, fruit and timber as well as an excellent amenity tree. Its leaves and young bark are recognized as an excellent animal fodder. The fruit can be eaten fresh, preserved, vinified and in some semi-arid areas dried for winter use. It is also pollarded to furnish round wood. The species provides excellent timber which is used for sports good as well as local needs in furniture. White mulberry is said to be potentially invasive and to compete with native forest vegetation. The male clones are sometimes used as avenue trees to avoid seeding as well as soiling of the ground by fallen fruit. Apart from this it is also known to have a wide medicinal importance for treating a number of diseases like cancer, improves blood circulation, cleanses blood, strengthens kidney, controls blood sugar speeds up recovery etc.

To establish priorities for the conservation and improvement of tree genetic resources, understanding of the degree of diversity among and between trees is required. The determination of amount, nature and cause of variation present in the species of interest is the first step towards any improvement programme. All differences among trees are the result of three things *viz*., the genetic differences among trees, different environment in which tree is growing and interaction between tree genotype and environment in which they grow.

Continuous development is possible if variation exists in a species. Variations are essential for adaptation and improvement of the species and the amount of variation determines the potential for improving it through breeding programmes. The species (*Morus alba* L.) offers an opportunity for studying variation among clones and to select superior individuals for further use in clonal seed orchard, production orchard and clone x site interaction trials etc.

Materials and Methods

The studies were carried out in the experimental field and laboratory of the Department of Tree Improvement and Genetic Resources, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) A clonal evaluation trial of 24 clones (procured from different areas) of *Morus alba* was raised in the experimental field of the department using Randomized Block Design with three replications. Observation were recorded, after ten years and six months, individually on each ramet for basal diameter, number of primary branches, crown spread, petiole length, lamina length, lamina width, leaf area and green leaf yield. As suggested by Panse and Sukhatme (1978) [8] data were subjected to variance analysis. The formula as suggested by Burton and De Vane (1953) [4] determined the phenotypic coefficient of variation (PCV) and genotypic coefficient variation (GCV). In accordance with the procedure provided by Burton and De Vane (1953) [4] and Johnson *et al.* (1955) [7], heritability (broad sense), genetic improvement (GA) and genetic benefit (GG) were worked out.In order to determine the correlation between different characteristics, simple correlation coefficients were computed according to the method provided by Panse and Sukhatme(1978) [8].

Result and Discussion

Variance analysis showed that there was significant variation between different clones with regard to different characters. The maximum basal diameter was recorded for Clone Tr10 (17.84) which was significantly at par with Clones S146 (15.53) and China white (15.27). The minimum basal diameter was recorded for clone L-6 (8.91). The maximum crown area was recorded for Clone Tr10 (22.27) which was significantly different from all other clones, however minimum crown area was found for L-6 (3.05). The maximum lamina width was recorded for Clone S146 (11.99) which was significantly different from all other clones, whereas minimum value was shown by clone L-3 (5.68). The maximum lamina length was recorded for the clone S146 (17.52) which was significantly different from all other clones, while minimum lamina length was recorded for clone L-4 (8.41). The maximum petiole length was recorded for the clone Berhampore (4.63) which was significantly at par with Clones Mandaley (4.52), S146 (4.27). However CloneL-3 (2.17) recorded the minimum value for petiole length. The maximum leaf area was recorded for the clone S146 (179.13) which was significantly different from all other clones, while minimum leaf area was recorded for the Clone L-3 (48.49). The maximum green leaf yield was recorded for the Clone Tr10 (7.60) which was significantly different from all other clones, however minimum green leaf yield was observed for the clone L-3 (3.81).

Overall the clones Tr10, S146, S36, S799 and Mandaley were found to be better for all the growth characteristics. The superiority of these clones could be attributed to their superior genetic makeup as the environment in which they were grown was the same for all. The above findings are in line with the investigations of Tikader and Kamble (2009) [12] who reported significant differences in growth and yield traits of different accessions of *Morus* spp. They observed that the relationship among different growth traits indicate that leaf yield is dependent on number of branches per plant. The present investigation is also supported by the findings of Peris *et al.* (2014) [9] in mulberry and Bajpai *et al.* (2015) [1] for different quantitative morphological characters of *Morus alba.*

Estimates of genetic parameters

The heritability acts as a partial measure of genetic gain that can be generated on any particular trait and thus allow the breeder concentrate on the properties that are under the tight genetic control. Johnson *et al.* (1955) [7] and Burton (1952) [3] proposed that GCV research and heritage estimate would provide the best picture of the progress to be made by selection. Estimates of genetic parameters (Table-3) showed that the PCV and GCV were highest for crown area (54.78% and 53.90%) followed by leaf area (39.15% and 39.13%), respectively.

However, minimum values for basal diameter of PCV and GCV (20.09 per cent and 15.13 per cent) were observed. For all morphometric parameters the values of PCV were higher than those of GCV. The results in Table-3 revealed that heritability in general ranged between low and high. The maximum heritability value for the leaf area (0.99) was observed followed by lamina length (0.99) and green leaf yield (0.99) indicating that these traits were under strong genetic regulation influence.

However, basal diameter (0.28) showed modest heritability. The genetic advance for petiole length and leaf area ranged from 1.49 to 61.88, respectively. The highest genetic benefit was reported for crown area (109.25 percent) followed by leaf area (80.48 percent) indicating that additive genetic effects are important in deciding these characteristics and that selection should be successful for those characteristics. The lowest genetic benefit value for basal diameter was reported (23.48 per cent).

Low heritability values and genetic gains suggest the expression of non-additive gene action and thus simple selection would be a limiting factor in improving it.The above findings support the findings of Thakur and Chauhan (2008) [10] who documented moderate to high genetic variation coefficient (GCV), heritability and genetic benefit for leaf yield, shoot height, shoot diameter and number of leaves in *Morus* spp 'sindicating that these characters can be effective for potential selection results. Bajpai *et al.* (2015) [1] recorded high PCV for various growth characteristics such as leaf length, leaf width, small leaf length, leaf area, internodal distance, number of nodes, fruit length, fruit width and fruit weight in *Morus alba*.

Correlation studies

The knowledge of relationship of various characters among themselves is most important for any programme of tree improvement. The expression of a character is the sum total of so many other characters' input and thus screening / selection should be performed on the basis of components that contribute to that character. The bio-metric tool to support this is 'correlation' which gives the nature and degree of association between different characteristics.

An appraisal of the results (Table-3) revealed that basal diameter showed positive and highly significant correlation with crown area (0.631), lamina length (0.635) and green leaf yield (.673), significant and positive correlation with number

of primary branches (0.481). Crown area showed significant and positive correlation with green leaf yield (0.441). Lamina width exhibited highly significant and positive correlation with petiole length (0.607) and leaf area (0.614), significant and positive correlation with green leaf yield (0.425) and lamina length (.448). Lamina length revealed significant and positive correlation with leaf area (0.723), significant and positive correlation with petiole length (.494) and green leaf yield (.433).

Petiole length recorded highly significant and positive correlation with leaf area (0.637), significant and positive correlation with green leaf yield (.512). However, rest of the correlation combinations were non-significant. Tikader and Kamble (2008) [11] reported substantial correlation coefficient between leaf yield and other growth traits. In agreement with present study. Doss *et al.* (2012) [5] reported that the yield of green leaf has shown significantly positive phenotypic and genotypic correlations with various growth traits.

Wani *et al.* (2014) [13] also advocated for the *Morus alba* leaves to have a significant and positive correlation between different leaf characters. Peris *et al.* (2014) [9] observed the significant and positive correlations between leaf yield characteristics in *Morus alba* except in internodal distance and number of branches which were significant and negatively correlated.

Table 1: Detail for clones of *Morus alba.*

Sr. No.	Name of clone	Place	State
1	Kanva 2	Panchkula	Haryana
2	S30	Sahaspur	Uttarakhand
3	Phillipino	Sahaspur	Uttarakhand
4	China White	Sahaspur	Uttarakhand
5	K2MS	Sahaspur	Uttarakhand
6	S146	Sahaspur	Uttarakhand
7	S1531	Sahaspur	Uttarakhand
8	S799	Sahaspur	Uttarakhand
9	S41	Sahaspur	Uttarakhand
10	Mandaley	Sahaspur	Uttarakhand
11	Berhampore	Jammu	Jammu & Kashmir
12	Mesuguama	Jammu	Jammu & Kashmir
13	Kali kothari	Jammu	Jammu & Kashmir
14	C741	Jammu	Jammu & Kashmir
15	S36	Jammu	Jammu & Kashmir
16	S1307	Jammu	Jammu & Kashmir
17	ME-65	CSGRC, TN	Tamilnadu
18	L-2	Sahaspur	Uttarakhand
19	L-3	Sahaspur	Uttarakhand
20	L-4	Sahaspur	Uttarakhand
21	L-6	Sahaspur	Uttarakhand
22	Tr8	Sahaspur	Uttarakhand
23	Tr10	Sahaspur	Uttarakhand
24	Nauni	Nauni	Himachal Pradesh

Table 2: Variation in growth characters among different clones of White mulberry (*Morus alba* L.)

Clone	Basal diameter (cm)	Crown area (m^2)	No. of primary branches	Lamina width (cm)	Lamina length (cm)	Petiole length (cm)	Leaf area (cm^2)	Green leaf yield (kg/tree)
Kanva 2	12.02	3.11	7.00	9.94	12.43	3.93	82.53	5.08
S30	14.29	4.58	5.67	7.89	14.05	3.35	86.81	6.03
Phillipino	12.97	4.68	6.67	7.30	10.17	2.26	60.88	4.50
China White	15.27	14.43	4.00	7.59	12.69	2.54	56.85	5.06
K2MS	14.87	5.19	5.33	5.99	12.34	3.02	57.99	5.55
S146	15.53	10.84	6.00	11.99	17.52	4.27	179.13	5.86
S1531	13.77	5.41	6.67	10.66	10.24	3.52	66.40	6.52
S799	14.77	7.65	3.67	9.70	12.45	4.23	75.81	5.50
S41	9.86	7.48	3.67	9.10	11.77	3.53	76.39	4.91
Mandaley	11.87	4.58	5.67	9.21	12.48	4.52	149.10	4.75
Berhampore	15.03	8.55	4.00	7.87	10.93	4.65	78.31	6.52
Mesuguawa	10.03	7.03	4.33	9.08	9.04	3.59	73.63	4.22
Kali Kothari	10.81	7.69	3.33	8.88	8.93	2.68	61.69	4.76
C741	11.66	7.47	3.33	8.99	11.09	3.50	78.38	3.97
S36	12.07	7.40	3.33	9.58	10.31	3.80	66.15	6.61
S1307	12.56	9.38	6.67	7.45	8.95	2.79	52.06	4.87
ME-65	12.87	9.34	5.33	7.81	12.15	2.39	76.07	4.05
L-2	9.67	5.65	3.00	9.24	8.62	2.48	58.29	4.78
L-3	11.88	5.95	3.33	5.68	8.96	2.17	48.49	3.81
L-4	11.90	6.16	4.00	6.65	8.41	2.78	49.36	3.90
L-6	8.91	3.05	4.33	7.88	8.64	2.83	78.55	4.21
Tr8	12.01	7.80	3.67	8.08	10.34	2.63	81.48	4.79
Tr10	17.84	22.27	7.33	9.39	12.65	3.74	95.93	7.60
Nauni	12.03	4.07	3.67	8.51	11.12	2.55	52.87	5.67
Mean	12.69	7.49	4.75	8.52	11.09	3.24	76.80	5.15
$C.D_{0.05}$	2.76	1.20	1.94	0.55	0.27	0.26	1.36	0.15

Table 3: Estimate of different genetic parameters for morphometric characters in different clones of White mulberry (*Morus alba* L.).

Character	Mean (X)	Range	GCV (%)	PCV (%)	H^2	Genetic advance	Gain
Lamina width	8.52	5.68-11.99	16.68	17.14	0.95	2.85	33.44
Lamina length	11.09	8.41-17.52	19.13	19.18	0.99	4.36	39.30
Petiole length	3.24	2.17-4.63	22.79	23.33	0.95	1.49	45.89
Leaf area	76.80	48.49-179.13	39.13	39.15	0.99	61.88	80.58
No. of primary branches	4.75	3.00-7.33	25.51	35.66	0.51	1.79	37.59
Basal diameter	12.69	8.91-17.84	15.13	20.09	0.57	2.98	23.48
Crown area	7.49	3.05-22.27	53.90	54.78	0.97	8.18	109.25
Green leaf yield	5.15	3.81-7.60	19.21	19.29	0.99	2.03	39.41

Table 4: Estimate of simple correlation among morphometric traits of White mulberry (*Morus alba* L.).

	Basal Diameter	Crown area	No of primary branches	Lamina width	Lamina length	Petiole length	Leaf area	Green leaf yield
Basal diameter (cm)	1	.631**	.481*	0.087	.635**	0.32	0.261	.673**
Crown area (m^2)		1	0.205	0.154	0.298	0.117	0.169	.441*
No of primary branches			1	0.195	0.38	0.206	0.333	0.35
Lamina width(cm)				1	.448*	.607**	.614**	.425*
Lamina length (cm)					1	.494*	.723**	.433*
Petiole length (cm)						1	.637**	.512*
Leaf area (cm^2)							1	0.224
Green leaf yield kg/tree								1

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

Conclusion

Based on performance of progeny of selected ortets, Clone Tr10 displayed better morphometric traits then others with highest (7.60 kg/tree) green leaf yield. High heritability for leaf area and crown area with high genetic gain was recorded, while high heritability with moderate genetic gain was observed for green leaf yield and lamina length. Significant and positive correlations among basal diameter, green leaf yield, lamina width, lamina length, petiole length and leaf area were found.

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