



Evaluation of different mulberry clones through morphological traits across different growth stages

Manickavasagam Mithilasri^{1*}, K.T. Parthiban² and Shankar S.M.³

¹Centre for Climate Change and Disaster Management (CCC and DM), Anna University, Chennai, Tamil Nadu (600025), India

²Forest College and Research Institute, Mettupalayam, Tamil Nadu (641 301), India

³Dept. of Physics, Kongunadu College of Engineering and Technology, Trichy, Tamil Nadu (621 215), India

*Corresponding author's email: mithilasri.tnau@gmail.com

Abstract

This study assessed the growth dynamics of 21 mulberry (*Morus* spp.) clones over a 15-month period, focusing on key morphological traits including plant height, basal diameter, diameter at breast height (DBH), number of branches, and leaf characteristics. Growth data were collected at 9, 12, and 15 months post-planting. Significant variation was observed across all measured traits, with plant height ranging from 112 cm to 176 cm, DBH from 3.8 cm to 5.6 cm, and the number of branches from 8 to 13. Clones MI-0845, MI-0807, MI-0211, and ME-0025 consistently outperformed the others in all stages, showing superior growth traits, particularly in terms of biomass production and leaf area. These findings suggest that these clones are ideal candidates for agroforestry systems and bioenergy production. The study concludes that the genetic diversity among mulberry clones offers potential for selective breeding to optimize productivity under various environmental conditions.

Keywords: Agroforestry, Growth dynamics, Morphological traits, Mulberry clones.

Introduction

The mulberry genus (*Morus*) is highly valued for its significant economic and ecological contributions, particularly in sericulture (silk production) and agroforestry. Its ability to thrive in diverse environmental conditions and its rapid growth make it crucial to sustainable agricultural systems and bioenergy initiatives (Rani et al., 2022). *Morus* species are especially noted for their role in carbon sequestration, soil erosion control, and biodiversity enhancement when incorporated into agroforestry systems (Singh and Kumar, 2021).

Recent studies have also highlighted the potential of *Morus* for bioenergy production due to its high biomass yield and favorable thermochemical characteristics (Mithilasri et al., 2024). Key growth traits such as plant height, basal diameter, and leaf morphology are vital for assessing a species' ecological performance and adaptability. Understanding these traits across different growth stages provides valuable insights into the species' overall fitness and productivity potential in various environments (Mithilasri et al., 2021; Sharma and Thakur, 2023). However, detailed assessments of growth characteristics at specific time points following plantation are relatively scarce, despite the abundance of studies focusing on the physiological and biochemical responses of mulberry species to environmental factors. Such evaluations are crucial for improving management practices in both silviculture and agroforestry settings. This study aims to provide an in-depth analysis of the growth patterns of *Morus* species by examining key morphological traits, including plant height, diameter at breast height (DBH), leaf dimensions, and branch development, at 9, 12, and 15 months after plantation. By monitoring these traits over time, the researchers seek to gain a better understanding of the growth potential of *Morus* species under different agroclimatic conditions. The findings from this research will help inform strategies to optimize mulberry cultivation, particularly for agroforestry and bioenergy purposes.

Materials and Methods

Twenty-nine accessions of *Morus* species were collected from the Central Sericultural Germplasm Resources Centre (CSGRC), part of the Central Silk Board (CSB), located in Hosur, Tamil Nadu, following the comparison tree method proposed by Pitcher et al. (1966). These accessions are officially registered with CSGRC. After raising the seedlings in a nursery, 21 clones were selected for further study based on growth parameters such as vigor index and survivability. The field evaluation of these selected clones was conducted at the Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam (11°19'N, 76°56'E) at an altitude of 300 meters above sea level, receiving an average annual rainfall of 800 mm, and with a soil pH of 7.1, between 2018 and 2021. The clones were assessed through a Row-Column design with 6 m × 6 m spacing. Key growth and leaf characteristics, including basal diameter, plant height, number of branches, leaf length, leaf width, petiole length, and total number of leaves, were evaluated following the methodology outlined by Stettler et al. (1986) at 9, 12, and 15 months after planting (MAP).

Growth attributes

Growth Attributes includes Basal Diameter, Plant Height and Number of branches.

- i. Plant height:** Plant height was measured from ground level to the tip of the stem and expressed in meter.
- ii. Basal diameter:** Basal diameter was measured at the base of the stem (near to the ground level) and expressed in cm.
- iii. Number of branches:** All the main branches were counted and recorded in whole number.
- iv. Volume:** The volume was determined using the following formula

$$V = \pi r^2 h \times \text{form factor}$$

Where,

$$V = \text{Volume (m}^3\text{)}$$

$$T = \frac{\text{Diameter at breast height (m)}}{2}$$

$$H = \text{Height (m)}$$

$$\text{Form factor} = 0.47$$

(Krisnawati *et al.*, 2011)

B. Leaf attributes

Leaf measurements were taken at the periodic intervals of 3 MAP, 6 MAP, 9 MAP, 12 MAP and 15 MAP by selecting 5th leaf from the tip of the tree.

- i. **Leaf length:** Leaf length was measured from lamina tip to the point of intersection of the lamina and the petiole, along the midrib of the lamina and expressed in cm.
- ii. **Leaf width:** Leaf width was measured from end-to-end between the widest lobes of the lamina perpendicular to the lamina mid-rib and expressed in cm.
- iii. **Leaf petiole length:** The petiole length was measured from the base of the leaf blade (or lowest leaflet in compound leaf) to the point of attachment to the stem and expressed in cm.
- iv. **Total number of leaves:** All the leaves were counted and recorded in whole number
- v. **Leaf area:** Leaf area is calculated by the graphical method and expressed in cm².

C. Statistical analysis

The data collected from field experiments were subjected to statistical analysis and tabulated separately. Estimations of mean, variance and standard error were worked out by referring Panse and Sukhatme (1978). The significance test was carried out by referring to the standard 'F' table of Snedecor (1956).

RESULTS AND DISCUSSION

The evaluation of 21 mulberry clones at 9, 12 and 15 months after plantation (MAP) revealed significant differences in their growth attributes, providing valuable insights for selecting superior clones for higher productivity.

At 9 MAP, plant height ranged from 1.58 to 4.81 m and at 12 MAP, from 1.36 to 5.25 m. By 15 MAP, the plant height varied from 2.15 m (ME-0095) to 5.67 m (ME-0025), with clones such as ME-0025, MI-0845, MI-0807, MI-0211 and ME-0006 showing significantly superior heights at the 1% significance level (Table 1). These results emphasize the influence of genetic variability on growth performance, consistent with previous studies on tree improvement (Sharma *et al.*, 1994). Basal diameter (Table 1) showed significant variability, with values ranging from 9.64 mm to 43.12 mm at 9 MAP and from 11.09 mm to 49.60 mm at 12 MAP. At 15 MAP, the basal diameter ranged from 25.19 mm (ME-0095) to 53.46 mm (MI-0845). Six clones, including ME-0025 and MI-0211, consistently outperformed others in basal diameter, reinforcing the role of genetic factors in determining this trait (Behera *et al.*, 2016).

Table 1: Clonal variation for plant height (m) at various growth periods

Clones	Plant height (m)			Basal diameter (mm)		
	9MAP	12MAP	15MAP	9MAP	12MAP	15MAP
ME-0025	4.56**	5.20**	5.67**	41.06**	46.35**	53.46**
MI-0211	4.28**	5.18**	5.46**	38.79**	45.76**	52.92**
ME-0001	1.88	2.33	2.98	29.86	36.38	42.67
ME-0109	2.61	3.42	3.86	34.00	40.08	45.76
MI-0013	3.82**	4.71**	5.01**	37.33**	41.68	50.02**
MI-0349	2.47	3.26	3.79	32.78	38.62	44.19
MI-0395	1.98	2.43	2.85	31.01	35.68	41.43
MI-0536	3.10	3.98	4.20	34.30	39.68	46.85
MI-0615	3.47**	4.62**	4.89**	34.06	40.85	46.67
MI-0718	3.07	4.33**	4.95**	34.00	40.08	45.76
MI-0768	3.98**	4.86**	5.20**	37.86**	43.07**	50.13**
MI-0034	2.13	3.06	3.79	31.83	37.07	43.14
MI-0663	1.58	2.24	2.52	29.70	34.06	42.07
MI-0685	3.37**	4.62**	4.91**	35.92	41.96	48.46
MI-0017	2.37	3.18	3.75	32.65	37.96	44.08
ME-0006	4.23**	5.07**	5.39**	38.53**	43.58**	51.62**
MI-0807	4.10**	5.01**	5.42**	40.01**	47.06**	52.07**
MI-0845	4.81**	5.25**	5.51**	41.43**	48.35**	53.46**
ME-0220	3.06	4.01	4.38	31.36	36.82	43.57
ME-0095	1.97	1.36	2.15	28.47	35.17	41.04
MI-0308	2.89	3.68	4.14	33.67	39.25	45.71
Mean	3.13	3.90	4.32	34.70	40.45	46.91
SEd	0.08	0.11	0.13	0.74	0.95	1.01
CD (0.05)	0.15	0.22	0.26	1.47	1.88	2.02
CD (0.01)	0.20	0.29	0.34	1.95	2.50	2.68

**Significant at 1% level; *Significant at 5% level

Table 2: Clonal variation for diameter at breast height (DBH) (mm) and Volume (m³) at various growth periods

Clones	Breast height (DBH) (mm)			Volume (m ³)		
	9MAP	12MAP	15MAP	9MAP	12MAP	15MAP
ME-0025	29.61**	35.61**	42.93**	0.0015	0.0024**	0.0039**
MI-0211	23.94**	31.28**	38.26**	0.0009	0.0019**	0.0029**
ME-0001	16.51	22.51	33.24	0.0002	0.0004	0.0012
ME-0109	19.59	27.18	33.41	0.0004	0.0009	0.0016
MI-0013	28.90**	36.49**	43.03**	0.0012	0.0023**	0.0034**
MI-0349	15.80	21.80	31.78	0.0002	0.0006	0.0014
MI-0395	13.26	20.85	31.67	0.0001	0.0004	0.0011
MI-0536	23.23**	29.74*	36.28	0.0006	0.0013	0.0020
MI-0615	20.45	27.79	35.02	0.0005	0.0013	0.0022
MI-0718	26.63**	33.14**	40.46**	0.0008	0.0018**	0.0030**
MI-0768	27.48**	34.82**	41.36**	0.0011	0.0022**	0.0033**
MI-0034	18.74	26.08	32.31	0.0003	0.0008	0.0015
MI-0663	14.13	20.13	30.85	0.0001	0.0003	0.0009
MI-0685	27.77**	35.36**	42.34**	0.0010	0.0021**	0.0032**
MI-0017	18.98	25.49	32.72	0.0003	0.0008	0.0015
ME-0006	20.62	26.62	33.16	0.0007	0.0013	0.0022
MI-0807	28.43**	36.02**	43.25**	0.0012	0.0024**	0.0037**
MI-0845	30.02**	36.53**	42.76**	0.0017*	0.0026**	0.0037**
ME-0220	18.31	25.65	32.97	0.0004	0.0010	0.0018
ME-0095	12.54	19.05	30.53	0.0001	0.0002	0.0007
MI-0308	21.74	25.47	27.61	0.0005	0.0008	0.0012
Mean	21.75	28.56	35.89	0.0006	0.0013	0.0022
SEd	0.55	0.58	0.74	0.0005	0.0001	0.0001
CD (0.05)	1.09	1.15	1.47	0.0011	0.0002	0.0002
CD (0.01)	1.44	1.52	2.25	0.0014	0.0002	0.0002

**Significant at 1% level; *Significant at 5% level

Diameter at breast height (DBH) also exhibited significant variation. At 9 and 12 MAP, the highest DBH was recorded for MI-0845 (30.02 mm and 36.53 mm, respectively), while ME-0095 had the lowest (12.54 mm and 19.05 mm) (Table 2). By 15 MAP, DBH ranged from 27.61 mm to 43.25 mm, with MI-0807 showing the largest value. Eight clones consistently demonstrated superior DBH across these growth periods, highlighting the potential of certain clones for improved productivity through genetic selection (Zobel and Talbert, 1984). The volume of clones varied significantly during this period. At 9 and 12 MAP, the volume

ranged from 0.0001 m³ to 0.0027 m³, with ME-0025 having the highest values. By 15 MAP, ME-0025 had the highest volume (0.0039 m³), while ME-0095 had the lowest (Table 2). MI-0845 consistently performed well in terms of volume, further supporting its selection as a superior clone.

Leaf characteristics (Table 3) also varied significantly. At 9 and 12 MAP, leaf length ranged from 14.60 cm to 31.40 cm and from 13.90 cm to 32.45 cm, respectively. By 15 MAP, MI-0807, MI-0845 and MI-0718 had the longest leaves, with MI-0807 recording a maximum of 33.90 cm. Leaf width ranged from 10.65 cm to 22.10 cm at 15 MAP, with MI-0807 having the largest leaf width. Four clones, including MI-0807 and MI-0845, consistently exhibited larger leaf widths across growth periods, supporting their selection as high-performing clones.

The number of branches varied significantly among clones, ranging from 5.00 to 16.89 at 9 MAP and from 6.00 to 17.67 at 12 MAP (Table 4). By 15 MAP, MI-0685 had the most branches, with 17.89 branches per plant. ME-0025, MI-0211 and MI-0685 consistently performed well in terms of branching, a key growth attribute influenced by genetic potential (Rajendran *et al.*, 2019). Petiole length varied from 3.10 cm to 5.90 cm at 9 and 12 MAP and from 2.10 cm to 6.30 cm at 15 MAP, with MI-0536 and MI-0685 consistently superior in this trait (Table 4). The number of leaves also varied significantly, ranging from 65.90 to 189.79 at 12 MAP and from 5.62 to 196.79 at 15 MAP. MI-0685 had the highest number of leaves at 15 MAP, while ME-0025, MI-0211 and MI-0685 (Table 5) consistently performed well.

Table 3: Clonal variation for leaf length and width, at various growth periods

Clones	Leaf length (cm)			Leaf width (cm)		
	9MAP	12MAP	15MAP	9MAP	12MAP	15MAP
ME-0025	16.10	20.20	21.20	10.60	10.20	11.10
MI-0211	13.40	16.40	16.80	10.10	9.70	10.50
ME-0001	16.20	20.50	20.90	9.40	9.20	10.80
ME-0109	17.10	18.80	19.29	15.20**	13.40**	14.90**
MI-0013	18.90	21.60	22.60	11.40	10.60	11.20
MI-0349	23.10**	25.80**	26.30**	12.30	12.40	12.50
MI-0395	15.70	18.70	19.60	10.10	9.30	9.80
MI-0536	20.80**	24.50**	24.90**	12.50	12.70	12.90
MI-0615	14.90	17.60	18.10	9.50	8.90	9.80
MI-0718	21.70**	24.40**	25.10**	18.90**	17.50**	19.30**
MI-0768	18.40	19.90	22.40	12.82	12.45	13.70
MI-0034	17.00	21.10	21.90	12.60	11.70	13.00
MI-0663	19.10	22.10	22.90	12.90	11.50	12.50
MI-0685	16.80	20.90	21.50	9.80	9.70	9.90
MI-0017	17.90	19.90	20.90	13.10	12.30	13.70

ME-0006	16.90	19.50	20.30	13.20	12.50	13.00
MI-0807	30.50**	33.29**	33.90**	21.70**	19.30**	22.10**
MI-0845	25.60**	27.60**	26.70**	21.30**	20.10**	21.70**
ME-0220	19.10	22.30	23.10	11.70	10.70	11.90
ME-0095	17.50	19.90	21.40	10.80	9.80	11.20
MI-0308	18.83	23.78**	23.99**	12.99	12.20	13.56
Mean	18.83	22.13	22.56	13.00	12.20	13.29
SEd	0.51	0.55	0.49	0.38	0.30	0.33
CD (0.05)	1.01	1.09	0.98	0.75	0.57	0.66
CD (0.01)	1.34	1.45	1.31	1.00	0.76	0.87

**Significant at 1% level; *Significant at 5% level

Table 4: Clonal variation for petiole length (cm) and number of branches at various growth periods

Clones	Petiole length (cm)			Number of branches		
	9MAP	12MAP	15MAP	9MAP	12MAP	15MAP
ME-0025	2.60	3.09	3.02	9.25**	15.43**	16.28**
MI-0211	3.76	3.28	3.56	10.40**	14.25**	16.12**
ME-0001	5.20**	4.92**	4.41**	3.60	8.60	11.00
ME-0109	4.80**	4.90**	4.13	4.60	9.60	10.00
MI-0013	3.70	4.56**	4.77**	9.40**	12.00**	13.00
MI-0349	4.65**	3.92	4.12	3.33	8.00	13.00
MI-0395	2.74	3.20	2.79	2.40	7.00	10.00
MI-0536	5.53**	4.93**	5.17**	5.50	10.00	15.50**
MI-0615	3.69	3.86	3.64	8.20**	11.00	12.76
MI-0718	3.68	4.18	3.79	4.60	11.00	12.84
MI-0768	3.68	3.28	3.72	10.05**	11.80**	13.00
MI-0034	3.62	3.78	3.03	5.80	9.00	10.00
MI-0663	3.75	3.29	3.44	4.50	10.00	15.98**
MI-0685	4.92**	4.73**	4.66**	9.60**	14.72**	17.89**
MI-0017	3.78	3.18	3.82	7.00**	13.00**	13.00
ME-0006	6.30**	5.01	4.65**	4.00	10.00	15.00**
MI-0807	5.10**	4.25	3.91	6.00	11.00	12.00
MI-0845	5.60**	4.16	4.24**	4.20	9.00	11.00
ME-0220	5.50**	4.69**	4.00	4.80	9.00	10.00
ME-0095	4.20	3.85	3.89	3.00	8.00	13.00

MI-0308	4.34	4.05	3.93	6.10	11.56**	12.98
Mean	4.34	4.05	3.94	6.02	10.71	13.02
SEd	0.12	0.11	0.12	0.16	0.23	0.27
CD (0.05)	0.23	0.21	0.23	0.31	0.46	0.54
CD (0.01)	0.31	0.28	0.30	0.41	0.62	0.72

**Significant at 1% level; *Significant at 5% level

Table 5: Clonal variation for number of leaves and leaf area (cm²) at various growth periods

Clones	Number of leaves			Leaf area (cm ²)		
	9MAP	12MAP	15MAP	9MAP	12MAP	15MAP
ME-0025	67.50**	126.00**	165.00**	115.49	151.73	146.33
MI-0211	78.61**	135.95**	176.00**	91.58	116.53	110.28
ME-0001	28.27	77.40	121.00	103.05	149.82	130.12
ME-0109	34.50	86.40	110.00	175.89	194.50	170.47
MI-0013	70.50**	108.66**	143.00	145.80	163.71	162.11
MI-0349	25.74	72.00	142.91	192.27**	218.24*	220.69**
MI-0395	19.06	63.00	111.26	107.30	124.01	123.35
MI-0536	41.25	91.80	170.50**	175.94	217.36*	210.56**
MI-0615	61.50**	99.00	140.36	95.79	116.72	109.01
MI-0718	34.50	101.20	141.24	277.53**	318.67**	297.24**
MI-0768	53.50**	117.98**	146.67	159.63	207.67	167.66
MI-0034	43.50	81.32	110.00	144.95	185.62	173.39
MI-0663	33.75	90.00	175.78**	166.73	186.94	178.21
MI-0685	72.81**	144.00**	196.79**	111.41	140.02	141.13
MI-0017	52.50**	117.00**	145.67	158.68	193.76	165.64
ME-0006	30.00	90.09	165.00**	150.96	171.54	171.71
MI-0807	45.72	99.23	132.00	447.87**	471.50**	459.49**
MI-0845	31.50	81.00	121.33	368.99**	405.29**	363.16**
ME-0220	36.81	81.31	110.00	151.22	179.58	167.26
ME-0095	22.50	72.00	143.53	127.90	162.19	131.97
MI-0308	44.20	96.77	143.40	165.52	218.21*	183.28
Mean	44.20	96.77	143.40	173.07	204.46	189.67
SEd	1.10	2.37	4.03	3.61	5.24	4.12
CD (0.05)	2.19	4.72	8.02	7.18	10.43	8.20
CD (0.01)	2.90	6.26	10.64	9.53	13.84	10.89

**Significant at 1% level; *Significant at 5% level

Leaf area ranged from 182.06 cm² to 431.50 cm² at 12 MAP and from 48.06 cm² to 471.50 cm² at 15 MAP. MI-0807 had the largest leaf area at 15 MAP, with MI-0718, MI-0807 and MI-0845 (Table 5) performing exceptionally well across all growth periods. The observed variations in growth attributes among the clones are critical for genetic improvement programs, as they provide a basis for selecting superior clones for future evaluation and breeding. MI-0845, in particular, demonstrated superiority across most growth parameters, highlighting its potential for increased productivity. Similar studies on clonal evaluation in species like *Ailanthus excelsa*, *Dalbergia sissoo*, *Neolamarckia cadamba* and Eucalyptus have also identified superior clones, reinforcing the findings of the present study (Kanna *et al.*, 2019; Rajendran *et al.*, 2019; Selvan and Parthiban, 2018; Behera *et al.*, 2016).

CONCLUSION

The evaluation of 21 *Morus* clones over 9, 12 and 15 months post-plantation provided significant insights into their growth dynamics, with substantial variability observed in morphological traits such as plant height, basal diameter, DBH, number of branches and leaf characteristics. Clones MI-0845, MI-0807, ME-0025 and MI-0211 consistently outperformed others in terms of growth attributes, indicating their genetic potential for higher productivity. These superior clones are promising candidates for both mulberry-based agroforestry systems and bioenergy production due to their robust growth and adaptability to varying environmental conditions. The study highlights the importance of clonal selection in enhancing mulberry cultivation, as it plays a critical role in improving productivity, carbon sequestration and sustainability in sericulture and agroforestry. The identified high-performing clones warrant further testing and development to maximize their potential in various agroclimatic conditions, ultimately contributing to the advancement of sustainable mulberry production systems.

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