On-farm Tree Mulberry Geometry: Biochemical, Growth and Yield Analysis in The Traditional Areas of Sericulture.

ABSTRACT

Navigation from bush to tree mulberry plantation has been in force in recent years to conquer water scarcity and high-temperature impact in traditional areas. Despite no scientific recommendation, Seri-farmers are practicing varied geometry as per their knowledge and expediency wherein a systematic analysis of the growth, leaf quality, and yield parameters is lacking. Thus, tree mulberry gardens in traditional districts - Kolar and Chikkaballapura were selected to analyze the impact of varied geometry on biochemical, growth, and yield parameters of mulberry variety V_1. Surprisingly, diverse geometry of 5'x5', 6'x6', 7'x5', 8'x4', 8'x8', 9'x5', 10'x5', 10'x10', and 12'x12' is in practice in the tree mulberry plantations of the study area. The highest leaf moisture measuring 75.80% was recorded from an 8'x4' mulberry plantation, whereas the highest total carbohydrate of 18.85mg/100 g was recorded in a 10'x10' geometry. The foliage of tree mulberry raised under 12'x12' geometry possesses the highest total crude protein (30.81mg/100g), nitrogen (4.93%), phosphorus (0.39%), and potassium (1.66%) contents. Among growth yield parameters, the highest number of shoots per tree recorded was 62, the number of leaves - 881, maximum shoot height - 157 cm, fresh weight of leaves - 4.18 g, and leaf yield - 3.876 kg in 12'x12' mulberry plantation. The data stated that the number of tree mulberry recorded was 3625 per hectare of plantation under 8'x4' geometry, giving rise to the highest leaf yield of 49209 kg per hectare per year with a gross return of Rs.761000. Computing all these data, we infer that rather than following capricious geometry for establishing tree mulberry plantation, we suggest following a scientific basis of geometry wherein mulberry crop quality and yield are steadfast to harvest cocoons qualitatively and quantitatively good.

Keywords: Tree Mulberry, Geometry, Biochemical, Growth and Yield

1. INTRODUCTION

Mulberry (*Morus* spp.) is a fast-growing perennial woody plant with a deep rooting nature, cultivating under varied climatic conditions - temperate to tropical for foliage to rear silkworms

for the production of silk cocoons. Mulberry has been cultivated in heterogeneous agro-climatic conditions following diverse cultivation methods and practices, as a low bush with comparatively closer spacing of 2' x 6' to 3' x 3' in plains of Southern and Western parts of India while it has been cultivated as a large/medium tree with the spacing of 5' x 5' to 10' x 10' depending on soil topography in hilly areas of Jammu and Kashmir (Dandin and Sengupta 1988). However, the mulberry plant is allowed to grow tall with a crown height of 5' to 6' from the ground level and a stem girth of 4 to 5 inches referred to as tree mulberry (Dasgupta 1961).

Spacing has a direct influence on plant growth which includes plant height, number of branches per plant, shoot length, number of leaves per plant, and leaf yield. Due to lack of space, plants battle for air, light, soil moisture, nutrients, etc., leading to poor quality of foliage and yield (Bongale 1991). Thus, the growth and development of the larvae and the economic characteristics of cocoons are profoundly influenced by the nutritional contents of mulberry leaves. Because mulberry leaves as food for silkworms (*Bombay mori*) meet nutritional requirements - carbohydrates, proteins, moisture, essential vitamins, minerals, etc. for the production of cocoons. However, among different factors that govern successful cocoon yield, mulberry foliage shares a major share of 38.2% (Miyashita, 1986), while the quality of leaves determines the success in the production of quality cocoons with high yield, the quantum of foliage produced enhance the profit. Thus, it is a challenging task to elevate productivity.

In recent years, the concept of tree mulberry cultivation has been diffusing into plain areas as comparatively it is advantageous over bush plantation for sustainable foliage production and hassle-free cultural operations. This phenomenal change is because of a steep rise in annual mean temperature, irregular rainfall, declined groundwater resources, and scarcity of manpower. Thus, more farmers are showing interest in tree mulberry plantations to overcome these two major problems following drip irrigation and mechanization. Seri-farmers have been adopting varied plantation and cultivation practices as per their knowledge, convenience, and experience gained over the years. This unscientific approach not only affects the accurate assessment of mulberry leaf production in a year or ensuing years but also estimates the number of disease-free layings of silkworm (purebred/hybrid) required for rearing accordingly (Megharaja *et al.,* 2021).

Towards this, albeit tree mulberry plantation is not a new venture, unlike hilly areas wherein tree plantation is mostly in practice, it needs systematic study to establish a defined package of

practices that suit plan areas with a main goal of increasing leaf yield and income. With this, seri-farmers can start establishing tree mulberry plantations with less cost, minimal usage of water, and pest and disease incidence. Keeping the gap in the scientific basis of recommendation in view, this on-farm study was undertaken not only to uncover the current prevailing diversity in tree mulberry plantation, which has an impact on leaf quality and yield including cost-benefit, but to advocate appropriate technology to the seri-farmers.

2. MATERIALS AND METHODS

The study was carried out during 2021-2022 and 2022-23 in Kolar and Chikkaballapura districts of Karnataka state. A total of five tree mulberry plants in three replicates from each garden of different geometry of 5'x5', 6'x6', 7'x5', 8'x4', 8'x8', 9'x5', 10'x5', 10'x10', 12'x12' were randomly selected and labeled to record the observations throughout the study. The growth and yield parameters *viz.*, number of shoots per tree, shoot height (cm), number of leaves per tree, fresh weight leaf (g), leaf yield/tree (kg), and yield per hectare per year (kg) were recorded in the selected tree mulberry gardens which are more than three year old.

A composite leaf sample was collected from the labeled plants and air dried followed by a hot-air oven dry at 60°C for 18 hours. The leaf samples were powdered and stored in polythene bags. These samples were used to analyze total carbohydrates (mg/100 g), total crude protein (mg/100g), nitrogen (%), phosphorus (%), and potassium (%) following standard procedures. Leaf moisture (%) content was estimated using fresh and dry weights of ten composite sample leaves. The moisture content of the leaf was calculated using the following formula,

$$\text{Moisture content of leaf (\%)} = \frac{\text{Fresh wt.} - \text{Dry wt}}{\text{Fresh wt.}} \times 100$$

During the two years of investigation, ten crop data were recorded from farmers who adopted different geometry tree mulberry plantations and collected information on mulberry varieties, spacing, input application, irrigation regimes, organic/inorganic fertilizer, leaf yield, number of crops per year and extent of mechanization. Similarly, silkworm rearing data was also collected on the number of disease-free layings brushed, cocoon yield, cost of the cocoon, and cost incurred on rearing. Finally, mulberry (V_1) leaf yield v/s cocoon (PM x CSR_2) production concerning tree mulberry geometry was estimated.

Statistical analysis: All the data recorded was statistically analyzed.

3. RESULTS AND DISCUSSION

Growth and yield

Seri-farmers practicing diverse geometry in tree mulberry cultivation is obvious as has been reported earlier (Megharaja *et al*., 2021), wherein the scientific basis of plantation is lacking. Moreover, all of them have been practicing varied cultural operations and packages of practices as per their knowledge, experience over the years, and affordability, which lead to explicit different quality and yield parameters. However, the number of shoots per tree (62), shoot height (157 cm), number of leaves per tree (881), fresh leaf weight (4.18 g), and leaf yield per tree (3.876 kg) recorded were significantly highest in the tree mulberry plantation with 12'x12' geometry. Slightly similar results were also observed in the 10'x10' geometry plantation (58 no, 150 cm, 865 no, 4.10 g, 3.83 kg respectively) both spacing were significantly superior over all other spacing. These phenomenal changes could be due to wider spacing, which reduces the competency over light and nutrients among plants in a unit area and promotes exponential growth of the tree, which conforms to Ravikumar *et al.* (2019) and Vinod Kumar *et al*. (2020). As the tree mulberry spacing reduces to 8'x8' and 8'x4' number of shoots recorded per tree was 45 and 40, shoot height was 123 and 103 cm, the number of leaves per tree was 754 and 624, fresh leaf weight was 3.90 and 3.60 g and leaf yield per tree was 3.147 and 2.715 kg respectively. Whereas tree mulberry raised under 5'x5' and 6'x6' geometry exhibit the least number of shoots per tree (29 and 32 no), shoot height (83 and 88 cm), number of leaves per tree (410 and 498 no), fresh leaf weight (2.48 and 2.87g) and leaf yield per tree (0.923 and 1.576 kg) (Table-1). These indicate that mulberry trees grown under closer spacing resulted in low yield parameters as plants have a greater competition for the nutrients and space to establish as has been observed by Vinod Kumar *et al*. (2020) and Megharaja *et al*., (2021). Interestingly, among all the geometry, the highest leaf yield/hectare/year recorded was 49209 kg from 8'x4' tree mulberry geometry followed by 38640 kg in 9'x5' geometry. Contrastingly, the least leaf yield of 14534 kg per hectare per year was recorded from the wider spacing of 12'x12' geometry. The cause for the change among low, medium, and wider spacing is due to a substantial number of trees (3625/ha) accommodated under 8'x4' geometry, which yielded a higher quantum of foliage. Correspondingly, less number of trees (750/ha) accommodated in 12'x12 plantations yielded low

leaf yield/hectare/year as has been reported by Sudhakar *et al.* (2018). Though wider and closer tree plant geometry recorded the highest and least growth and yield contributing parameters viz., number of shoots, shoot height, number and fresh weight of leaves/ tree respectively, the plant population plays an important role in determining higher leaf yield (Hasegawa 1967), which has an economical value. Thus, the optimized tree mulberry geometry of 8'x4' or 8'x5' has been proposed earlier (Megharaja *et al.,* 2021) to achieve steady foliage yield (65 MT/ha/year) production around the year.

Biochemical parameters of tree mulberry

Despite, the wide variation that has been noticed in on-farm tree mulberry plantations concerning plant geometry associated with growth and yield, not much disparity was observed in the moisture content of the leaf. However, among geometry plantations, 75.80% of leaf moisture was recorded from the leaves harvested from 8'x4' being the highest among varied geometry plantations, while it was 75.51% from 8'x8' geometry plantation, which is slightly lesser than the former and the least leaf moisture content of 75.04% was recorded from 10'x5' geometry. Moreover, significant variation was noticed in other biochemical parameters with the highest total carbohydrates of 18.54 mg/100 g, and total crude protein contents of 30.81 mg/100g in the tree mulberry plantation with 12'x12' geometry, which is on par with 10'x10' geometry (18.85 and 30.35 mg/100 g respectively). Further, 16.75 and 16.68 mg/100 g of total carbohydrates and 28.63 and 28.38 mg/100 g of total crude protein contents were recorded in the leaves harvested from the mulberry garden with a spacing of 8'x8' and 8'x4'geometry. Whereas, the lowest total carbohydrates (12.54 and 12.81mg/100g) and total crude protein contents (24.04 and 25.31 mg/100g) were observed in 5'x5' and 6'x6' geometry. Correspondingly, higher nutritional elements like nitrogen (4.93 and 4.86%), phosphorous (0.39 and 0.37%), and potassium (1.66 and 1.56%) were also recorded from 12’x12’and 10'x 10' geometry tree mulberry plantation. Similarly, 4.64, 0.37, and 1.53% in 10'x 5' geometry, 4.62, 0.36, and 1.50% in 9'x 5' geometry, 4.58, 0.34 and 1.44% in 8'x8' geometry and 4.54, 0.33 and 1.40% of nitrogen, phosphorous and potassium respectively from 8'x4' geometry tree mulberry plantation. Least nitrogen (3.85, 4.05and 4.19%), phosphorous (0.23, 0.28and 0.30%) and potassium (1.20, 1.23 and 1.35%) contents were observed in 5'x5', 6'x6' and 7'x5' geometry respectively (Table-2). All these data

are in concordance with the findings of Yogananda Murthy *et al.* (2013) and Vanitha *et al*. (2019).

Leaf yield v/s Cocoon production

Mulberry leaf, being chief food for silkworms, provides the required amount of nutrients for the silkworm for its not only growth but also biosynthesis of silk protein that is expelled in the form of cocoon, accounting for 38.2% share among other factors. Thus, mulberry leaf yield per unit area plays a pivotal role in harvesting substantial cocoon crop yield – the higher the leaf quality greater the cocoon yield. In this regard, higher cocoon yield (1700 and 1594 kgs) was obtained by brushing cross breed (PMxCSR2) of 2000 and 1875 dfls/ha/year for the most significant utilization of maximum quantum of 49210 and 38640 kg/ha/year mulberry leaves harvested from the mulberry plantation with a geometry of 8'x4' and 8'x8' respectively, which yielded a gross return Rs.761000 and Rs.721250 compared to other mulberry plantation with varied geometry. On the other hand, tree mulberry plantations with 10'x10' and 12'x12' geometry are known to accommodate less number of trees (1075 and 750 respectively) resulting in lower leaf yield of 20590 and 14535 kg/ha/year and the corresponding number of dfls brushed were 1250 and 625 dfls/ha/year which intern has low gross return of Rs.4,77,500 and Rs.2,19,375 respectively (Table-3). All these data are again in agreement with the observation of Sudhakar *et al.* (2018).

Correspondingly, closer geometry of 5'x5', 6'x6', and 7'x5' albeit accommodate more number of tree mulberry but leaf yield recorded was 19605, 23635 and 29880 kg/ha/year respectively. Eventually, the number of DFLs brushed per hectare per year was 2500, 2250, and 2150 dfls/ha/year respectively and the gross return obtained was Rs.641250, Rs.581125, and Rs.578075 respectively.

4. CONCLUSION

Tree mulberry cultivation albeit not a new concept in Karnataka, in recent years, most of the Seri-farmers have been navigated to tree mulberry plantations, due to labour and water scarcity, intercrop cultivation, and the need to utilize mechanized cultural operations. However, the basis of tree plantation and the package of cultivation practices is merely arbitrary, which is fabricated through interactive verbal dialogues between farmers without substantial scientific evidence for this strategy. Consequently, this study suggests that keeping the leaf quality and yield as an

economical value, among diverse tree mulberry plantations, 8'x4' geometry is promising as opined by Megharaja *et al.*, (2021) who have suggested optimized spacing of 8'x5', which yielded higher leaf yield 49209 kg/hectare/year and a gross return of Rs.761000/-. However, systematic investigation is warranted to suggest standard geometry with a precise package of practices to protect the time and wealth of the Seri-farmers.

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Table 1: Impact of On-farm Tree Mulberry Geometry on growth and yield parameters of mulberry - variety V1

Geometry	Number of shoots per tree	Shoot height (cm)	Number of leaves per tree	Fresh weight leaf (g)	leaf yield/tree (Kg)	No.pl/ ha	Leaf yield/ha/ year (kg)	Leaf yield (mt/ha/yr)
5'x5'	29^{e}	83^{g}	410^{f}	2.48^{g}	0.923^{h}	4250	19605	19.61
6'x6'	32^{e}	88^{fg}	498^{f}	2.87^{f}	1.576^{g}	3000	23635	23.64
7'x5'	34^{e}	93^{f}	593^{e}	3.40^{e}	2.079^{f}	2875	29882	29.88
8'x4'	40^{d}	103^{e}	624^{e}	3.60^{d}	2.715^{e}	3625	49209	49.12
8'x8'	45^{d}	123^{d}	754^{d}	3.90^{c}	3.147^{d}	1625	25571	25.57
9'x5'	51^{c}	134^{c}	787^{cd}	3.97^{bc}	3.254^{cd}	2375	38640	38.64

10'x5'	55[bc]	148[b]	814[bc]	4.02[bc]	3.587[b]	2050	36769	36.77
10'x10'	58[ab]	150[b]	865[ab]	4.10[ab]	3.830[a]	1075	20589	20.59
12'x12'	62[a]	157[a]	881[a]	4.18[a]	3.876[a]	750	14534	14.53
S.Em±	**1.65**	**1.90**	**18.73**	**0.05**	**0.06**			
CD at 5%	**4.90**	**5.64**	**55.64**	**0.14**	**0.18**			

Table 2: Impact of On-farm Tree Mulberry Geometry on Biochemical parameters of mulberry leaves

Geometry	Leaf moisture (%)	Total carbohydrates (mg/100g)	Total crude protein (mg/100g)	Nitrogen (%)	Phosphorous (%)	Potassium (%)
5'x5'	75.16[a]	12.54[d]	24.04[d]	3.85[c]	0.23[d]	1.20[c]
6'x6'	75.47[a]	12.81[d]	25.31[cd]	4.05[bc]	0.28[cd]	1.23[c]
7'x5'	75.62[a]	14.64[c]	26.19[cd]	4.19[bc]	0.30[bcd]	1.35[bc]
8'x4'	75.80[a]	16.68[b]	28.38[bc]	4.54[ab]	0.33[abc]	1.40[bc]
8'x8'	75.51[a]	16.75[b]	28.63[bc]	4.58[ab]	0.34[abc]	1.44[abc]
9'x5'	75.48[a]	17.09[b]	28.85[bc]	4.62[ab]	0.36[ab]	1.50[ab]
10'x5'	75.04[a]	18.08[ab]	29.00[bc]	4.64[ab]	0.37[a]	1.53[ab]
10'x10'	75.09[a]	18.85[a]	30.35[b]	4.86[a]	0.37[a]	1.56[ab]
12'x12'	75.32[a]	18.54[a]	30.81[a]	4.93[a]	0.39[a]	1.66[a]
S.Em±	**0.53**	**0.55**	**1.32**	**0.21**	**0.02**	**0.08**
CD at 5%	**1.59**	**1.60**	**3.91**	**0.62**	**0.07**	**0.24**

Table 3: Comparative analysis of mulberry (V_1) leaf yield and cocoon production (Cross Breed: PMxCSR$_2$) in relation to tree mulberry geometry

Geometry/ Parameters	5'x5'	6'x6'	7'x5'	8'x4'	8'x8'	9'x5'	10'x5'	10'x10'	12'x12'
No. of Plants/ha	4250	3000	2875	3625	1625	2375	2050	1075	750
Leaf yield (kg/ha/yr)	19605	23635	29880	49210	25570	38640	36770	20590	14535
Mulberry Cultivation Cost/ hectare/yr	200000	175000	150000	125000	115000	110000	110000	100000	70000
Silkworm Rearing/ Hectare:									
No. of DFLs brushed /acre/crop	200	180	170	160	150	130	120	100	50
No. of DFLs brushed/ha/yr	2500	2250	2150	2000	1875	1625	1500	1250	625
Cost of Chawki (Rs.3200/100DFLs)	80000	72000	68800	64000	60000	52000	48000	40000	20000
Cocoon Yield (75 & 85 & 90 kg/ 100 DFLs)	1875	1688	1613	1700	1594	1381	1275	1063	531
Cost of Cocoon /ha/yr (@ Rs. 550 & 650/kg)	1031250	928125	886875	1020000	956250	828750	765000	637500	329375
Input cost of rearing/yr	110000	100000	90000	70000	60000	50000	30000	20000	20000
Total cost of input (Rs)	390000	347000	308800	259000	235000	212000	188000	160000	110000
Gross return (Rs)	**641250**	**581125**	**578075**	**761000**	**721250**	**616750**	**577000**	**477500**	**219375**