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Research Article

Influence of Spacing and Nutrient Management on Growth and Yield of Tree Mulberry Genotypes

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Abstract

The KSSRDI conducted research from 2018 to 2021 in Bengaluru, assessing tree mulberry growth, yield and moisture with 8′×8′ and 10′×10′ spacings and four nutrient levels. Data from eight crop cycles were collected and analysis used a three-factor split-split-plot design *via* OPSTAT. The study compared V_1 and Vishala mulberry genotypes, highlighting Vishala's superior growth and yield. Vishala had more branches tree^{-1} (35.50), longer branches (143.23 cm), more leaves branch^{-1} (31.69), higher leaf and stem yield (27.18 and 18.42 mt ha^{-1}yr^{-1}). V_1 exhibited higher leaf stem^{-1} moisture (74.69% and 71.77%) compared to Vishala (69.76% and 67.26%). Among specific combinations, S_1N_4 and S_1N_3 yielded the highest leaf stem^{-1} output (29.90 and 19.70 mt ha^{-1}yr^{-1}), while S_2N_4 and S_2N_3 had more branches tree^{-1} and longer branches. This study highlights Vishala's potential for increased productivity and sheds light on nutrient levels and spacing effects on mulberry growth and yield. Interactions between factors did not significantly affect mulberry growth and yield parameters. The study recommends an 8′×8′ spacing with 75% of the recommended fertilizer dose (105:42:42 kg NPK acre^{-1}year^{-1}), alongside the application of 10 tons acre^{-1}year^{-1} of Farm Yard Manure, biofertilizers Prakruthi and Seri-Phos, and green manure crops like Sunhemp and Cowpea.

Keywords: Chemical fertilizers, FYM, Green manures, V_1, Vishala

Introduction

Mulberry cultivation is commonly practiced in three distinct forms: bush, low-cut and tree, each yielding varying quality outcomes due to rearing techniques. The quality and yield of mulberry leaves have been impacted by changes in water availability and increasing water resource depletion, leading to a reduction in leaf quality. This situation has prompted sericulturists to adapt by reducing the size of mulberry gardens to accommodate water constraints.

To address this issue, some farmers have transitioned to cultivating mulberry as small trees, optimizing limited irrigation water and minimizing labor requirements. A spacing of 8′×8′ or 10′×10′ with tree heights of 4′ to 5′ is maintained, both under rainfed and irrigated conditions (Du *et al.*, 2001; Shi, 2005). This approach facilitates mechanized cultural practices, intercropping and drip irrigation, effectively reducing labor costs while maintaining leaf quality. Notably, mulberry leaf quality from trees surpasses that of conventional gardens. To ensure the sustained production of high-quality mulberry leaves, adopting the step-up and step-down method of pruning is essential. This technique involves retaining a desired number of branches based on plant spacing, promoting proshape and size and creating an umbrella-like crown that exposes shoots to enhanced sunlight and aeration. Successful establishment of a productive tree mulberry garden necessitates planting saplings that are at least 8 months old. Deep-rooted mulberry varieties such as S13, S1635, MSG2, RC1, RC2, RFS175, V_1 and Vishala are well-suited for this approach. Overall, the combination of strategic pruning methods and appropriate variety selection contributes to healthy tree

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mulberry growth and superior leaf quality.

Mulberry trees exhibit exceptional resilience, enduring 20 days of inundation during growth a rarity among xerophytic plants. Their robust water-logging tolerance during dormancy further sets them apart. In India, recent decades have witnessed environmental shifts, including erratic monsoons and altered rainfall patterns. These changes have compelled farmers to adopt strategies like reduced planting with wider spacing and improved irrigation methods (AMITs) to maintain quality and quantity of mulberry leaf yield (Sudhakar *et al.*, 2021). Mulberry (*Morus* spp.) is a swiftly growing deciduous woody perennial, typically pruned to a bush or dwarf tree form (Magadum *et al.*, 2019). Spacing and mulberry species significantly impact growth parameters. Notably, Vishwa variety under 4′×4′ spacing has shown substantial yield improvement and enhanced phytochemical traits (Eltayb *et al.*, 2013; Murthy *et al.*, 2013). For feeding the Jammu SH6 × NB4D2 hybrid silkworm, the mulberry variety TR-10 both in bush and cultivated tree forms alongside a wild tree of the same age were selected. This selection was based on suitability for the Jammu region (Singh *et al*., 2016).

The quality and quantity of mulberry vary based on factors like nutrient supply, soil fertility, climate and variety. Over 70% of the nutrients needed for silk protein synthesis (Sericin and fibroin) come from mulberry leaves. Leaf nutrient quality *viz*., crude protein (18.66%), total sugar (3.36%), starch (14.55%), crude fiber (9.32%), CHO (17.91%), moisture content (76.52%) and minerals (9.35%) is higher in mulberry trees compared to low-cut and bush forms (Qader, 1991). A combination of chemical and organic fertilizers, green manuring and bio-fertilizers has been effective in maintaining consistent crop output over extended periods (Nambiar and Abrol, 1992). In tropical regions with abundant solar radiation, FYM decomposition is rapid and around 80% of applied phosphorus becomes fixed in the soil.

The growth and yield parameters of mulberry, including moisture content and nutrient uptake, exhibited significant improvement when using different genotypes combined with wider spacing and the step-up method of leaf harvesting compared to closer spacing. Additionally, there was a notable increase in silkworm economic parameters, though no significant differences were observed concerning genotypes, spacing and treatments (Bongale, 2000; Shivaprakash *et al*., 2000). In studies exploring interactions, no significant difference was found in yield and growth parameters. However, the combination of NPK 150:25:50 kg ha^{-1}year^{-1} with a spacing of 120×90 cm was found to be superior compared to 100:50:50 NPK with a spacing of 90×90 cm (Das *et al.*, 1993; Fotedar *et al.*, 1995). Closer spacing (60×60 cm) resulted in higher leaf moisture, nitrogen uptake and leaf and stem yield, while wider spacing yielded significantly higher values for other parameters. Notably, wider plant spacing did not favor leaf and shoot yields (Bongale, 2000).

Devamani *et al.* (2024) recorded micronutrients treated mulberry led to higher values in larval weight, shell weight, rendita and denier, with values of 42.90 g, 0.42 g, 6.14 kg and 2.33 d, respectively. Recommended dose of macro- with micro-nutrients also showed promising results, with a larval weight of 42 g, shell weight of 0.38 g, rendita of 6.2 kg and denier of 2.65 d. For single cocoon weight, highest value showed at 1.88 g. Hence, the current study was conducted to investigate the response of the V_1 and Vishala mulberry varieties to different nutrient application levels at various plant spacings.

Materials and Methods

The study was conducted during 2018-2021 at KSSRDI in Bengaluru, under irrigated conditions. The experiment took place in an established tree mulberry garden, involving two mulberry varieties (V_1 and Vishala) and two different spacings (8ˈ×8ˈ and 10ˈ×10ˈ). The research followed a Randomized Complete Block Design (RCBD) and included four treatments with three replications each. Various growth parameters of mulberry trees were assessed, including the number of branches tree^{-1}, number of leaves branch^{-1}, shoot length, yield and stem yield. Moisture content was also evaluated 52-60 days after fertilizer application, involving the harvesting of fresh and dry leaf and stem weights from the treated trees (80 trees genotype^{-1}). Total leaf weight tree^{-1} crop^{-1} was recorded and subsequently converted into yield hectare^{-1} year^{-1}. Soil chemical analysis was conducted using established methods: Walkley and Black's method (1934) for soil organic carbon, Kjeldahl's method (1883) for nitrogen, Olsen *et al*.'s method (1954) for phosphorus, Jackson's method (1973) for boron and Lindsay and Norvel's method (1978) for micronutrient analysis. Boron estimated by Azomethine-H method (John *et al.*, 1975) and data analysis employed the OP-STAT software, utilizing the split-plot method (Two-way ANOVA). The details of the treatments are as follows:

N_1: 25 t FYM ha^{-1}year^{-1} + 75 t GM ha^{-1}year^{-1}

N_2: 25 t FYM ha^{-1}year^{-1} + 25 t GM ha^{-1}year^{-1} + 50% RDF

N_3: 25 t FYM ha^{-1}year^{-1} + 25 t GM ha^{-1}year^{-1} + 75% RDF

N_4: 25 t FYM ha^{-1}year^{-1} + 100% RDF

Results and Discussion

Mulberry cultivating as a large/dwarf tree with the spacing of 8ˈ×8ˈ to 10ˈ×10ˈ are better suitable plants for conservation of water and soil with small land/area, reduction in runoff during flooding can be up to 10-20% (Du *et al.*, 2001; Shi, 2005) with a crown height of 5ˈ to 6ˈ from the ground level and stem girth of 4 to 5 inches referred to tree mulberry (Fotedar *et al.*, 1995). 3ˈ and 3.5ˈ stump height was the most followed by the farmers as it facilitates them harvesting leaves/shoots and pruning with ease, despite, a study states that 1ˈ to 1.5ˈ stump height is convenient for cultural operations (Sudhakar *et al.*, 2018).

Leaf and Stem Yield

Regarding the genotypes, Vishala exhibited significantly higher leaf yield (27.18 MT) and stem yield (18.42 MT) compared to V_1 (23.24 and 14.47 mt ha^{-1}year^{-1}). Among the various spacings and nutrient levels tested, S_1N_4 (8′×8′ with 25 tons FYM ha^{-1}year^{-1} + 100% RDF) demonstrated the highest leaf and stem yield (29.90 and 19.70 mt ha^{-1}year^{-1}). It was on par with S_1N_3 (8′×8′ with 25 tons FYM ha^{-1}year^{-1} + 25 tons GM ha^{-1}year^{-1} + 75% RDF) (29.46 and 19.07 mt ha^{-1}year^{-1}) followed by S_2N_4 (10′×10′ with 25 tons FYM ha^{-1}year^{-1} + 100% RDF) (28.74 and 18.83 mt ha^{-1}year^{-1}) which was also on par with S_2N_3 (10′×10′ with 25 tons FYM mt ha^{-1}year^{-1} + 25 tons GM ha^{-1}year^{-1} + 75% RDF) (28.34 and 18.45 mt ha^{-1}year^{-1}) (Table 5). In contrast, leaf and stem yield were lower in S_2N_1 (10′×10′ with 25 tons FYM ha^{-1}year^{-1} + 75 tons GM ha^{-1}year^{-1}) (18.50 and 12.08 mt ha^{-1}year^{-1}). These spacing-related findings align with the studies of Magadum *et al.* (2020) and Yadav *et al*. (2020).

No significant differences were observed among interactions in terms of leaf and stem yield, consistent with the findings of Das *et al*. (1993) (Table 2).

Growth Parameters

In terms of genotypes, Vishala displayed significantly higher values for various growth parameters compared to V_1. Specifically, Vishala had a higher number of branches tree^{-1} (35.50 *vs*. 31.48), greater branch length (143.23 cm *vs*. 136.25 cm) and more leaves branch^{-1} (31.69 *vs*. 26.92).

Among the different spacings and nutrient levels, S_2N_4 (10′×10′ with 25 tons FYM ha^{-1}year^{-1} + 100% RDF) demonstrated significantly higher values for the number of branches tree^{-1} (39.80), branch length (153.80 cm) and leaves branch^{-1} (34.53). It was on par with S_2N_3 (10′×10′ with 25 tons FYM ha^{-1}year^{-1} + 25 tons GM ha^{-1}year^{-1} + 75% RDF) (38.52, 150.90 cm and 33.37 respectively), followed by S_1N_4 (8′×8′ with 25 tons FYM ha^{-1}year^{-1} + 100% RDF) (35.73, 146.60 cm and 32.19) which was on par with S_1N_3 (8′×8′ with 25 tons FYM ha^{-1}year^{-1} + 25 tons GM ha^{-1}year^{-1} + 75% RDF) (34.90, 143.50 cm and 31.12 respectively) (Table 5). However, growth parameters were lower in S_1N_1 (8′×8′ with 25 tons FYM ha^{-1}year^{-1} + 75 tons GM ha^{-1}year^{-1}) (26.77, 121.90 cm and 22.96). These findings align with studies by Magadum *et al*. (2020) and Yadav *et al.* (2020), which demonstrate the influence of spacing. Interactions did not yield significant differences in terms of the number of branches tree^{-1}, branch length and leaves branch^{-1}, consistent with the findings of Das *et al*. (1993) (Table 2).

Leaf and Stem Moisture

In terms of genotypes, V_1 exhibited significantly higher leaf and stem moisture content (74.69% and 71.77%), followed by Vishala (69.76% and 67.26%). Regarding the different spacings and nutrient levels, S_2N_1 (10′×10′ with 25 t FYM ha^{-1}year^{-1} + 75 t GM ha^{-1}year^{-1}) recorded notably higher leaf and stem moisture (72.77% and 70.96%) and was on par with S_2N_2 (10′×10′ with 25 t FYM ha^{-1}year^{-1} + 25 t GM ha^{-1}year^{-1} + 50% RDF) (72.61% and 70.68%). This was followed by S_1N_1 (8′×8′ with 25 t FYM ha^{-1}year^{-1} + 75 t GM ha^{-1}year^{-1}) (72.12% and 69.75%), which was on par with S_1N_2 (8′×8′ with 25 t FYM ha^{-1}year^{-1} + 25 t GM ha^{-1}year^{-1} + 50% RDF) (72.06% and 69.33%) (Table 5). Conversely S_1N_4 (8′×8′ with 25 tons FYM ha^{-1}year^{-1} + 100% RDF) displayed lower leaf and stem moisture content (69.87% and 66.18%). Interactions did not yield any significant differences in terms of leaf and stem moisture percentage, consistent with findings by Murthy *et al*. (2013), Das *et al*. (1993) (Table 2).

Genotypes: V_1 vs. Vishala

The Vishala mulberry variety demonstrated a notable superiority in growth and yield parameters. Specifically, it recorded significantly higher numbers of branches tree^{-1} (35.50), longer branch lengths (143.23 cm) and a greater number of leaves branch (31.69). Additionally, Vishala outperformed the V_1 variety in terms of leaf and stem yield achieving 27.18 and 18.42 mt ha^{-1}year^{-1}, respectively. In comparison V_1 achieved values of 31.48, 136.25 cm, 26.92 mt ha^{-1}year^{-1} for branches tree^{-1}, branch length and leaf yield; while 23.24 and 14.47 mt ha^{-1}year^{-1}, respectively for stem yield. Regarding moisture content, V_1 displayed significantly higher leaf and stem moisture percentages (74.69% and 71.77%) in contrast to Vishala (69.76% and 67.26%) (Table 2).

Spacings: 8′×8′ vs. 10′×10′

Among the two spacings evaluated, S_1 (8′×8′) exhibited significantly higher leaf and stem yields (29.90 and 19.70 MT), comparable to S_1 (8′×8′) (29.46 and 19.07 mt ha^{-1}year^{-1}). Conversely, S_2 (10′×10′) recorded significantly higher values for the number of branches tree^{-1} (39.80), branch length (153.80 cm) and leaves branch^{-1} (34.53) and its on par with S_2 (10′×10′) (38.52, 150.90 cm and 33.37 respectively). Similarly, S_2 (10′×10′) displayed significantly higher leaf and stem moisture percentages (72.77% and 70.96%). Notably S_2 (10′×10′) demonstrated lower leaf and stem yields (18.50 and 12.08 mt ha^{-1}year^{-1}). These findings regarding spacing align with studies by Magadum *et al.* (2020) and Yadav *et al.* (2020) (Table 2).

Treatments

Among the four nutrient levels investigated, N_4 (25 tons FYM ha^{-1}year^{-1} + 100% RDF) demonstrated significantly higher growth and yield parameters. Specifically, it achieved superior leaf and stem yields (29.90 and 19.70 mt ha^{-1}year^{-1}) and displayed higher numbers of branches tree^{-1} (39.80), longer branch lengths (153.80 cm) and more leaves branch^{-1} (34.53). It was on par with N_3 (25 tons FYM ha^{-1}year^{-1} + 25 tons GM ha^{-1}year^{-1} + 75% RDF) which achieved comparable results (29.46 and 19.07 mt ha^{-1}year^{-1}) for leaf and stem yields, as well as (38.52, 150.90 cm and 33.37 respectively) for the other parameters.

Meanwhile, N_1 (25 t FYM ha^{-1}year^{-1} + 75t GM ha^{-1}year^{-1}) recorded significantly higher leaf and stem moisture percentages (72.77% and 70.96%), comparable to N_2 (25 t FYM ha^{-1}year^{-1} + 25 t GM ha^{-1}year^{-1} + 50% RDF) which achieved (72.61% and 70.68%). However, N_1 displayed lower leaf and stem yields (18.50 and 12.08 mt ha^{-1}year^{-1}). These observations, as summarized in table 2, reflect the influence of different nutrient levels on growth and yield parameters.

Soil Fertility Status

Similarly, during the initial, first and second years of the experiment, the soil parameters including N, P, K, S, Ca, Mg, Zn, Fe, Mn, Cu and B were notably higher in the 8′×8′ spacing with treatment N_4 (25 t FYM ha^{-1}year^{-1} + 100% RDF) and this

Table 1: Initial soil fertility status of tree mulberry garden, KSSRDI

Sl. No.	Plot no. and Spacing	Variety	Depth	pH	EC (dSm^{-1})	OC (%)	N	P	K	Ca	Mg	S	Zn	Fe	Mn	Cu	B
							($kg\ ha^{-1}$)			(meq./ 100 g soil)		(ppm)					
1	Plot 1 (10′×10′)	Vishala	0-1′	7.0	0.57	0.59	143.07	22.02	160.33	9.63	2.9	9.99	2.56	3.65	5.52	3.03	1.00
2			1′-2′	6.9	0.59	0.59	100.35	22.79	143.28	8.52	1.6	9.08	2.77	2.98	3.24	2.45	0.77
3			Comp. (1′ and 2′)	6.9	0.58	0.46	128.16	19.87	142.66	10.40	2.2	8.33	2.61	3.80	4.51	2.77	0.77
4		V_1	0′-1′	7.0	0.57	0.46	125.44	26.33	147.24	9.32	3.7	9.91	3.26	3.64	5.60	2.64	1.02
5			1′-2′	6.8	0.57	0.51	143.07	25.41	111.84	8.50	2.1	9.41	1.35	1.18	5.72	1.74	0.95
6			Comp. (1′ and 2′)	6.9	0.58	0.32	124.32	21.26	89.93	8.55	2.2	7.69	1.00	0.72	5.52	1.86	0.42
7	Plot 2 (8′×8′)	Vishala	0′-1′	6.8	0.58	0.37	112.89	25.53	168.16	8.91	3.7	11.83	3.09	2.25	5.33	2.66	1.27
8			1′-2′	6.8	0.59	0.42	112.89	26.31	162.20	8.72	2.8	10.48	3.09	1.22	4.25	2.64	0.67
9			Comp. (1′ and 2′)	6.8	0.58	0.42	87.80	25.00	123.45	8.11	3.4	10.09	2.75	2.22	5.12	2.51	0.75
10		V_1	0′-1′	7.0	0.58	0.63	112.89	26.64	120.36	8.42	3.1	11.03	3.34	0.44	6.11	2.95	1.20
11			1′-2′	7.0	0.59	0.34	75.26	25.34	107.63	7.53	2.5	9.11	2.21	2.43	5.44	2.38	0.67
12			Comp. (1 and 2′)	6.9	0.58	0.25	100.35	25.31	101.32	7.52	2.5	8.38	1.35	1.02	5.63	1.96	0.27
13	Plot 3 (8′×8′)	Vishala	0′-1′	6.8	0.59	0.29	130.52	23.63	188.36	9.55	3.2	10.09	3.48	2.19	5.62	2.71	0.90
14			1′-2′	6.8	0.58	0.61	125.44	26.63	180.67	7.62	3.2	9.83	2.55	0.21	4.86	2.21	0.57
15			Comp. (1′ and 2′)	6.7	0.59	0.32	125.44	24.53	146.68	7.43	2.7	8.33	3.06	0.88	5.44	2.59	1.75
16		V_1	0′-1′	6.8	0.58	0.49	200.70	25.62	128.52	9.23	3.5	11.11	1.45	1.97	5.44	2.33	0.42
17			1′-2′	6.8	0.58	0.38	125.44	23.34	85.32	7.32	2.9	10.45	1.33	0.99	5.63	1.96	0.42
18			Comp. (1′ and 2′)	6.8	0.59	0.49	150.52	24.48	100.68	8.53	2.5	8.69	2.13	0.33	5.45	2.04	0.40

[Abbreviation: pH = negative logarithm of hydrogen; EC = electric conductivity; OC = organic carbon; N, P, K = available nitrogen, phosphorus, potash; S = sulphur; Ca = exchangeable calcium; Mg = exchangeable magnesium; Cu = copper; Zn = zinc; Fe = iron and Mn = manganese]

Table 2: Growth and yield parameters of mulberry genotypes as influenced by spacing with different nutrient levels (Pooled data of 8 crops)

Treatment	LY $ha^{-1}year^{-1}$ (mt)	SY $ha^{-1}year^{-1}$ (mt)	No. of branch $tree^{-1}$	Branch length	No of Leaves $shoot^{-1}$	Leaf Moisture (%)	Stem Moisture (%)
G_1	23.24	14.47	31.48	136.25	26.92	74.69	71.77
G_2	27.18	18.42	35.50	143.23	31.69	69.76	67.26
SEm±	0.20	0.26	0.15	0.50	0.23	0.24	0.29
CD @ 5%	0.79	1.06	0.58	2.00	0.91	0.96	1.18
Sub plot							
S_1N_1	19.11	12.64	26.77	121.90	22.96	72.12	69.75
S_1N_2	24.05	15.41	30.01	133.90	26.87	72.06	69.33
S_1N_3	29.46	19.07	34.90	143.50	31.12	71.11	67.57
S_1N_4	29.90	19.70	35.73	146.60	32.19	69.87	66.18
S_2N_1	18.50	12.08	28.59	126.80	24.75	72.77	70.96
S_2N_2	23.59	15.37	33.70	140.50	28.98	72.61	70.68
S_2N_3	28.34	18.45	38.52	150.90	33.37	71.65	68.68
S_2N_4	28.74	18.83	39.80	153.80	34.53	70.22	66.29
SEm±	0.35	0.37	0.46	1.26	0.46	0.30	0.35
CD @ 5%	1.00	1.04	1.32	3.57	1.32	0.84	0.99
Interaction (A×B)							
$G_1S_1N_1$	17.35	10.93	23.43	118.00	21.41	74.85	71.36
$G_1S_1N_2$	20.86	13.69	28.75	129.80	25.45	74.46	71.24
$G_1S_1N_3$	26.15	16.82	33.13	138.80	29.62	74.17	69.65
G_1S1N_4	26.24	16.86	34.49	142.00	30.32	72.64	68.91
$G_1S_2N_1$	17.14	10.82	26.35	126.40	22.82	75.52	73.00
$G_1S_2N_2$	19.86	13.34	31.96	138.40	26.42	75.33	72.72
$G_1S_2N_3$	22.21	14.34	36.36	148.00	29.04	74.21	70.99
$G_1S_2N_4$	25.15	15.94	37.34	148.60	30.28	73.97	69.15
$G_2S_1N_1$	25.89	16.35	30.11	125.80	24.50	69.62	69.25
$G_2S_1N_2$	27.50	17.24	31.26	138.00	28.28	69.51	67.06
$G_2S_1N_3$	31.61	21.32	36.67	148.20	32.62	68.05	65.48
$G_2S_1N_4$	32.29	22.16	36.98	151.20	34.05	68.11	65.11
$G_2S_2N_1$	22.02	13.95	30.83	127.20	26.68	70.06	69.63
$G_2S_2N_2$	27.31	17.06	35.44	142.60	31.53	70.00	69.35
$G_2S_2N_3$	30.44	20.96	40.46	153.80	37.10	68.56	66.12
$G_2S_2N_4$	31.32	21.32	42.26	159.00	38.78	68.16	65.43
SEm±	0.51	0.55	0.63	1.73	0.66	0.46	0.55
CD@5%	NS	NS	NS	NS	NS	NS	NS

[Abbreviation: N = Treatment, S = Spacing, G = Genotype, S_1 = 8′×8′, S_2= 10′×10′, G_1 = V_1, G_2 = Vishala; LY = Leaf yield; SY = Stem yield]

was comparable to the results from N_3 (25 t FYM $ha^{-1}year^{-1}$ + 25 t GM $ha^{-1}year^{-1}$ + 75% RDF). Elevated soil organic carbon (OC) levels were observed in both 8′×8′ and 10′×10′ spacings with treatment N_1 (25 t FYM $ha^{-1}year^{-1}$ + 75 t GM $ha^{-1}year^{-1}$), which were on par with the results from 8′×8′ and 10′×10′ spacings with treatment N_2 (25 t FYM $ha^{-1}year^{-1}$ + 25t GM $ha^{-1}year^{-1}$ + 50% RDF) (Table 1, 3 and 4).

Benefit-Cost Ratio (B:C)

Benefit cost ratio recorded higher in $G_2S_1N_3$ (0.88) followed by $G_2S_1N_4$ (0.87) and low in $G_1S_2N_1$ (0.16) (Table 5).

Table 3: Soil fertility status after one year (4-crops) of treatments in tree mulberry garden, KSSRDI

Treatment	pH	EC (dSm^{-1})	OC (%)	N	P_2O_5	K_2O	Ca	Mg	S	Zn	Fe	Mn	Cu	B
				($kg\ ha^{-1}$)			(meq./ 100 g soil)		(ppm)					
Main Plot														
G_1	6.94	0.64	0.67	248.28	27.55	184.58	10.95	3.92	13.43	1.81	2.48	4.14	0.29	0.72
G_2	6.95	0.64	0.66	247.03	27.80	185.68	10.88	4.00	13.63	1.82	2.48	4.09	0.30	0.74
SEm±	0.01	0.00	0.00	1.81	0.11	1.61	0.12	0.03	0.07	0.00	0.01	0.01	0.01	0.01
CD @ 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub Plot														
S_1N_1	6.96	0.62	0.70	186.20	25.00	127.20	7.20	2.84	10.40	1.28	1.76	2.68	0.17	0.36
S_1N_2	6.92	0.63	0.66	245.00	26.90	166.80	11.10	3.82	12.80	1.67	2.22	4.23	0.28	0.60
S_1N_3	6.93	0.65	0.62	287.80	31.60	229.30	13.20	4.83	16.00	2.20	2.90	4.90	0.41	0.92
S_1N_4	6.9	0.67	0.62	292.60	32.60	238.50	13.10	5.04	16.40	2.27	2.95	5.03	0.43	1.00
S_2N_1	6.97	0.62	0.70	174.60	23.20	122.90	7.30	2.40	10.20	1.28	1.64	2.55	0.16	0.36
S_2N_2	6.97	0.63	0.65	236.80	24.80	153.10	9.40	3.38	12.20	1.56	2.10	4.08	0.24	0.62
S_2N_3	6.95	0.65	0.61	276.90	28.50	220.10	11.70	4.42	14.80	2.10	2.50	4.66	0.34	0.82
S_2N_4	6.96	0.67	0.60	281.30	28.80	223.10	12.50	4.54	15.60	2.16	2.67	4.74	0.34	0.84
SEm±	0.04	0.01	0.01	5.99	0.55	5.91	0.68	0.32	0.55	0.10	0.12	0.14	0.020	0.067
CD @ 5%	NS	NS	0.031	17.01	1.56	16.77	1.94	0.90	1.57	0.20	0.33	0.41	0.057	0.190
Interaction (A×B)														
$G_1S_1N_1$	6.98	0.618	0.68	186.2	25.0	126.2	7.2	2.80	10.2	1.28	1.74	2.72	0.16	0.42
$G_1S_1N_2$	6.88	0.632	0.64	244.0	26.6	166.0	11.6	4.04	12.6	1.64	2.60	4.28	0.26	0.78
$G_1S_1N_3$	6.98	0.654	0.63	287.2	31.4	228.0	13.0	4.32	15.6	2.18	2.88	4.94	0.40	0.88
$G_1S_1N_4$	6.86	0.672	0.63	292.2	32.4	237.2	13.6	4.94	16.2	2.26	2.92	5.06	0.42	0.96
$G_1S_2N_1$	6.98	0.618	0.73	174.4	23.2	123.6	7.4	2.60	10.2	1.28	1.64	2.56	0.16	0.36
$G_1S_2N_2$	6.96	0.632	0.70	244.6	24.8	153.6	10.6	3.78	12.2	1.56	2.82	4.10	0.24	0.70
$G_1S_2N_3$	6.92	0.654	0.68	276.6	28.4	218.2	11.8	4.34	14.8	2.10	2.52	4.66	0.34	0.80
$G_1S_2N_4$	6.96	0.672	0.66	281.0	28.6	223.8	12.4	4.54	15.6	2.16	2.72	4.76	0.34	0.84
$G_2S_1N_1$	6.94	0.618	0.66	186.2	25.0	128.2	7.2	2.88	10.6	1.28	1.78	2.64	0.18	0.42
$G_2S_1N_2$	6.96	0.632	0.64	246.0	27.2	167.6	11.0	4.20	13.0	1.70	2.64	4.18	0.30	0.78
$G_2S_1N_3$	6.88	0.654	0.62	288.4	31.8	230.6	13.4	4.54	16.0	2.22	2.92	4.86	0.42	0.96
$G_2S_1N_4$	6.94	0.672	0.62	293.0	32.8	239.8	12.6	5.14	16.6	2.28	2.98	5.00	0.44	1.04
$G_2S_2N_1$	6.96	0.618	0.72	174.8	23.2	122.2	7.2	2.60	10.2	1.28	1.64	2.54	0.16	0.36
$G_2S_2N_2$	6.98	0.632	0.69	229.0	24.8	152.6	11.4	3.78	12.2	1.56	2.78	4.06	0.24	0.70
$G_2S_2N_3$	6.98	0.654	0.68	277.2	28.6	222.0	11.6	4.34	14.8	2.10	2.48	4.66	0.34	0.80
$G_2S_2N_4$	6.96	0.672	0.67	281.6	29.0	222.4	12.6	4.54	15.6	2.16	2.62	4.72	0.34	0.84
SEm±	0.05	0.010	0.02	8.12	0.74	7.98	0.91	0.42	0.73	0.10	0.16	0.20	0.03	0.09
CD @ 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[Abbreviation: N = Treatment, S = Spacing, G = Genotype, S_1 = 8′×8′, S_2 = 10′×10′, G_1 = V_1, G_2 = Vishala; pH = negative logarithm of hydrogen; EC = electric conductivity; OC = organic carbon; N, P, K = available nitrogen, phosphorus, potash; S = sulphur; Ca = exchangeable calcium; Mg = exchangeable magnesium; Cu = copper; Zn = zinc; Fe = iron and Mn = manganese]

Table 4: Soil fertility status after two years (8-crops) of treatments in tree mulberry garden, KSSRDI

Treatment	pH	EC (dSm^{-1})	OC (%)	N	P_2O_5	K_2O	Ca	Mg	S	Zn	Fe	Mn	Cu	B
				($kg\ ha^{-1}$)			(meq./ 100 g soil)		(ppm)					
Main Plot														
G_1	6.94	0.64	0.70	278.08	30.50	201.38	11.70	4.06	14.10	2.05	2.78	4.4	0.35	0.78
G_2	6.97	0.64	0.70	276.68	30.93	205.55	11.70	4.17	14.45	2.14	2.93	4.4	0.39	0.80
SEm±	0.01	0.00	0.00	1.75	0.12	0.87	0.11	0.03	0.17	0.04	0.03	0.0	0.02	0.01
CD @ 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub Plot														
S_1N_1	6.96	0.62	0.73	201.1	26.1	129.6	7.8	3.05	10.7	1.66	1.89	3.56	0.20	0.60
S_1N_2	6.96	0.63	0.68	297.8	30.7	179.0	11.3	4.18	13.5	2.27	3.03	4.52	0.32	0.78
S_1N_3	6.96	0.65	0.63	336.8	34.7	257.9	14.0	4.98	16.6	2.56	4.16	5.14	0.46	0.96
S_1N_4	6.95	0.67	0.63	343.3	35.5	283.5	14.9	5.10	17.1	2.62	4.32	5.28	0.49	1.00
S_2N_1	6.95	0.62	0.73	196.2	24.8	128.3	7.7	2.75	10.7	1.46	1.84	2.70	0.21	0.56
S_2N_2	6.95	0.63	0.68	252.0	30.1	160.9	11.8	3.94	13.2	1.68	2.93	4.22	0.32	0.71
S_2N_3	6.95	0.65	0.63	295.2	32.3	241.7	14.2	4.89	15.8	2.18	4.12	4.86	0.48	0.90
S_2N_4	6.94	0.67	0.63	296.6	31.5	257.7	14.9	4.96	16.6	2.31	4.16	4.88	0.46	0.90
SEm±	0.03	0.01	0.02	9.19	0.73	7.63	0.78	0.29	0.71	0.11	0.17	0.20	0.05	0.07
CD @ 5%	NS	NS	0.04	26.09	2.08	21.67	2.21	0.81	2.02	0.31	0.47	0.56	0.13	0.18
Interaction (A×B)														
$G_1S_1N_1$	6.96	0.62	0.68	200.2	26.0	129.2	7.8	3.00	10.4	1.60	1.86	3.56	0.18	0.60
$G_1S_1N_2$	6.96	0.63	0.64	306.8	30.4	178.8	12.4	4.32	13.2	2.20	2.92	4.52	0.30	0.84
$G_1S_1N_3$	6.96	0.65	0.63	335.8	34.4	246.0	14.2	4.42	16.2	2.46	3.10	5.14	0.44	0.92
$G_1S_1N_4$	6.94	0.67	0.63	341.8	35.2	282.2	14.2	5.04	16.6	2.56	3.12	5.28	0.46	0.99
$G_1S_2N_1$	6.92	0.62	0.73	196.2	24.8	128.0	7.8	2.72	10.8	1.46	1.84	2.70	0.20	0.38
$G_1S_2N_2$	6.92	0.63	0.70	252.0	30.0	160.2	11.4	3.90	13.2	1.68	3.00	4.22	0.30	0.74
$G_1S_2N_3$	6.92	0.65	0.68	295.2	32.0	232.4	12.6	4.44	15.8	2.16	3.12	4.86	0.46	0.88
$G_1S_2N_4$	6.92	0.67	0.66	296.6	31.2	254.2	13.2	4.64	16.6	2.28	3.26	4.88	0.44	0.88
$G_2S_1N_1$	6.96	0.62	0.66	202.0	26.2	130.0	7.8	3.10	11.0	1.72	1.92	3.56	0.22	0.60
$G_2S_1N_2$	6.96	0.63	0.64	288.8	31.0	179.2	12.2	4.40	13.8	2.34	2.94	4.52	0.34	0.86
$G_2S_1N_3$	6.96	0.65	0.62	337.8	35.0	248.0	13.8	4.54	17.0	2.66	3.48	5.14	0.48	0.96
$G_2S_1N_4$	6.96	0.67	0.62	344.8	35.8	284.8	13.6	5.16	17.6	2.68	3.56	5.28	0.52	1.01
$G_2S_2N_1$	6.98	0.62	0.72	196.2	24.8	128.6	7.6	2.78	10.6	1.46	1.84	2.70	0.22	0.40
$G_2S_2N_2$	6.98	0.63	0.69	252.0	30.2	161.6	12.2	3.98	13.2	1.68	3.04	4.22	0.34	0.76
$G_2S_2N_3$	6.98	0.65	0.68	295.2	32.6	251.0	13.0	4.54	15.8	2.20	3.26	4.86	0.50	0.92
$G_2S_2N_4$	6.96	0.67	0.67	296.6	31.8	261.2	13.4	4.82	16.6	2.34	3.42	4.88	0.48	0.92
SEm±	0.04	0.01	0.02	12.28	0.98	10.13	1.03	0.38	0.96	0.15	0.22	0.26	0.06	0.09
CD @ 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[Abbreviation: N = Treatment, S = Spacing, G = Genotype, S_1 = 8'x8', S_2 = 10'x10', G_1 = V_1, G_2 = Vishala; pH = negative logarithm of hydrogen; EC = electric conductivity; OC = organic carbon; N, P, K = available nitrogen, phosphorus, potash; S = sulphur; Ca = exchangeable calcium; Mg = exchangeable magnesium; Cu = copper; Zn = zinc; Fe = iron and Mn = manganese]

Table 5: Benefit Cost ratio on development of package of practices for tree mulberry cultivation and its popularization

Treatments	Cost of cultivation	Gross return	Net return	B:C ratio
$G_1S_1N_1$	62,049.00	75,010.00	12,961.00	0.21
$G_1S_1N_2$	69,424.00	87,590.00	18,166.00	0.26
$G_1S_1N_3$	74,093.00	110,080.00	35,987.00	0.49
$G_1S_1N_4$	76,763.00	114,020.00	37,257.00	0.49
$G_1S_2N_1$	60,549.00	70,440.00	9,891.00	0.16
$G_1S_2N_2$	69,434.00	83,410.00	13,976.00	0.20
$G_1S_2N_3$	74,089.00	97,180.00	23,091.00	0.31
$G_1S_2N_4$	76,711.00	101,790.00	25,079.00	0.33
$G_2S_1N_1$	62,049.00	95,900.00	33,851.00	0.55
$G_2S_1N_2$	69,424.00	115,140.00	45,716.00	0.66
$G_2S_1N_3$	74,093.00	138,540.00	64,447.00	0.88
$G_2S_1N_4$	76,763.00	144,600.00	67,837.00	0.87
$G_2S_2N_1$	60,549.00	86,680.00	26,131.00	0.43
$G_2S_2N_2$	69,434.00	111,110.00	41,676.00	0.60
$G_2S_2N_3$	74,089.00	125,060.00	50,971.00	0.69
$G_2S_2N_4$	76,711.00	128,070.00	51,359.00	0.67

[Abbreviation: N = Treatment, S = Spacing, G = Genotype, S_1 = 8′×8′, S_2 = 10′×10′, G_1 = V_1, G_2 = Vishala]

Conclusion

When considering the two genotypes along with their respective treatments and spacings, it becomes evident that Vishala, specifically in 8′×8′ spacing with treatment N_4, achieved significantly higher leaf and stem yields. In the case of Vishala, within a 10′×10′ spacing and treatment N_4, there was a noteworthy increase in the number of branches tree^{-1}, the number of leaves shoot^{-1} and shoot length, surpassing other genotypes, spacings and treatments. High leaf and stem moisture percentages were observed in V_1 with 10′×10′ spacing and treatment N_1, comparable to V_1 with 10′×10′ spacing and treatment N_2, when compared to other genotypes, spacings and treatments.

Among the four treatments, N_4 stood out with elevated yield and growth parameters, with the exception of moisture percentage, aligning closely with N_3. Similarly, over the initial, first and second years of the experiment, soil parameters, including N, P, K, S, Ca, Mg, Zn, Fe, Mn, Cu and B, exhibited elevated levels in the 8′×8′ spacing with treatment N_4, remaining consistent with N_3. Soil organic carbon content was notably higher in both 8′×8′ and 10′×10′ spacings with treatment N_1, paralleling the results from 8′×8′ and 10′×10′ spacings with treatment N_2. No significant differences were observed among the genotypes and interactions did not yield significant variations either. Based on these experimental findings, it can be deduced that employing an 8′×8′ spacing with 75% of the recommended fertilizer dose (105:42:42 kg NPK acre^{-1}year^{-1}) is advisable for both V_1 and Vishala mulberry varieties. This translates to adding approximately 31 g of nitrogen, 12.35 g of phosphorus (P_2O_5) and 12.35 g of potassium (K_2O) tree^{-1} crop^{-1}. Furthermore, the application of Farm Yard Manure at a rate of 10 tons acre^{-1}year^{-1}, divided into two split doses during June-July and December-January, is recommended.

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