International Journal of Advanced Biochemistry Research 2026; SP-10(1): 622-628

International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(1): 622-628
www.biochemjournal.com
Received: 21-10-2025
Accepted: 25-11-2025

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Influence of organic nutrient management on growth and yield attributes of mulberry (*Morus* spp.) under temperate conditions

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DOI: https://www.doi.org/10.33545/26174693.2026.v10.i1Sh.7042

Abstract
Mulberry (*Morus spp.*), the primary food source for the silkworm (*Bombyx mori* L.), requires specific nutrient management to maintain high leaf productivity and quality to sustain a good cocoon crop. The study evaluated the influence of purely organic nutrient management on mulberry var. Goshoerami under Kashmir conditions over a period of two years. The treatments involved three organic manures *viz.,* Farm Yard Manure (10 MT/ha/yr), vermicompost (5 MT/ha/yr) and poultry manure (5 MT/ha/yr) alone and in combination with three biofertilizers *viz.,* Nitrogen Fixing Bacteria (NFB), Phosphate Solubilizing Bacteria (PSB) and Potassium Solubilizing Bacteria (KSB). Results revealed that treatment T_{10} (Vermicompost + NFB + PSB + KSB) was significantly superior, recording the highest number of shootlets per plant (133.64), maximum shootlet length (Spring: 36.91 cm and Autumn: 156.12 cm) and maximum fresh weight of 100 leaves (Spring: 369.70 g and Autumn: 395.73 g). Furthermore, T_{10} achieved the highest leaf yield per plant (Spring: 4.47 kg and Autumn: 5.01 kg), showing a substantial increase over the absolute control (Spring: 3.62 kg and Autumn: 3.87 kg). The study concluded that the application of vermicompost integrated with a multi-strain bacterial consortium provides a sustainable and eco-friendly alternative for maximizing mulberry leaf yield under temperate climatic condition of Kashmir as against conventional practice.

Keywords: Mulberry, organic, yield, sustainable

Introduction
Mulberry (M*orus spp.*), a fast growing woody perennial plant belonging to the family *Moraceae*, is widely distributed from temperate and sub-tropical regions of the Northern hemisphere to the tropics of the Southern hemisphere (Rafiqui *et al.*, 2024) [8]. The foliage of mulberry is valued for being the primary food for silkworm (*Bombyx mori L.*) which produce high-quality silk yarn in the form of the cocoon and thus supporting the silk industry. Therefore, maximization of leaf yield and improvement in the leaf quality are considered to be the most important steps for improving the cocoon production which in turn relies upon the soil type, availability of plant nutrients, plant variety and agro-ecological conditions.

Leaf productivity is highly dependent on soil nutrients and their replenishment through various organic and inorganic sources becomes imperative for maintaining soil fertility and hence sustainable crop productivity. The plant nutrients, particularly NPK, are supplied to mulberry mainly through Urea, Diammonium Phosphate (DAP) and Muriate of Potash (MOP) and feebly through farmyard manure (FYM). This is a big cause of worry as it greatly affects the soil and water resources (Rashmi *et al.*, 2020) [11]. Moreover, availability and increased cost of cultivation with fertilizer application often becomes a bottleneck in mulberry cultivation. Nonetheless, there is an increased demand for improved crop yield with minimal impact on the soil fertility in present times which has led to innovation in crop cultivation practices (Arumugavel *et al.*, 2023) [1]. In this scenario, the application of organic farming concept in mulberry cultivation has tremendous potential. This system would reduce cost of farming while maintaining soil productivity and the health of plant and animal. Therefore, adoption of organic farming in mulberry can be helpful for better economic returns by ensuring quality leaf production leading to a more sustainable cocoon production.

The temperate climatic conditions of Kashmir present unique challenges and opportunities for mulberry cultivation necessitating region-specific studies to optimize yield and quality while further facilitating access to the global niche market of organic silk. A plethora of research on mulberry farming and nutrition management system, particularly integrated nutrient management, is available (Sudhakar *et al.*, 2000; Setua *et al.*, 2007; Ram *et al.*, 2018; Mahesh *et al.*, 2021) [13, 12, 7, 5], but no comprehensive, low cost, eco-friendly and improved package of practices is available in respect of purely organic farming approach under temperate climatic conditions thereby necessitating the conduct of such studies in the region.

Material and Methods

The experiment was undertaken on mulberry plantation maintained under rain-fed conditions during spring and autumn seasons of 2022 and 2023 as per the following details:

Experimental site	:	CTS, Mirgund
Target Crop	:	Mulberry
Test Genotype	:	Goshoerami
Type of plantation	:	Dwarf
No. of treatments	:	16
No. of replications	:	03
No. of plants/ replications	:	04
Design of experiment	:	RBD

The treatment details are given below:

T%1	:	FYM
$T_{\%2}$	:	FYM + NFB
$T_{\%3}$	:	FYM + PSB
T_4	:	FYM + KSB
T_5	:	FYM + NFB + PSB + KSB
T_6	:	Vermicompost
T_7	:	Vermicompost + NFB
T_8	:	Vermicompost + PSB
T_9	:	Vermicompost + KSB
T_{10}	:	Vermicompost + NFB + PSB + KSB
T_{11}	:	Poultry manure
T_{12}	:	Poultry manure + NFB
T_{13}	:	Poultry manure + PSB
T_{14}	:	Poultry manure + KSB
T_{15}	:	Poultry manure + NFB + PSB + KSB
T_{16}	:	Absolute control

Three organic manures *viz.*, Farm Yard Manure (FYM), Poultry manure and Vermicompost were tested alone and in combination with three bacterial biofertilizers *viz.*, Nitrogen Fixing Bacteria (NFB: *Azotobacter chroococcum*), Phosphorus Solubilising Bacteria (PSB: *Bacillus subtilis*) and Potassium Solubilising Bacteria (KSB: *Pseudomonas extremorientalis*). The treatments were applied around the plant and mixed well with the soil during the first fortnight of March. FYM was applied at the rate of 10 tons per hectare. Vermicompost and poultry manure was applied at the rate of 5 tons per hectare. No chemical fertilizer was applied in any of the treatments. Treatment 16 acted as absolute control with no manure/fertilizer application. The biofertilizer solution was separately mixed in a carrier (manure) in the ratio of 1:10 *i.e.*, 1 litre of solution was mixed with 10 kg of carrier and applied at the rate of 1kg/ plant near the root zone.

The following growth and yield parameters of mulberry were recorded in Spring (May-June) and Autumn (August-September) seasons coinciding with fifth instar of two commercial silkworm rearings of the region:

- **No. of shootlets/branches per plant**
  The shootlets and branches respectively during spring and autumn were counted manually.
- **Average shootlet/ shoot length per plant (cm)**
  All the shootlets and branches respectively during spring and autumn were measured by means of a measuring tape and the average was calculated by taking mean of all the values recorded.
- **Fresh weight of 100 leaves (g)**
  Composite sampling of 100 leaves compromising almost equal number of tender, medium and coarse leaves was harvested early in the morning and weighed immediately.
- **Leaf yield per plant (kg)**
  Leaf yield was taken by harvesting and weighing full leaf of three plants per treatment per replication.

Results

No. of shootlets/branches per plant

The number of shootlet per plant increased by the use of organic nutrient sources as compared to absolute control (T_{16}). During spring, number of shootlets was the highest (133.64) in T_{10} being statistically at par with T_{15} with a value of 132.92. T_{12} occupied second rank with a value of 130.42. Lowest number of shootlets per plant (121.96) was recorded in T_{16} (Table-1). However, during autumn, the number of branches per plant showed non-significant difference among different treatments (Table 1 and Fig.1).

Average shootlet/ shoot length per plant (cm)

The average shootlet length per plant increased by the use of organic nutrient sources as compared to absolute control (T_{16}). In spring, the average shootlet length per plant was the maximum (36.91 cm) in T_{10} being statistically significant over rest of the treatments. T_7 occupied second rank with value of 36.31 cm. However, T_{15} (36.71 cm) was statistically at par with T_{10} and T_7. Minimum shootlet length per plant (33.18 cm) was recorded in T_{16} (Table-1).

During autumn, the average shoot length per plant was the maximum (156.12 cm) in T_{10} being statistically significant over rest of the treatments. T_{15} occupied second rank with value of 154.33 cm. Minimum shootlet length per plant (120.84 cm) was recorded in T_{16} (Table and Fig.2-3).

Table 1: Effect of different organic nutrient sources on growth of mulberry (Pooled over 2022 and 2023)

Treatments	No. of shootlets per plant (Spring)	No. of branches per plant (Autumn)	Average shootlet length per plant (cm) Spring	Average shoot length per plant (cm) Autumn
T%1: FYM	124.82^{e}	32.86	34.28^{e}	134.49^{g}
$T_{\%2}$: FYM + NFB	126.81^{d}	33.02	35.42^{cd}	140.24^{f}
$T_{\%3}$: FYM + PSB	126.39^{d}	32.41	35.43^{cd}	140.29^{f}
T_4: FYM + KSB	125.91^{de}	32.91	35.28^{c}	140.99^{f}

T_5: FYM + NFB + PSB +KSB	129.15[c]	33.11	35.98[bc]	145.23[e]
T_6: Vermicompost	126.93[d]	33.06	35.29[d]	141.35[f]
T_7: Vermicompost+ NFB	130.21[bc]	32.03	36.31[b]	150.63[c]
T_8: Vermicompost + PSB	129.67[bc]	32.82	36.11[bc]	150.03[cd]
T_9: Vermicompost + KSB	129.88[bc]	33.31	36.13[bc]	149.42[cd]
T_{10}: Vermicompost + NFB + PSB+KSB	133.64[a]	33.53	36.91[a]	156.12[a]
T_{11}: Poultry Manure	126.20[d]	32.97	35.25[d]	141.32[f]
T_{12}: Poultry Manure + NFB	130.42[b]	33.47	35.96[bc]	148.48[d]
T_{13}: Poultry Manure + PSB	128.41[c]	32.74	36.03[bc]	149.24[d]
T_{14}: Poultry Manure + KSB	129.63[bc]	33.08	35.79[c]	147.98[d]
T_{15}: Poultry Manure + NFB + PSB+KSB	132.92[a]	33.08	36.71[ab]	154.33[b]
T_{16}: Absolute Control	121.96[f]	32.17	33.18[f]	120.84[h]
C.D.($p \leq 0.05$)	1.171	NS	0.451	1.314

*Figures superscripted with the same letter/s in the column do not differ significantly

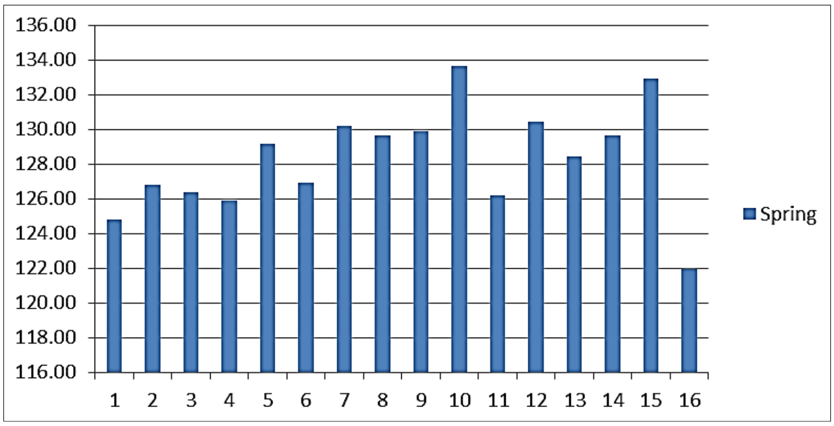

Fig 1: Graphical representation of the effect of organic nutrient sources on number of shootlets per plant of mulberry

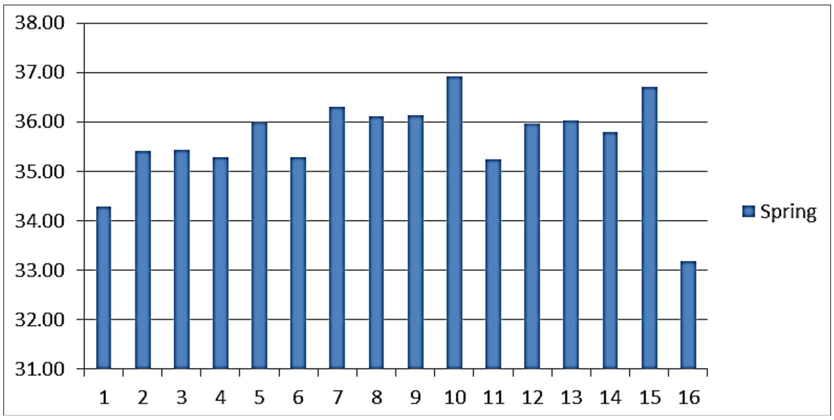

Fig 2: Graphical representation of the effect of organic nutrient sources on average shootlet length per plant of mulberry

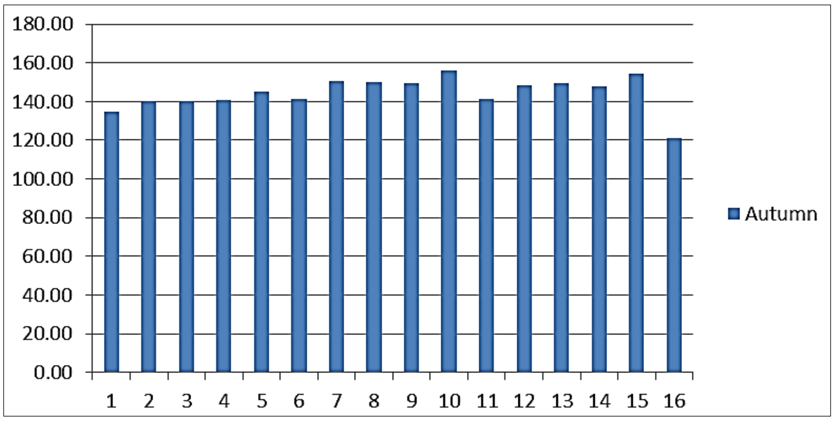

Fig 3: Graphical representation of the effect of organic nutrient sources on average shoot length per plant of mulberry

Fresh weight of 100 leaves (g)

The fresh weigh of 100 leaves in general increased by the use of organic nutrient sources as compared to absolute control (T_{16}). During spring, it was the maximum (369.70g) in T_{10} being statistically significant over rest of the treatments. T_{15} occupied second rank with a value of 358.31g. Minimum value of 313.21g was recorded in T_{16} (Table 2 and Fig. 4).

During autumn, the fresh weight of 100 leaves was in general higher than that of spring. It was the maximum (395.73g) in T_{10} being statistically significant over rest of the treatments. T_{15} occupied second rank with a value of 384.50g. Lowest value of 325.27g was recorded in T_{16} (Table 2 and Fig. 4).

Leaf yield per plant (kg): The leaf yield per plant in general increased by the use of organic nutrient sources as compared to absolute control (T_{16}). During spring, it was the maximum (4.47 kg) in T_{10} being statistically significant over rest of the treatments. T_9 (4.34 kg), T_8 (4.34kg), T_{14} (4.31 kg), T_{13} (4.30kg) and $T_{\%2}$ (4.28kg) were statistically at par and together occupied second rank. However, T_{15} (4.41 kg), T_5 (4.38kg), T_7 (4.37 kg) and T_{12} (4.35 kg) were statistically at par with T_{10}, T_9, T_8, T_{14}, T_{13} and $T_{\%2}$. Minimum value of 3.62 kg was recorded in T_{16} (Table2 and Fig.5)

During autumn, the leaf yield per plant was in general higher than that during spring. It was the maximum (5.01 kg) again in T_{10} which was statistically significant over rest of the treatments. T_5, T_{12}, T_8 and T_9 were statistically at par and together occupied second rank with a value of 4.84, 4.84, 4.82 and 4.80 kg respectively. However, T_{15} (4.97 kg) and T_7 (4.87 kg) were statistically at par with T_{10}, T_5, T_{12}, T_8 and T_9. Minimum value of 3.87 kg was recorded in T_{16} (Table2 and and Fig.5).

Table 2: Effect of different organic nutrient sources on fresh weight of 100 leaves and leaf yield of mulberry (Pooled over 2022 and 2023)

Treatments	Fresh weight of 100 leaves g		Leaf yield per plant kg	
	Spring	Autumn	Spring	Autumn
T%1: FYM	326.75^{i}	344.97^{j}	4.08^{c}	4.55^{c}
$T_{\%2}$: FYM + NFB	338.34^{f}	357.79^{g}	4.28^{bc}	4.70^{bc}
$T_{\%3}$: FYM + PSB	333.48^{g}	351.66^{hi}	4.24^{bc}	4.63^{c}
T_4: FYM + KSB	333.84^{g}	349.95^{i}	4.24^{bc}	4.63^{c}
T_5: FYM + NFB + PSB +KSB	345.85^{d}	366.31^{d}	4.38^{ab}	4.84^{b}
T_6: Vermicompost	335.91^{fg}	357.51^{g}	4.27^{bc}	4.72^{bc}
T_7: Vermicompost+ NFB	349.51^{c}	372.61^{c}	4.37^{ab}	4.87^{ab}
T_8: Vermicompost + PSB	343.67^{de}	363.96^{e}	4.34^{b}	4.82^{b}
T_9: Vermicompost + KSB	343.71^{de}	365.36^{de}	4.34^{b}	4.80^{b}
T_{10}: Vermicompost + NFB + PSB +KSB	369.70^{a}	395.73^{a}	4.47^{a}	5.01^{a}
T_{11}: Poultry Manure	330.53^{h}	352.37^{h}	4.16^{c}	4.62^{c}
T_{12}: Poultry Manure + NFB	345.71^{d}	365.28^{de}	4.35^{ab}	4.84^{b}
T_{13}: Poultry Manure + PSB	341.06^{ef}	360.10^{f}	4.30^{b}	4.75^{bc}
T_{14}: Poultry Manure + KSB	342.79^{e}	360.75^{f}	4.31^{b}	4.77^{bc}
T_{15}: Poultry Manure + NFB + PSB +KSB	358.31^{b}	384.50^{b}	4.41^{ab}	4.97^{ab}
T_{16}: Absolute Control	313.21^{j}	325.27^{k}	3.62^{d}	3.87^{d}
C.D.($p \leq 0.05$)	2.909	2.087	0.113	0.141

*Figures superscripted with the same letter/s in the column do not differ significantly

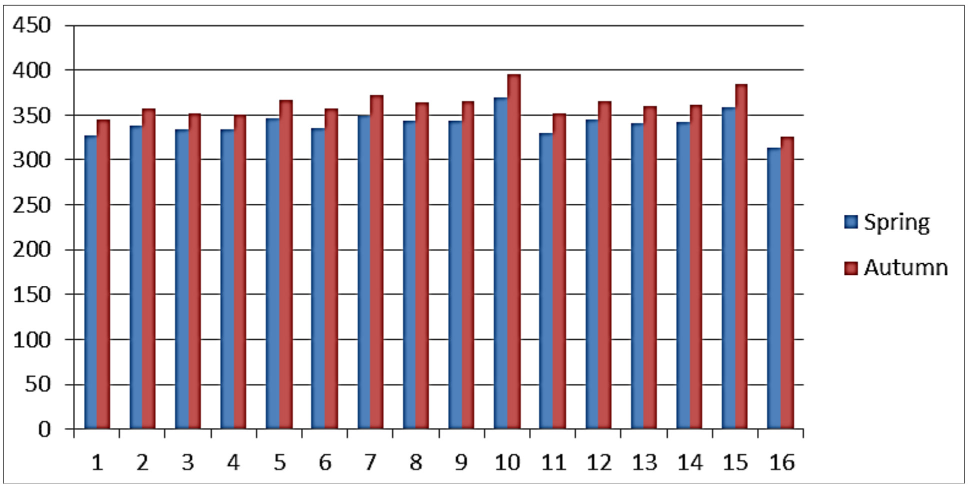

Fig 4: Graphical representation of the effect of organic nutrient sources on fresh weight of 100 leaves of mulberry

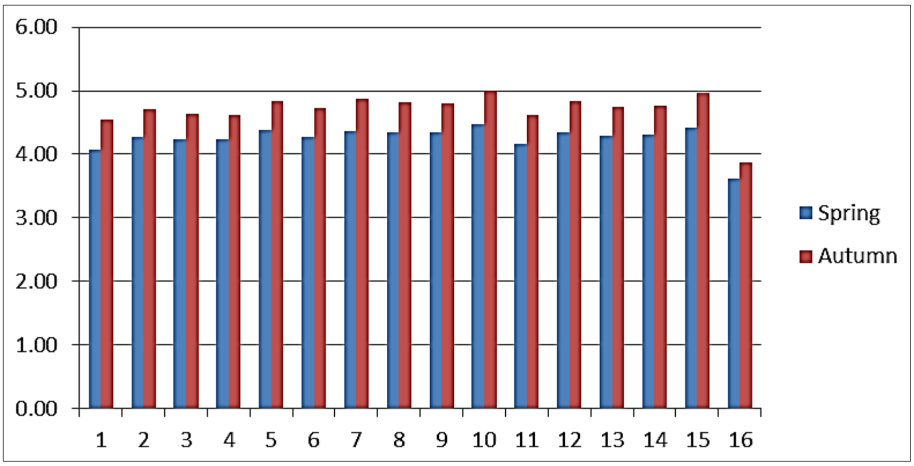

Fig 5: Graphical representation of the effect of organic nutrient sources on leaf yield of mulberry

Discussion

The observations recorded during the study are discussed here under

The number of shootlets/branches per plant is a primary morphometric indicator of the vegetative vigor and canopy architecture of the mulberry tree. It is directly linked to the total leaf-bearing capacity of the plant as a higher number of branches increases the available surface area for foliage development and also indicates a healthy and active root system. In the present investigation, during spring, the number of shootlet per plant was the highest (133.64) in T_{10} being statistically at par with T_{15} with a value of 132.92. The lowest number of shootlets per plant was recorded in T_{16} (121.96). However, during autumn, the number of branches per plant showed non-significant difference among different treatments. The results are supported by the findings of Nandini and Prakasha (2022) [7] who reported that organic nutrient management in mulberry through mulberry stalk biochar in combination with other manures significantly increased number of shoots per plant. Similar results have been reported by Farooq (2024) in mulberry with the application of microbial consortium. The superior shootlet number recorded in T_{10} and T_{15} could be attributed to a sustained release of nutrients and humic substances in vermicompost that promote long-term root-to-shoot signalling while as rapid burst of uric acid and concentrated nitrogen in poultry manure might have stimulated vegetative flush. Simultaneously, microbial consortium might have produced phytohormones like Indole-3-Acetic Acid (IAA) which in high concentrations at the root level stimulates the production of cytokinins. These cytokinins stimulate the outgrowth of lateral axillary buds (Tan *et al.*, 2019) [15].

Average shoot length is a vital vegetative parameter that directly determines the vertical growth and overall biomass accumulation of the mulberry plant. Shoot elongation is a sensitive indicator of the plant's nitrogen and phosphorus status as these nutrients are essential for the synthesis of structural proteins and genomic material during the rapid growth phase of the terminal buds (Wang *et al.*, 2024; Xu *et al.*, 2025) [16, 17]. Generally, longer shoots are highly desirable as they provide more nodes for leaf attachment thereby increasing the total leaf-bearing area. In the present investigation, the average shootlet length per plant was the maximum (36.91 cm) in T_{10} being statistically significant over rest of the treatments. The minimum shootlet length per plant was recorded in T_{16} (33.18 cm). During autumn, the average shoot length per plant was maximum (156.12 cm) in T_{10} being statistically significant over rest of the treatments. The minimum shootlet length per plant was recorded in T_{16} (120.84 cm). These findings are supported by Mahesh *et al.* (2021) [5] who reported significantly higher shoot height with more number of shoots per plant in V1 mulberry variety when recommended practice is supplemented with vermicompost. The significantly superior shoot length recorded in T_{10} across both seasons could be attributed to the enhanced synthesis of plant growth promoters such as Gibberellins and Auxins induced by the vermicompost-biofertilizer interaction. The diverse microflora present in vermicompost along with microbial consortium are prolific producers of phytohormones that stimulate cell elongation and division at the apical meristem. This could also be attributed to a possible overall improvement in soil moisture, organic matter and soil nutrient status in this treatment over rest of the treatments.

The fresh weight of 100 leaves is a critical yield component that reflects the individual leaf's density and succulence. A higher weight per leaf indicates greater moisture making the foliage more efficient for silkworm rearing ultimately translating into increased efficiency of leaf conversion into larval biomass and silk. In the present investigation, during spring, the fresh weigh of 100 leaves was the maximum (369.70 and 395.73g during spring and autumn respectively) in T_{10} being statistically significant over rest of the treatments. The minimum value was recorded in T_{16} (313.21 and 325.27g). Similar results were reported by Sujathamma *et al.* (2014) [14] showed significant increase in weight of 100 fresh leaves in all the treatments with organic manures (Aishwarya granules, Biophophos granules, Biopotash granules and New Suryamin) over control. The results also receive support from the findings of Farooq (2024) [3] who reported significant improvement in fresh weight of 100 leaves in mulberry with the use of microbial consortium over control. Significantly higher maximum fresh weight of 100 leaves recorded in T_{10} could be attributed to the synergistic effect of enhanced nutrient uptake and improved plant-water relations. Vermicompost is rich in nutrient and other plant growth-promoting substances such as auxins and cytokinins which stimulate cell division leading to succulent leaf. This is supplemented by the activity of microbial consortium that might have ensured a steady supply of nitrogen for protein synthesis and potassium for osmoregulation. Furthermore, this treatment might have also improved soil physical properties and moisture-holding capacity of soil allowing consistent hydration of the plant and hence succulent foliage.

Leaf yield per plant is the represents the final economic output of the mulberry cultivation. This parameter integrates the plant's ability to capture solar energy, absorb soil nutrients and convert them into harvestable biomass. Leaf yield is the most significant factor determining the carrying capacity of a silkworm rearing house, the number of silkworm larvae that can be successfully reared per unit area. In the present investigation, during spring, the leaf yield per plant was the maximum (4.47 and 5.01 kg during spring and autumn respectively) in T_{10} being statistically significant over rest of the treatments. Minimum value was recorded in T_{16} (3.62 and 3.87 kg during spring and autumn respectively). These findings supported by Padma and Sukumar (2015) who reported significant improvement in leaf yield of V1 mulberry variety in treatments receiving combined inoculation of microorganisms (*Azotobacter* + P-solubilizers + P-mobilizers-VAM + K-mobilizing bacteria) at reduced NPK (75%). Similar findings are reported by Mala and Chandrashekhar (2020) [6] and Arumugavel *et al.* (2023) [1] through the use of manures and biofertilizers. A significant increase in leaf yield of mulberry through the use of phyto-mulches has also been reported (Ganie *et al.*, 2025) [4]. The statistically superior leaf yield in T_{10} could be attributed to the improvements observed in primary growth drivers such as increase in shootlet number per plant, average shootlet/ branch length per plant and fresh weight of 100 leaves. The synergistic interaction between the nutrient-rich vermicompost and the bio-fertilizer consortium created a "priming effect" in the rhizosphere which might have enhanced nutrient bioavailability and uptake efficiency. The nitrogen fixed by *Azotobacter* might have directly fueled the vegetative expansion while Phosphorus (PSB) and Potassium (KSB) provided the metabolic energy and osmotic pressure required for the development of a dense, lush canopy. A similar increase in mulberry leaf yield due to application of vermicompost/ vermicompost+ biofertlizer as compared to other nutrient sources has been reported by Rao *et al.* (2005) [10] and Chowdhury *et al.* (2009) [2].

Conclusion

The study concludes that T_{10} (Vermicompost + NFB + PSB + KSB) resulted in superior growth and yield parameters of mulberry with highest/ maximum number of shootlets per plant, average shootlet length, average shoot length, weight of 100 leaves and leaf yield per plant across both the seasons. Therefore, the integration of vermicompost with a tripartite bacterial consortium is recommended to optimize leaf productivity as against conventional practice.

Competing interest

The authors declare no conflict of interest in the publication of this manuscript.

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