**Foliar Application of Multi-Nutrient Mixture for Growth and Productivity in Mulberry**

**ABSTRACT**

Foliar feeding, the application of nutrients directly to plant leaves, has emerged as a important technique for improving the crop productivity, particularly in mulberry cultivation. This method addresses nutrient deficiencies in soils with poor fertility, where traditional soil fertilization is often inadequate. Foliar feeding allows for rapid nutrient absorption, effectively mitigating soil deficiencies and enhancing plant vigour and productivity. Balanced nutrition, particularly with macronutrients like nitrogen (N), phosphorus (P), and potassium (K), alongside essential micronutrients such as zinc (Zn) and boron (B), is crucial for optimal growth and quality of mulberry leaves, which are vital for enhancing leaf quality in mulberry. Foliar spray of multi-nutrient formulation could supply the balanced nutrition to the crop. Evaluated two different multi-nutrient formulations (MNF-I and MNF-II with 0.25, 0.50, 0.75 concentration) through foliar application in mulberry. The study revealed that MNF-I at 0.75% significantly improved leaf yield and economic returns compared to control (no multi-nutrient application). The results demonstrated enhanced total soluble protein and sugar content in leaves, critical for silkworm nutrition. Additionally, improvements in chlorophyll content and moisture retention were observed, supporting the nutritional quality of the leaves. The findings underscore the effectiveness of foliar fertilization in optimizing nutrient use efficiency and overcoming soil-related limitations. The study advocates for the adoption of tailored multi-nutrient formulations to bolster sustainable sericulture practices. Overall, this study highlights the potential of foliar feeding as a viable strategy for enhancing mulberry productivity and supporting the sericulture industry sustainably.

**Keywords**: Foliar feeding, chlorophyll content, mulberry productivity, crop productivity

**Introduction**

Foliar feeding, the application of nutrients directly to plant leaves, has gained prominence as an effective horticultural technique. This method is particularly beneficial in addressing nutrient deficiencies in soils with poor fertility, where traditional soil fertilization alone often proves insufficient. While soil amendments improve nutrient availability, foliar feeding complements these efforts by rapidly delivering essential nutrients to plants and mitigating soil deficiencies within a shorter timeframe (Fageria et al., 2009).

The significance of nutrient application in mulberry cultivation cannot be overstated. Balanced nutrition, especially involving macronutrients like nitrogen (N), phosphorus (P), and potassium (K), supports vital physiological processes, enhancing plant vigour and productivity. Micronutrients, including zinc (Zn), boron (B), copper (Cu), and molybdenum (Mo), also play specific roles in plant growth, quality improvement, and nutrient uptake (Nandita et al., 2020). However, when fertilizers are applied solely through the soil, a significant portion may become unavailable due to leaching, fixation, or adverse soil reactions, necessitating higher quantities to achieve the desired effect.

Foliar fertilization provides a practical solution to these limitations. Numerous studies have demonstrated the efficacy of foliar nutrient application in correcting deficiencies and enhancing plant growth and productivity. For instance, Zn foliar application has been shown to improve Zn concentration in edible parts (Cakmak, 2008), while B application effectively addresses deficiencies under water-stressed conditions (Mortvedt, 2000). This method ensures rapid nutrient absorption through leaf cuticles or stomata, bypassing soil-related constraints and facilitating immediate availability to plants (Brown and Shelp, 1997; Nandita et al., 2022).

In mulberry cultivation, the quality and yield of leaves are crucial for optimal growth and development of silkworms (*Bombyx mori*), which feed exclusively on mulberry leaves. Research has consistently highlighted the positive impacts of foliar nutrition on crop yield and quality (Shete et al., 2018; Chetana Banasode and Math, 2018; Kar et al., 2017; Deepa Devi and Shanthi, 2012). Specifically, foliar application of multi-nutrient formulations has shown promise in enhancing the genetic potential of crops, increasing productivity, and improving nutrient use efficiency.

Recent advancements in water-soluble fertilizers, such as Polyfeed (19:19:19) and Potassium Nitrate (13:00:45), have further bolstered the adoption of foliar feeding. These specialty fertilizers, with their high solubility and low salt index, are tailored for foliar application and can be customized to meet crop-specific nutrient requirements at various growth stages (Mona et al., 2012). Multi-nutrient mixtures, combining NPK with other micronutrients, provide a holistic approach to site-specific nutrient management, correcting deficiencies and fostering robust plant growth.

Keeping in mind about the growing importance of foliar feeding in modern agriculture and sericulture, there is a pressing need to develop effective multi-nutrient formulations tailored for mulberry. The present study aimed to formulate and evaluate the efficacy of multi-nutrient mixtures for improving leaf yield and quality in mulberry, ultimately contributing to sustainable sericulture practices.

**Materials and Methods**

**Study area and Climatic conditions**

The experiment was conducted in a well-established mulberry garden of S1635 variety planted with a spacing of 3'x3' at CSB-Central Sericultural Research and Training Institute, Berhampore, located in the Northern zone of West Bengal, India (Latitude: 24º 05' N, Longitude: 88º 15' E) during the period of June to August 2019. The average annual temperature in the region is approximately 26.20°C, with an average annual rainfall of 1344 mm.

During the experimentation period, the total rainfall received was 379.20 mm. The monthly mean maximum temperature fluctuated between 35°C and 33°C, while the minimum temperature ranged from 28°C to 26°C. Relative humidity varied monthly with morning averages from 89.42% to 83.29% and evening averages from 83.57% to 73.71%. Monthly mean sunshine hours ranged from a high of 4.94 hours to a low of 1.88 hours.

**Preparation of Multi-Nutrient Formulations (MNF)**

Two distinct multi-nutrient formulations, MNF-I and MNF-II, were created using various water-soluble fertilizers. The components were as follows:

* **MNF-I**: All 19 (19% N, 19% P₂O₅, 19% K₂O) and Potassium Nitrate (13% N, 45% K₂O).
* **MNF-II**: Mono Ammonium Phosphate (12% N, 61% P₂O₅), Sulphate of Potash (50% K₂O), and Urea (46% N).

A stock solution of the multi-nutrient formulation was prepared with a nutrient ratio of N:P₂O₅: K₂O at 72:60:120 for both MNF-I and MNF-II. From this stock solution, various concentrations (0.25%, 0.50%, 0.75%, 1.0%, 2.0%, and 5.0%) were formulated and tested for phyto-suitability by spraying on mulberry leaves. Observations over one week revealed that concentrations at or above 1% caused scorching and necrotic spots on the leaves, leading to their exclusion from further testing. The remaining concentrations (0.25%, 0.50%, and 0.75%) were subsequently evaluated through foliar application in field experiments.

**Field Experiment**

Table 1 : The initial soil nutrient status before the start of the experiment:

|  |  |
| --- | --- |
| Soil Parameter | Value |
| pH | 7.55 |
| Electrical Conductivity (EC) | 0.24 dS m⁻¹ |
| Organic Carbon | 0.75% |
| Available Nitrogen | 142 kg ha⁻¹ |
| Available Phosphorus | 63 kg ha⁻¹ |
| Available Potassium | 551 kg ha⁻¹ |

Table 2: Treatment details

|  |  |
| --- | --- |
| **Treatment** | **Detail** |
| T1 | 0.25% MNF-I Foliar Spray |
| T2 | 0.50% MNF-I Foliar Spray |
| T3 | 0.75% MNF-I Foliar Spray |
| T4 | 0.25% MNF-II Foliar Spray |
| T5 | 0.50% MNF-II Foliar Spray |
| T6 | 0.75% MNF-II Foliar Spray |
| T7 | Control (No Foliar Spray) |

Treatments were applied twice on the 25th and 35th days post-pruning, while the control received no treatment. The recommended dose of 336 kg N ha-1, 180 kg P2O5 ha-1 and 112 kg K2O ha-1 were applied through urea, diammonium phosphate and muriate of potash respectively in both treatments and control plots on 15th day post-pruning. All other standard recommended agronomic practices were followed uniformly in both treatments and control plots.

**Data collection**

Ten plants were randomly selected from each net plot area within each treatment group for biometric observations. The following observations were recorded to assess the impact of MNF foliar spray on growth and development in mulberry.

* Number of shoots/plant
* Longest shoot length (cm)
* Number of leaves/shoot
* Leaf weight (g/plant)
* Leaf yield (Kg/ac)

Leaf quality parameters like moisture content (%), total soluble protein content, and SPAD value were also recorded post pruning. Economic parameters such as cost of cultivation, gross income, and benefit-cost ratio were worked out to study the economic impact of MNF foliar spray in mulberry cultivation.

**Statistical Analysis**

The experiment was conducted under randomized block design (RBD) with seven treatments and three replications under each treatment. Data collected from the experiments underwent statistical analysis using analysis of variance (ANOVA) as outlined by Gomez and Gomez (2010). Significant treatment differences were determined using F-tests at a p ≤0.05 probability level, with critical differences calculated accordingly; non-significant differences were denoted as NS.

**Results and Discussion**

The results of the study highlight the importance of foliar fertilization in enhancing the growth, yield, and quality of mulberry leaves. Foliar application of MNF-I and MNF-II significantly outperformed the control treatment (T7), whereas MNF-I at 0.75% (T3) demonstrated the highest effectiveness. The findings align with earlier research suggesting that foliar feeding bypasses soil constraints, such as nutrient immobilization and ensured the rapid uptake of nutrients through leaf stomata and cuticles (Cakmak, 2008; Mortvedt, 2000; Khatoon et al., 2021). This method provides an efficient pathway for supplying essential macro and micronutrients, particularly in soils with suboptimal fertility, as observed in the experimental site (Nandita et al., 2023).

The observed increase in leaf yield, particularly in T3 (3481 kg ac⁻¹ crop⁻¹), supports previous studies that underline the efficacy of foliar sprays in optimizing nutrient use efficiency. Singhvi et al. (2001) documented significant improvements in mulberry leaf yield and protein content with foliar applications of micronutrient formulations. Similarly, Ahmed et al. (2018) demonstrated that a combination of basal NPK fertilization with foliar sprays sustained higher mulberry productivity, corroborating the enhanced growth metrics observed in T3 and T4.

**Table 3. Effects of foliar spray of multi-nutrient mixture on leaf yield attributes in mulberry**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Treatments | Number of leaves | Number of shoots | Max. Shoot length | Leaf weight | Shoot weight |
| (cm) | (g plant-1) | (g plant-1) |
| T1-MNF-I:0.25% FS | 17.6d | 15bc | 144.1d | 584e | 627d |
| T2-MNF-I:0.50% FS | 18.3cd | 16.4ab | 149.7bc | 622c | 639c |
| T3-MNF-I:0.75% FS | 20.6ab | 17.5a | 151.5ab | 705a | 713a |
| T4-MNF-II:0.75% FS | 21.2a | 16.5ab | 154.8a | 644b | 673b |
| T5-MNF-II:0.50% FS | 20.1abc | 16.3ab | 151.3ab | 635b | 643c |
| T6-MNF-II:0.25% FS | 18.8bcd | 15.6b | 146.4cd | 608d | 637cd |
| T7- No FS (Control) | 15.41e | 13.6c | 131.25e | 437f | 424e |
| SE(D) | 1.15 | 0.73 | 5.57 | 36.04 | 34.97 |
| CD@5% | 2.46 | 1.57 | 11.94 | 77.36 | 75.02 |

Note: MNF: Multi Nutrient Formulation FS: Foliar Spray

In terms of biochemical quality, treatments T3 and T4 significantly enhanced total soluble protein and sugar content, key indicators of leaf nutritive value for silkworms (*Bombyx mori*). Previous research by Deepa et al. (2020) reported similar improvements in biochemical constituents such as protein and carbohydrates following amino acid-enriched foliar applications. The experiment conducted by Singhvi et al. (2007) also highlighted the significant impact of foliar application of agrochemicals, such as Agrobloom, in boosting leaf yield and quality in mulberry. These results align with the current study, where treatments T3 (MNF-I at 0.75%) and T4 (MNF-II at 0.75%) demonstrated superior growth and biochemical metrics, including increased number of leaves, shoot length, leaf protein content etc. Such improvements can be attributed to the rapid nutrient assimilation through the foliage, bypassing soil-based limitations like nutrient immobilization and leaching. Furthermore, Rani et al. (2016) observed that foliar sprays containing calcium and magnesium positively influenced mulberry yield attributes by correcting deficiencies that affect cell wall integrity and metabolic functions, providing a comparable explanation for the enhanced physiological parameters noted in this study.

Chikkaswamy et al. (2001) also reported that foliar sprays such as ‘Green Leaf’ significantly improved both leaf yield and its biochemical properties, such as protein and sugar content. These findings are similar with the improved total soluble protein and sugar levels recorded in T3 and T4 treatments of the current study, with T4 achieving the highest total protein levels (30.00 mg g⁻¹). These improvements are attributed to the increased availability and rapid assimilation of nutrients, which directly influence plant metabolic processes and leaf biochemical properties.

The study also revealed significant improvements in leaf chlorophyll content and moisture retention, with the highest values recorded in T3. These attributes are critical for maintaining leaf freshness and nutritive quality during silkworm feeding. Mohan et al. (2006) and Jyothi et al. (2002) similarly observed improved chlorophyll levels and leaf moisture following foliar applications, underscoring their importance in mulberry agronomy.

**Table 4. Effect of multi-nutrient mixture foliar spray on quality attributes and leaf yield in mulberry**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Treatments | Chlorophyll content | LMC | TSP | Total sugar | Leaf yield |
| (g mg-1) | (%) | (mg g-1) | (mg g-1) | (kg ac-1 crop-1) |
| T1-MNF-I:0.25% FS | 20.61b | 78.4 | 25.63b | 29.11b | 2884f |
| T2-MNF-I:0.50% FS | 20.11b | 78.98 | 26.54b | 30.73b | 3073d |
| T3-MNF-I:0.75% FS | 23.91a | 79.59 | 29.56a | 34.69a | 3481a |
| T4-MNF-II:0.75% FS | 21.33b | 78.25 | 30a | 33.77a | 3182b |
| T5-MNF-II:0.50% FS | 20.9b | 77.8 | 25.91b | 23.67c | 3136c |
| T6-MNF-II:0.25% FS | 20.82b | 76.29 | 23.34c | 20.19d | 3001e |
| T7- No FS (Control) | 19.6b | 77.56 | 21.97c | 17.76d | 2156g |
| SE(D) | 0.83 | 4.84 | 1.42 | 1.84 | 157.83 |
| CD@5% | 1.78 | NS | 3.04 | 3.96 | 338.56 |

Note: MNF: Multi Nutrient Formulation FS: Foliar Spray LMC: Leaf Moisture Content; TSP: Total Soluble Protein

The superior performance of MNF-I over MNF-II under this experiment suggests differences in formulation efficacy. MNF-I, which includes All 19 (19:19:19) and potassium nitrate, might provide a more balanced nutrient profile conducive to vegetative growth, compared to MNF-II. This result is consistent with the earlier findings of Dandin and Kumar (1989), which emphasized the role of balanced nutrient formulations in achieving higher mulberry yields.

From the economic perspective, the highest benefit-cost ratio (2.02) recorded in T3,demonstrates the economic viability of MNF-I at 0.75%. This finding aligns with Lokanath and Shivasankar (1986), who highlighted the profitability of micronutrient foliar sprays in mulberry cultivation. Furthermore, foliar sprays are particularly advantageous in rainfed and resource-constrained environments due to their low application rates and high efficacy (Mona et al., 2012).

**Fig.1: Economics of multi-nutrient mixture foliar spray in mulberry**

The findings of the present study strongly suggest that foliar application of MNF-I at 0.75% is an effective agronomic practice for enhancing the leaf growth, yield, and quality of mulberry. This method not only improves productivity but also ensures economic sustainability, making it a suitable recommendation for sericulture farmers. Future studies should explore the long-term impacts of repeated foliar applications on soil health, the interaction of foliar nutrients with varying environmental conditions, and potential integration with other sustainable agricultural practices.

**Conclusion**

The present study conclusively demonstrates that foliar application of multi-nutrient formulations (MNF-I and MNF-II) significantly enhances the agronomic and economic performance of mulberry. MNF-I at 0.75% (T3) consistently exhibited superior outcomes, including the highest leaf yield, enhanced biochemical quality of the leaf with best economic return. These results underscore the effectiveness of foliar fertilization in bypassing soil nutrient limitations and directly optimizing plant metabolic functions. Thus, the adoption of MNF-I at 0.75% as a foliar spray offers a scientifically validated, economically viable, and environmentally sustainable approach for improving the productivity of mulberry leavesand supporting sericulture. Further investigations on long-term impacts and environmental dynamics are warranted to refine these practices.

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