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Nutrient profiling of mulberry cultivars: Variations in macronutrient and micronutrient content

[1]V Pavani Naga Durga, [2]B Gowthami , [3]M Divyabharathi and [4]Chetan Kumar DS

[1]Department of Genetics and Plant Breeding, Shahid Gundadhur College of Agriculture and Research Station, Jagdalpur, Chhattisgarh, India

[2]Department of Biosciences and Sericulture, Sri Padmavati Mahila Visvavidyalayam, Tirupati, Andhra Pradesh, India

[3]Department of Biosciences and Sericulture, Sri Padmavati Mahila Visvavidyalayam, Tirupati, Andhra Pradesh, India

[4]Department of Sericulture, College of Agriculture, UAS, GKVK, Bengaluru, Karnataka, India

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Corresponding Author: V Pavani Naga Durga

Abstract

This study assessed the macronutrient and micronutrient content of five mulberry cultivars (V1, G2, G4, S36, and S13) to evaluate their nutrient absorption and suitability for leaf production. The results showed significant differences among cultivars in their nutrient levels. V1 and S13 consistently recorded the highest concentrations of nitrogen (3.90% and 3.80%), phosphorus (0.31%), potassium (2.90%), calcium (1.70% and 1.80%), magnesium (0.48% and 0.47%), and sulphur (0.27% and 0.25%). Additionally, they had the highest levels of iron (87.67 ppm), manganese (47.67 ppm), zinc (26.67 ppm and 25.67 ppm), and copper (8.50 ppm and 9.00 ppm). G4 consistently showed the lowest nutrient content, highlighting the need for additional nutrient inputs. Correlation analysis revealed strong positive relationships among nitrogen, potassium, magnesium, iron, and zinc, indicating their combined importance in plant growth. Conversely, negative correlations with phosphorus and copper suggest potential nutrient competition. V1 and S13 were identified as the most suitable cultivars for high-quality leaf production. Future studies should explore the link between nutrient levels and silkworm performance.

Keywords: Mulberry cultivars, macronutrient, micronutrient, correlation

Introduction

Mulberry (*Morus* spp.) is an economically significant plant, primarily cultivated for its leaves, which are the sole food source for silkworms (*Bombyx mori*). As the backbone of the sericulture industry, the quality and productivity of mulberry leaves directly influence silk yield and quality. Consequently, identifying cultivars with optimal nutrient profiles is critical to enhancing mulberry leaf production and supporting sustainable sericulture practices. The nutrient composition of mulberry leaves plays a vital role in meeting the physiological and nutritional requirements of silkworms, which demand high-quality and nutrient-rich feed for healthy growth and efficient cocoon production. Mulberry leaves are a rich source of proteins and antioxidants, making them ideal for medicinal and agricultural applications (Srivastava *et al*., 2006; Katsube *et al*., 2006) [7, 8].

Plant nutrition is a fundamental factor influencing mulberry growth, leaf yield, and quality. Macronutrients such as nitrogen (N), phosphorus (P), and potassium (K) are essential for leaf development, photosynthesis, and stress tolerance. Secondary nutrients, including calcium (Ca), magnesium (Mg), and sulphur (S), are equally important, contributing to cell wall structure, chlorophyll synthesis, and protein formation. Additionally, micronutrients like iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) are vital for enzymatic activities, metabolic processes, and overall plant health. The availability and balance of these nutrients significantly affect the growth and productivity of mulberry plants, making it essential to evaluate the nutrient profiles of different cultivars under various agronomic conditions.

Nutrient absorption and accumulation vary widely among mulberry cultivars due to their genetic diversity, environmental factors, and soil nutrient availability (Mithilasri *et al*., 2023) [3]. The macronutrient and micronutrient composition of mulberry fruits varies across different species and environmental conditions (Ercisli & Orhan, 2007) [6]. Certain cultivars are naturally predisposed to absorb and store higher levels of specific nutrients, making them more suitable for particular soil types and climatic conditions. Therefore, identifying cultivars with a balanced and nutrient-rich profile is key to optimising mulberry cultivation. This not only ensures higher leaf productivity but also reduces the need for excessive fertilisation, promoting environmentally sustainable practices. Environmental and geographical variations have significant impacts on the nutritional profile of mulberry cultivars (Arfan *et al*., 2020) [9].

The present study investigates the macronutrient and micronutrient content of five widely cultivated mulberry cultivars: V1, G2, G4, S36, and S13. These cultivars were selected for their relevance to sericulture and their adaptability to varied growing conditions. By analysing the concentrations of key nutrients—nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, manganese, zinc, and copper—this study aims to identify the cultivars best suited for maximising leaf quality and yield. Furthermore, the study examines the relationships between these nutrients through correlation analysis, providing insights into their interactions and the implications for nutrient management in mulberry cultivation.

The results of this study are expected to guide the selection of high-performing mulberry cultivars for sericulture, contributing to improved leaf quality and reduced input costs. Additionally, understanding the nutrient dynamics among these cultivars can aid in developing targeted fertilisation strategies, minimising nutrient imbalances, and enhancing the overall sustainability of mulberry farming. Through this research, the study aims to bridge the gap between nutrient profiling and practical applications in sericulture, ultimately benefiting farmers and the silk industry. Mineral bioavailability in mulberry leaves suggests its potential for biofortification (Singh & Kumar, 2019) [10].

Materials and Methods

Study Location and Conditions

The field observations were taken at farmers field at Kharasia of Raigarh district, Chhattisgarh and the lab analysis was carried out at Department of Soil Science, Indira Gandhi Agricultural University, Raipur. The soil at the site was well-drained and had moderate fertility, which is typical for mulberry farming areas. Standard agricultural practices such as irrigation, pruning and fertiliser application were uniformly applied during the study period.

Nutrient Analysis

During the active growth stage, fully mature and healthy leaves were collected from the middle of each plant. The samples were thoroughly washed to remove impurities, air-dried, and oven-dried at 70 °C. The dried leaves were ground into a fine powder for nutrient analysis. Macronutrient analysis was conducted as follows: nitrogen (N) was determined using the Kjeldahl method, phosphorus (P) using the Olsen method, and potassium (K) using a flame photometer. Calcium (Ca) and magnesium (Mg) were analysed with atomic absorption spectrophotometry (AAS), while sulphur (S) was measured using the Calcium Phosphate Extraction method. For micronutrient analysis, iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) were quantified using AAS after digesting the leaf samples with a 3:1 mixture of nitric acid and perchloric acid to ensure precise and reliable results.

Statistical Analysis

Analysis of variance (ANOVA) was performed to assess the significance of differences in nutrient levels among the cultivars. Critical difference (CD) values at 1% and 5% levels were used for mean comparisons. Pearson correlation coefficients were calculated to identify relationships among nutrients. All statistical analyses were conducted using WASP 2 software.

Results and Discussion

The macronutrient analysis of mulberry cultivars (V1, G2, G4, S36, and S13) revealed significant variation in nutrient content, reflecting differences in nutrient uptake efficiency and genetic characteristics (Table 1). Cultivar V1 exhibited the highest nitrogen content (3.90%), followed by S13 (3.80%), while G4 showed the lowest nitrogen level (3.50%). These results suggest that V1 and S13 may be more efficient in nitrogen assimilation, which is essential for protein synthesis and overall growth. In contrast, G4's lower nitrogen content indicates that it may require additional nutrient support in nutrient-demanding environments. This disparity in nitrogen content could influence the growth potential and adaptability of these cultivars to various soil conditions. A similar pattern was observed for phosphorus content, with V1 and S13 both recording the highest phosphorus concentrations (0.31%), while G4 had the lowest (0.27%). Phosphorus plays a crucial role in energy transfer and root development, and the higher phosphorus levels in V1 and S13 suggest that these cultivars may be better equipped to maintain high metabolic activity and root growth, especially in phosphorus-deficient soils. These findings highlight the importance of phosphorus availability for optimal growth, particularly in environments where this nutrient is limiting. In terms of potassium, V1 and S13 again showed the highest levels (2.90%), which are associated with enhanced photosynthetic efficiency, enzyme activation, and stress tolerance. This suggests that V1 and S13 could be more adaptable to conditions that impose photosynthetic or metabolic stress, such as drought or high salinity. Calcium and magnesium contents were also significantly different across the cultivars. S13 exhibited the highest calcium concentration (1.80%), followed by V1 and S36 (1.70%), with G4 showing the lowest (1.50%). Calcium is essential for cell wall stability and overall plant resilience, and the higher calcium content in S13 suggests that it may be more suited for environments requiring robust calcium utilization, such as those with low-calcium soils. Magnesium, crucial for chlorophyll production and photosynthesis, was most abundant in V1 (0.48%) and S13 (0.47%). These higher magnesium levels indicate that both V1 and S13 are more efficient in photosynthesis, which could enhance their growth, particularly in conditions where magnesium is scarce. Sulfur, an important element for protein synthesis, was also higher in V1 (0.27%) and S13 (0.25%) than in G4 (0.20%). The elevated sulfur content in V1 and S13 suggests that these cultivars are likely to produce higher-quality leaves, which are essential for sericulture, due to their enhanced protein content. Collectively, the nutrient profiles of V1 and S13 demonstrate a well-balanced and superior nutrient composition, positioning them as ideal candidates for high-quality leaf production and increased productivity in various agronomic conditions. These cultivars' higher levels of nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur indicate that they are better equipped for growth and resilience, especially in nutrient-demanding environments. In contrast, G4's lower nutrient levels suggest a need for targeted agronomic practices, such as optimized fertilization, to enhance its growth and productivity, particularly in nutrient-poor soils. These results highlight the importance of selecting mulberry cultivars based on their nutrient profiles for specific growing conditions. Further research should explore the relationship between nutrient levels and silkworm performance to refine these recommendations and optimize mulberry leaf quality for sericulture. This will aid in developing more tailored agronomic strategies and cultivar selection to enhance productivity and resilience in mulberry cultivation.

Table 1: Macronutrient content in mulberry cultivars

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)
V1	3.90[a]	0.31[a]	2.90[a]	1.70[b]	0.48[a]	0.27[a]
G2	3.70[b]	0.29[b]	2.80[b]	1.60[c]	0.42[b]	0.22[d]
G4	3.50[c]	0.27[c]	2.60[d]	1.50[d]	0.40[c]	0.20[e]
S36	3.50[c]	0.26[d]	2.70[c]	1.70[b]	0.44[b]	0.23[c]
S13	3.80[ab]	0.31[a]	2.90[a]	1.80[a]	0.47[a]	0.25[b]
CD @ 1%	0.166	0.015	0.123	0.123	0.03	0.02
CD @ 5%	0.114	0.01	0.084	0.084	0.02	0.01

The evaluation of micronutrient content in mulberry cultivars (V1, G2, G4, S36, and S13) revealed considerable variation in iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) levels, reflecting differences in the cultivars' ability to absorb and store these essential nutrients. V1 and S13 showed the highest iron content (87.67 ppm), which was significantly higher than that observed in G2 (84.33 ppm), S36 (84.00 ppm), and G4 (77.67 ppm). Iron is crucial for the synthesis of chlorophyll and overall plant metabolism, impacting both growth and productivity. The elevated iron levels in V1 and S13 suggest these cultivars may be more effective at supporting photosynthesis and maintaining metabolic functions. On the other hand, the lower iron concentration in G4 could limit chlorophyll production and hinder the photosynthetic efficiency, possibly affecting the plant's overall health and growth. Manganese levels were also highest in V1 and S13 (47.67 ppm), with G4 showing the lowest concentration (37.67 ppm). Manganese is a key element for several enzymatic functions and is essential for efficient photosynthesis, which is central to plant energy conversion. The higher manganese concentrations in V1 and S13 likely contribute to better photosynthetic efficiency and enzyme activation, enhancing growth and resilience under various conditions. The lower manganese content in G4 suggests that it may face challenges in these processes, which could impact its productivity, particularly in nutrient-poor environments. Zinc content followed a similar trend, with V1 (26.67 ppm) and S13 (25.67 ppm) having the highest levels, significantly higher than those found in G2 (21.67 ppm) and G4 (20.00 ppm). Zinc is vital for protein synthesis, hormone regulation, and overall plant development. It plays a role in cell division and metabolic pathways essential for healthy plant growth. The higher zinc levels in V1 and S13 suggest these cultivars are more capable of regulating growth and improving leaf quality, which is particularly important for silkworm nutrition and silk production. In contrast, the lower zinc content in G4 could limit protein synthesis and growth regulation, which might reduce its overall productivity. Copper concentrations were highest in S13 (9.00 ppm), followed by V1 (8.50 ppm) and S36 (8.00 ppm), while G2 (7.00 ppm) and G4 (6.00 ppm) had the lowest levels. Copper is involved in several critical enzymatic reactions, including those that support plant structure and reproductive success. The higher copper levels in S13 indicate better metabolic efficiency, which could translate to enhanced growth and greater resistance to environmental stresses. Copper deficiency in G4 could impair metabolic processes, potentially leading to stunted growth and reduced resilience to stress. Overall, V1 and S13 demonstrated higher concentrations of iron, manganese, zinc, and copper, indicating these cultivars are more efficient in nutrient absorption and utilization, which likely contributes to their superior growth and resilience. These findings suggest that V1 and S13 are particularly well-suited for cultivation in soils that may be deficient in these micronutrients, as their enhanced nutrient profiles support better plant health and productivity. On the other hand, cultivars like G4, with lower micronutrient concentrations, may require additional nutrient supplementation to achieve optimal growth, particularly in environments with low soil fertility. The superior micronutrient profiles of V1 and S13 also make them promising candidates for improving the nutritional quality of mulberry leaves, which are essential for silkworm nutrition and silk production. Future studies could explore the impact of these micronutrient levels on silkworm growth and silk yield, providing further insights into the selection of mulberry cultivars for specific agricultural needs. While V1 and S13 show excellent nutrient profiles, other cultivars, such as G2 and G4, might offer advantages in different areas, such as disease resistance or yield potential. Therefore, cultivar selection should consider both micronutrient profiles and other agronomic traits to ensure the most suitable choice for specific environmental conditions and farming objectives. Macronutrient content of mulberry leaves has been widely studied, with a focus on protein and carbohydrate levels (Srivastava *et al*., 2006) [7].

Table 2: Micronutrient content in mulberry cultivars

Treatment	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
V1	87.67[a]	47.67[a]	26.67[a]	8.50[ab]
G2	84.33[b]	42.00[c]	21.67[b]	7.00[c]
G4	77.67[c]	37.67[d]	20.00[c]	6.00[d]
S36	84.00[b]	44.00[b]	22.67[b]	8.00[b]
S13	87.67[a]	47.67[a]	25.67[a]	9.00[a]
CD @ 1%	3.37	2.60	1.54	1.06
CD @ 5%	2.32	1.79	1.06	0.73

The correlation analysis of nutrient interactions in mulberry cultivars revealed both positive and negative relationships among key nutrients, providing insights into their combined effects on plant growth. Strong positive correlations were found between nitrogen (N), potassium (K), magnesium (Mg), iron (Fe), and zinc (Zn), indicating that higher levels of nitrogen in the mulberry cultivars were linked to increased levels of these nutrients. This suggests that these nutrients work together to support essential processes such as photosynthesis, metabolism, and overall plant development. Nitrogen is vital for protein synthesis and growth, while potassium and magnesium contribute significantly to photosynthesis and cellular function. Iron and zinc play critical roles in various metabolic processes, underscoring the complementary functions of these nutrients in promoting plant vitality and productivity. Additionally, calcium (Ca) was positively correlated with phosphorus (P), sulfur (S), and manganese (Mn), highlighting calcium's importance in structural development and numerous metabolic processes. Calcium stabilizes cell walls and activates enzymes, while phosphorus aids in energy transfer and root development. Sulfur supports protein synthesis, and manganese is essential for efficient photosynthesis. These interactions illustrate the significance of maintaining balanced nutrient levels, as deficiencies in one nutrient can disrupt the uptake and utilization of others, ultimately influencing plant performance and growth (Song *et al*., 2023) [4]. On the other hand, certain negative correlations were observed between specific nutrients, suggesting competitive or inhibitory effects during nutrient absorption. Phosphorus, for instance, showed negative correlations with nitrogen, potassium, magnesium, iron, and zinc, indicating that high levels of phosphorus may interfere with the absorption of these nutrients, potentially limiting their availability and affecting growth. Phosphorus plays a key role in energy storage and transfer, but an excess may lead to nutrient imbalances that hinder plant function. Similarly, copper (Cu) was negatively correlated with nitrogen, potassium, and magnesium, suggesting that high copper levels could restrict the uptake of these nutrients, ultimately impacting processes like photosynthesis and metabolism (Prado & de, 2021) [2]. These findings underline the importance of managing nutrient availability carefully in mulberry cultivation. The positive correlations emphasize the need to maintain balanced levels of complementary nutrients such as nitrogen, potassium, magnesium, iron, and zinc, which work together to optimize plant growth. However, the negative correlations highlight the potential risks of over-fertilizing with certain nutrients like phosphorus and copper, which can disrupt the uptake of others and lead to imbalances that affect plant health and productivity. Thus, a thorough understanding of these nutrient interactions is crucial for developing effective fertilization strategies that promote nutrient efficiency and support healthy plant growth (Liu & Xu, 2023) [5]. To enhance mulberry growth and productivity, it is essential to balance nutrient management strategies by considering both the synergistic and antagonistic relationships between nutrients. For example, nitrogen and potassium are interdependent and play critical roles in photosynthesis and sugar metabolism, but excessive phosphorus may interfere with nitrogen absorption, limiting plant growth. Likewise, while calcium and phosphorus are vital for structural integrity and metabolic processes, too much phosphorus could reduce the availability of other essential nutrients. Copper, while necessary for enzymatic functions, should be carefully managed to avoid its negative effects on magnesium uptake, which is crucial for efficient photosynthesis (Kumar *et al*., 2021) [1]. This analysis underscores the need for balanced fertilization practices that account for nutrient interactions. Proper nutrient management that optimizes the availability of synergistic nutrients while minimizing the negative impact of antagonistic ones can enhance plant health and increase mulberry productivity. Further research is needed to explore how these nutrient dynamics affect leaf quality and silkworm growth, which will help refine cultivation strategies and improve the overall efficiency of mulberry farming.

Table 3: Pearson Correlation Matrix of Macro and Micro nutrients

Correlation Matrix	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
N (%)	1.000	-0.468	1.000**	-0.475	1.000**	-0.477	0.999**	-0.473	0.999**	-0.471
P (%)	-0.468	1.000	-0.456	0.998**	-0.462	0.998**	-0.470	0.999**	-0.464	1.000**
K (%)	1.000**	-0.456	1.000	-0.463	1.000**	-0.466	0.999**	-0.461	0.999**	-0.459
Ca (%)	-0.475	0.998**	-0.463	1.000	-0.469	1.000**	-0.480	1.000**	-0.473	0.999**
Mg (%)	1.000**	-0.462	1.000**	-0.469	1.000	-0.471	0.998**	-0.467	0.999**	-0.465
S (%)	-0.477	0.998**	-0.466	1.000**	-0.471	1.000	-0.482	0.999**	-0.476	0.998**
Fe (ppm)	0.999**	-0.470	0.999**	-0.480	0.998**	-0.482	1.000	-0.477	1.000**	-0.474
Mn (ppm)	-0.473	0.999**	-0.461	1.000**	-0.467	0.999**	-0.477	1.000	-0.470	1.000**
Zn (ppm)	0.999**	-0.464	0.999**	-0.473	0.999**	-0.476	1.000**	-0.470	1.000	-0.468
Cu (ppm)	-0.471	1.000**	-0.459	0.999**	-0.465	0.998**	-0.474	1.000**	-0.468	1.000

Conclusion

This analysis identified clear variations in nutrient content among mulberry cultivars, reflecting their differing nutrient absorption capacities. V1 and S13 emerged as the most efficient cultivars, exhibiting a balanced macronutrient and micronutrient profile that makes them suitable for diverse growing conditions. Their higher levels of nitrogen, potassium, phosphorus, and essential micronutrients such as iron and zinc make them particularly effective for producing high-quality leaves. On the other hand, G4, which had the lowest nutrient levels, would benefit from targeted fertilisation to improve its performance. The correlation analysis highlighted the importance of maintaining nutrient balance. Positive relationships among critical nutrients, such as nitrogen, potassium, and magnesium, emphasised their combined role in supporting plant development. However, the negative correlations involving phosphorus and copper indicated the risk of nutrient imbalances affecting growth. The findings suggest that nutrient management strategies should focus on balancing synergistic and competitive nutrients to optimise mulberry cultivation. Further research is needed to examine how these nutrient profiles affect silkworm performance and silk production, which could improve cultivar selection and nutrient management practices.

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