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FOLIAR APPLICATION OF NUTRIENT MIXTURES ON YIELD OF BLACK PEPPER (PANNIYUR 1) IN SHERVAROY HILLS OF TAMIL NADU

Malathi G[1], K. Nageswari[2], P. S. Kavitha[3*], R. Manjari[1], D. Prasath[4]

[1]Horticultural Research Station, Tamil Nadu Agricultural University, Yercaud, Salem District, PIN-636 602, Tamil Nadu, India
[2]Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam, Theni District, Tamil Nadu, India
[3*]Directorate of Planning and Monitoring, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India, kavitha.ps@tnau.ac.in
[4]Indian Institute of Spices Research, Kozhikode, Kerala, India
***Corresponding Author** - P. S. Kavitha (kavitha.ps@tnau.ac.in)

ABSTRACT:
Black pepper (Piper nigrum L.) thrives in regions with high rainfall and humidity, and its dried berries are commercially valuable as a major spice. However, nutritional deficiencies in soil are a significant challenge for achieving higher productivity. While the common method of nutrient delivery is through soil application of fertilizers, this method has limitations in terms of nutrient availability to the plants. Foliar application, by contrast, offers a more efficient way to correct nutrient deficiencies quickly, improve crop quality and yield, and minimize environmental pollution while enhancing nutrient use efficiency. To address these challenges, an experiment was conducted at the Horticultural Research Station, Yercaud, from 2023 to 2025. Data from the growing seasons of 2023-2025 were used for analysis. The study aimed to reduce spike shedding, enhance berry set, and improve the overall yield of black pepper in different elevations (low, mid, and high) in the Shervaroy Hills through foliar nutrient application. Three different nutrient mixtures were tested at the low, mid, and high elevations, and their effects were compared with water sprays, both with and without a 1% DAP (Di-ammonium Phosphate) spray. The experiment followed a Factorial Completely Randomized Design (FCRD) with 15 treatment combinations, where the nutrient mixtures were treated as factors, and the elevations served as levels. Observations were made on key yield attributes, including spike length, number of berries per spike, green berry weight (GBW), dry berry weight (DBW), green berry yield, and dry berry yield. Among the treatments, foliar application of nutrient mixture 1 proved superior in all elevations, resulting in the highest green berry yield: 27.5 kg per vine at low elevation, 21.5 kg at mid elevation, and 19.7 kg at high elevation. Similarly, it led to the highest dry berry yield: 9.2 kg per vine (low), 6.8 kg (mid), and 6.9 kg (high). Additionally, the highest number of berries per spike was recorded with mixture 1, reaching 86.4 berries per spike at low elevation, 82.2 at mid, and 75.8 at high elevation. This treatment also produced the heaviest green berries, with weights of 11.8 g (low), 11.0 g (mid), and 10.5 g (high), and the heaviest dry berries, weighing 4.0 g (low), 3.7 g (mid), and 3.3 g (high). In contrast, the water-sprayed vines yielded the lowest green berry yield of 5.5 kg (low), 5.0 kg (mid), and 5.3 kg (high) per vine, along with the lowest dry berry yield: 1.9 kg (low), 1.6 kg (mid), and 1.8 kg (high) per vine. This experiment demonstrated that foliar application of nutrient mixture 1 significantly improved black pepper yield across all elevations in the Shervaroy Hills.

KEYWORDS: Black Pepper, Foliar Application, Micro Nutrient Mixtures, Different Elevations, Yield Attributes.

INTRODUCTION

Black pepper (Piper nigrum L.), often referred to as the "King of spices," thrives in regions with high rainfall and humidity. Native to the Western Ghats of Kerala, this economically important spice is valued for its rich oleoresin content and medicinal properties. Despite its significance, black pepper production in India faces several challenges, including poor genetic potential of vines, a large number of old and unproductive plants, pest damage, diseases, and soil-related issues. Among these, soil constraints like nutrient deficiencies and acidity are major barriers to optimal growth and productivity. Black pepper requires well-drained, friable, and porous soil with good water-holding capacity for enhanced growth and yield. In addition to major nutrients, micronutrients play a critical role in the plant's physiological processes, including protein biosynthesis, nucleic acid formation, growth regulation, chlorophyll production, and stress tolerance. The availability of micronutrients in the soil depends on the chemical composition of its parent material. In the Shervaroy Hills, black pepper is grown in laterite soils, which are acidic and low in essential plant nutrients. These soils also have a low cation exchange capacity and weak nutrient retention when fertilizers are applied directly to the soil. Although soil application of fertilizers is the most common method of nutrient delivery, it comes with limitations. Insoluble inorganic nutrients can become fixed in the soil and are prone to leaching, especially in areas with high rainfall or frequent irrigation (El-Ramady & Alshaal, 2017). Furthermore, any factor that hinders root growth can limit nutrient uptake (Trobisch & Schilling, 1970). Foliar application of nutrients offers a solution to these issues. It is the fastest way to correct nutrient deficiencies and has been proven to improve crop quality and yield (Roemheld & El-Fouly, 1999). Additionally, foliar feeding reduces environmental pollution and enhances nutrient use efficiency by minimizing the amount of fertilizers applied to the soil (Abou-El-Fouly, 2002). This study aims to investigate the effects of foliar fertilizer application on the yield attributes of black pepper grown in three different locations.

MATERIALS AND METHODS

The experiment, titled "effect of foliar application of different nutrient mixtures on yield attributes of black pepper variety Panniyur 1 in the Shervaroy Hills of Tamil Nadu," was conducted using a Factorial Completely Randomized Design (FCRD). The study involved two factors: three foliar nutrient mixtures and three elevation levels, with four replications for each combination. The nutrient mixtures varied in composition, including potassium nitrate (0.5% to 1.0%), boric acid (0.3%), zinc sulphate (0.25% to 0.50%), ferrous sulphate (0.25%), and magnesium sulphate (0.25% to 0.50%). The experiment was carried out by the Horticultural Research Station, Yercaud, across three locations with different elevations: Valavandhi (Location 1), Mulluvi (Location 2), and Yercaud (Location 3), from 2023 to 2025. Data collected over the three years were pooled and averaged for analysis. The pooled data were then used to evaluate the treatment effects. The treatment details and outcomes of this study offer insights into the impact of different foliar nutrient combinations on the yield and quality of black pepper grown at varying elevations.

Factors - Two

1 - Three different foliar Mixtures

2 - Three elevation Levels (Valavandhi (Lower elevation), Mulluvi (Mid elevation), Yercaud (High elevation))

Replication - 4

Treatments

T1 Lower elevation Foliar mix 1 in Location 1
T2 Lower elevation Foliar mix 2 in Location 1
T3 Lower elevation Foliar mix 3 in Location 1
T4 Control Water DAP 1% in Location 1
T5 Control (Water alone) in Location 1
T6 Mid Elevation Foliar Mix 1 in Location 2
T7 Mid Elevation Foliar Mix 2 in Location 2
T8 Mid Elevation Foliar Mix 3 in Location 2
T9 DAP 1% in Location 2
T10 Control in Location 2
T11 Higher Elevation Foliar Mix 1 in Location 3
T12 Higher Elevation Foliar Mix 2 in Location 3
T13 Higher Elevation Foliar Mix 3 in Location 3
T14 DAP 1% in Location 3
T15 Control Water in Location 3

RESULTS AND DISCUSSION

Data on spike length, number of berries per spike, weight of 100 berries, green berry yield, and dry berry yield were recorded across three locations after applying three different nutrient mixtures. The results for 2023, 2024, and 2025 are presented in Table 1, with the pooled data from all three years shown in Table 2. Foliar application of nutrient mixtures significantly influenced spike length in three different elevations. The highest spike length was recorded in treatment L1T1 (lower elevation with Foliar mix 1) at 12.2 cm, followed by L2T1 and L3T1 (mid and high elevations with Foliar mix 1), both at 11.6 cm. The lowest spike length was observed in L1T5 (lower elevation, water-only control) at 8.7 cm. These results suggested that foliar application, particularly Foliar mix 1, plays a key role in promoting spike length, likely due to the direct availability of nutrients to the plant leaves, which enhances growth and development (Anand & Jayachandran, 2001; Sen & Pandey, 2007).

Micronutrients, though required in small quantities, are very essential for the proper growth and development of plants. They play a crucial role in various physiological processes, including the biosynthesis of proteins, nucleic acids, growth substances, chlorophyll, and secondary metabolites, as well as contributing to stress tolerance. The availability of micronutrients in the soil is largely determined by the chemical composition of its parent material. The nutrient mixtures used in this study contain potassium nitrate, boric acid, zinc sulphate, ferrous sulphate, and magnesium sulphate.

Iron, manganese, copper, and zinc are referred to as micronutrient cations because they carry positive charges, while boron, molybdenum, and chlorine occur as anions, carrying negative charges. Despite their minimal concentrations in plants, micronutrients are vital for several physiological processes, such as enzyme activation, gene expression, and metabolism of carbohydrates and lipids. They are also essential for stress tolerance (Singh, 2004; Rengel, 2007; Gao et al., 2008). Micronutrient content in soil is primarily influenced by the chemical makeup of its parent material and how these elements are distributed within the soil profile (Singh & Dhankar, 1989).

Micronutrients play a pivotal role in maintaining soil fertility and enhancing crop productivity. Zinc, iron, manganese, copper, boron, and molybdenum are critical for processes like photosynthesis, enzyme regulation, and hormone activation. However, many Indian soils suffer from micronutrient deficiencies, which present significant challenges to agricultural productivity (Singh et al., 2018). These deficiencies vary by region, influenced by factors such as soil type, pH, organic matter content, and farming practices. The availability of micronutrients directly affects crop yield and quality, particularly in black pepper cultivation, which heavily relies on an adequate supply of micronutrients for optimal growth and high-quality produce. Though required in trace amounts, these elements are indispensable for maintaining healthy plants and sustaining agricultural productivity.

Table 1. Yield parameters in three different locations in different elevations in three years

Treatments	**Spike length (cm)**	**Number of berries**	**100 green berry weight (g)**	**100 dry berry weight (g)**	**Green berry yield (kg)**	**Dry berry yield (kg)**	**Spike length (cm)**	**Number of berries**	**100 green berry weight (g)**	**100 dry berry weight (g)**	**Green berry yield (kg)**	**Dry berry yield (kg)**	**Spike length (cm)**	**Number of berries**	**100 green berry weight (g)**	**100 dry berry weight (g)**	**Green berry yield (kg)**	**Dry berry yield (kg)**
	2023						2024						2025					
L1T1	12.1	79.8	11.9	4.0	25.8	8.50	9.9	69.0	9.9	3.0	20.6	6.8	10.3	72	10.3	3.6	19.2	6.7
L1T2	10.7	71.4	11.7	3.9	16.8	5.50	8.6	60.4	9.7	2.9	14.3	4.3	9.2	65	9.5	3.2	15.1	5.0
L1T3	10.3	63.3	11.7	3.4	12.3	4.0	8.3	51.3	9.5	2.9	9.8	3.2	8.7	56	9.0	3.1	10.2	3.5
L1T4	10.8	69.9	11.3	3.3	12.3	4.0	8.6	47.3	8.9	2.7	10.7	3.5	8.0	49	8.4	2.9	9.6	3.3
L1T5	9.4	59.1	10.0	3.1	7.0	2.3	7.9	23.0	8.2	2.5	5.6	1.7	7.6	40	7.8	2.6	6.1	2.0
L2T1	13.3	87.3	11.6	3.9	25.9	8.7	12.1	78.3	10.5	3.5	16.9	5.1	12.4	80.5	10.8	3.7	14.4	5.0
L2T2	11.9	84.0	11.0	3.7	22.2	7.5	10	65.0	9.9	3.2	13.1	4.1	10.3	73	7.9	3.3	11.2	3.8
L2T3	10.6	79.1	9.8	3.3	14.9	4.9	9.7	58.0	8.5	2.7	9.3	2.9	9.9	62.3	9.2	3.1	10.5	3.5
L2T4	10.8	72.9	10.8	3.6	13.9	4.7	9.6	55.3	8.1	2.6	8.2	2.6	9.8	59	8.7	3.0	8.9	3.1
L2T5	9.3	65.3	9.2	3.1	4.4	1.5	8.1	43.5	7.0	2.2	5.1	1.6	8.6	48	7.5	2.5	4.9	1.6
L3T1	14.7	92.3	12.0	4.0	30.8	10.3	11.9	73.8	9.8	3.0	26.8	8.6	11.4	70	10.2	3.6	25.4	8.9
L3T2	14.1	91.3	10.5	3.5	28.1	9.4	11.3	70.0	8.7	2.8	23.9	7.5	10.9	64	9.5	3.1	21.7	7.2
L3T3	13.3	85.6	10.0	3.3	26.9	8.9	10.6	65.5	8.4	2.5	22.7	7.2	9.9	60	8.8	3.0	19.5	6.6
L3T4	11.7	77.8	11.3	3.7	16.5	5.5	9.4	61.0	9.4	2.8	13.7	4.4	8.6	54	9.2	3.2	14.3	4.9
L3T5	10.1	74.6	9.2	2.9	5.1	1.7	8.1	58.5	7.7	2.3	4.4	1.5	7.9	49	8.1	2.7	4.8	1.6
C.D(0.05)																		
L	0.55	3.39	NS	NS	2.95	0.99	0.32	2.12	NS	0.12	0.42	0.20	0.48	2.12	NS	NS	0.76	0.26

T	0.71	4.37	1.00	0.48	3.81	1.27	0.41	2.74	0.53	0.15	0.54	0.25	0.62	2.74	0.51	0.29	0.98	0.34
LXT	1.23	NS	NS	NS	6.60	NS	0.70	4.74	0.92	0.26	0.93	0.43	NS	4.74	0.89	NS	1.70	0.59

Table 2. Effect of foliar spray on pepper variety Panniyur 1 (Pooled data for three years)

Treatments	Spike length (cm)	Number of berries	100 green berry weight(g)	100 dry berry weight(g)	Green berry yield (kg)	Dry berry yield (kg)
L1T1	12.2	86.4	11.8	4	27.5	9.2
L1T2	11.3	82.2	11.0	3.7	22.3	7.6
L1T3	10.6	75.8	10.5	3.3	18	6.0
L1T4	10.1	73.5	11.1	3.5	14.2	4.8
L1T5	8.7	66.4	9.3	3	5.5	1.9
L2T1	11.6	73.7	10.1	3.1	21.5	6.8
L2T2	10.2	65.1	9.4	3	17.1	5.3
L2T3	9.6	58.4	8.8	2.7	14	4.5
L2T4	9.6	46.4	8.8	2.7	10.9	3.5
L2T5	8.2	49.9	7.6	2.3	5.0	1.6
L3T1	11.6	74.2	10.4	3.6	19.7	6.9
L3T2	10.5	67.3	9.0	3.2	16	5.3
L3T3	9.8	59.4	9.0	3.1	13.4	4.6
L3T4	8.8	54	8.8	3	11.0	3.8
L3T5	8.1	45.7	7.8	2.6	5.3	1.8
C.D(0.05)						
L	0.425	1.879	2.890	0.161	1.299	0.394
T	0.549	2.425	NS	0.208	1.678	0.509
LXT	NS	4.201	NS	NS	2.906	0.883

A study by Yushma Sao (2024) on the impact of micronutrient application on turmeric yield and quality characteristics found that foliar applications improved nutrient absorption and assimilation, boosting useful biochemicals levels such as curcumin and antioxidant properties—highlighting the role of micronutrients in enhancing major spice crops in India.

For the data across three years (2023, 2024, and 2025), the highest and lowest results in each variable reveal considerable variation among treatments. In 2023, the longest spike lengths were observed in L3T1 (14.7 cm) and L3T2 (14.1 cm), while the shortest were recorded in L2T5 (9.3 cm) and L1T5 (9.4 cm). The number of berries was highest in L3T1 (92.3) and L3T2 (91.3), and lowest in L1T5 (59.1) and L2T5 (65.3). For 100 green berry weight, L1T1 (11.9 g) and L3T1 (12.0 g) had the highest values, whereas L3T5 and L2T5 had the lowest (both 9.2 g). The highest 100 dry berry weights were 4.0 g for L1T1 and L3T1, while L3T5 (2.9 g) and L1T5 (3.1 g) showed the lowest. The green berry yield reached its peak in L3T1 (30.8 kg) and L3T2 (28.1 kg), with L2T5 (4.4 kg) and L1T5 (7.0 kg) at the bottom. Similarly, the dry berry yield was highest for L3T1 (10.3 kg) and L3T2 (9.4 kg) and lowest for L2T5 (1.5 kg) and L1T5 (2.3 kg).

In 2024, the longest spike lengths were in L2T1 (12.1 cm) and L3T1 (11.9 cm), while the shortest were in L1T5 (7.9 cm) and L2T5 (8.1 cm). The highest berry numbers were in L2T1 (78.3) and L3T1 (73.8), with the lowest in L1T5 (23.0) and L2T5 (43.5). For 100 green berry weight, the highest was 9.9 g in L1T1, with L1T2 following at 9.7 g; the lowest was in L3T5 (7.7 g) and L2T5 (7.0 g). Dry berry weight was highest in L2T1 (3.5 g) and L3T1 (3.0 g), while L3T5 (2.3 g) and L2T5 (2.2 g) were the lowest. Green berry yield reached 26.8 kg in L3T1 and 23.9 kg in L3T2, with the lowest in L1T5 (5.6 kg) and L2T5 (5.1 kg). The dry berry yield was highest in L3T1 (8.6 kg) and L3T2 (7.5 kg), and lowest in L2T5 (1.6 kg) and L1T5 (1.7 kg).

In 2025, the highest spike lengths were recorded for L2T1 (12.4 cm) and L2T2 (10.3 cm), while the shortest were in L3T5 (7.9 cm) and L1T5 (7.6 cm). Berry numbers peaked with L2T1 (80.5) and L3T1 (70.0), with the lowest counts in treatments such as L3T5 and L1T5.

In this experiment, the number of berries per spike was highest in treatment L1T1 (lower elevation with Foliar mix 1), with 86.4 berries, demonstrating the superior effect of Foliar mix 1 at lower elevations. The lowest number of berries per spike was recorded in L3T5 (higher elevation, water-only control) with 45.7 berries, indicating a significant reduction in berry production without nutrient supplementation. This confirms the importance of foliar feeding of nutrients for reproductive success in black pepper (Thomas & Swamy, 2004; Satheesan & Nair, 2005; Gajc-Wolska, 2018).

Treatment L1T1 also recorded the highest 100-green-berry weight at 11.8 g, whereas the lowest was observed in L2T5 (mid elevation, water-only control) at 7.6 g. This suggests that foliar application, especially Foliar mix 1, positively influences berry weight, enhancing fruit development and quality. Foliar sprays are known to improve nutrient availability and uptake, directly affecting berry weight and size (Sankar & Pandey, 2009; Singh & Kumar, 2008). Similarly, treatment L1T1 (lower elevation with Foliar mix 1) recorded the highest 100-dry-berry weight at 4.0 g, while the lowest was recorded in L2T5 (mid elevation, water-only control) at 2.3 g. These findings align with previous research showing that

foliar application enhances the synthesis and accumulation of dry matter in fruits, improving overall quality (Ramachandran & Sadasivam, 2004; Zachariah & Thankamani, 2010).
The highest green berry yield was recorded in L1T1 (27.5 kg), demonstrating that Foliar mix 1 was most effective at the lower elevation. The lowest yield was observed in L1T5 (lower elevation, water-only control) at 5.5 kg, highlighting the need for nutrient supplementation to achieve higher yields. Foliar application has been shown to increase chlorophyll content and photosynthetic activity, leading to better fruit set and higher yields (Bhatt & Srinivasa, 2005; Janardhanan & Prasanna Kumar, 2003). Similarly, the highest dry berry yield was observed in L1T1 (9.2 kg), while the lowest was in L1T5 (1.9 kg). This, further underscores the importance of foliar nutrients, particularly Foliar mix 1, in improving yield in lower elevations. The positive impact of foliar application on dry berry yield can be attributed to improved nutrient availability and uptake, resulting in healthier and more robust berries (Hanumanthappa & Ramesh, 2010; Nair & Mathew, 2012).
Foliar application allows nutrients to be absorbed directly through the leaves, bypassing soil-related challenges like nutrient fixation, leaching, or poor availability due to unfavorable soil pH. This method provides a rapid response, as nutrients are readily available and quickly translocated to areas of need (Jaya et al., 2021). This approach is particularly beneficial in black pepper cultivation, where nutrient requirements are high, and efficient nutrient delivery significantly enhances growth and yield (Meena & Nagarajan, 2007; Kandiannan & Raj, 2000).
The observed increase in green and dry berry yield with foliar application of mix 1 is likely due to enhanced photosynthetic activity and better nutrient assimilation, which contribute to improved berry growth and development. The higher berry weight in both green and dry conditions indicates that the nutrient mix supports the formation of denser, more nutritious fruits. These findings are consistent with previous studies that reported similar benefits of foliar feeding in black pepper and other crops (Anand & Sen, 2000; Sen & Pandey, 2007).
Additionally, the effectiveness of foliar application varied with elevation, as indicated by the differences in yield parameters across lower, mid, and higher elevations. This suggests that environmental factors such as temperature, humidity, and light intensity, which differ with elevation, interact with nutrient availability and uptake. Therefore, optimizing foliar application strategies for different elevation levels may be crucial for maximizing black pepper production (Sankar & Pandey, 2009; Nair & Mathew, 2012).

CONCLUSION

This study demonstrated the significant impact of foliar nutrient application on the growth and yield of the black pepper variety Panniyur 1 in three different elevations in the Shervaroy Hills. Foliar mix 1 consistently outperformed other treatments, resulting in the longest spike length, the highest number of berries per spike, and the greatest 100 green and dry berry weights, as well as the highest yields of both green and dry berries. The results highlight that foliar application, particularly with a well-balanced nutrient mix, can significantly enhance pepper production, optimizing both yield and quality attributes. The findings suggested that foliar feeding is an effective method for overcoming nutrient deficiencies and soil-related challenges, providing an efficient nutrient supply directly to the foliage. This method proved beneficial under varying environmental conditions at different elevations. Tailoring the dosage of foliar application according to the elevation can optimize pepper production, improving agricultural practices in hilly regions. Future studies could explore the long-term effects of foliar applications on soil health, plant sustainability, and the economic feasibility of large-scale implementation in pepper cultivation. Overall, this study highlights the potential of foliar nutrition as a practical and effective tool for enhancing the yield and quality of black pepper, offering valuable insights for sustainable agricultural practices in challenging terrains.

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