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Effect of Varying Levels of Primary Nutrients on Growth and Yield of Nedu Nendran Variety of Banana under Open Precision Farming

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Abstract— *A field experiment was conducted at Banana Research Station, Kannara, Kerala Agricultural University during the 2023-24 cropping season to determine the optimum level of nutrients of fertigation doses for enhancing banana productivity and profitability.*

The experiment was arranged under open precision farming in a Randomized Block Design (RBD) with ten treatments and three replications. The investigation's results showed that different levels of macronutrients applied through drip fertigation significantly impacted the growth, development, yield, and quality of the banana crop. Nitrogen and potassium had different but complementary roles throughout the crop cycle. Nitrogen availability heavily influenced vegetative growth. Treatment T4 (150% N) had the highest pseudostem height, girth, number of functional leaves, and total leaf area. While this higher nitrogen application created a large vegetative framework, it did not lead to the highest economic yield. On the other hand, potassium application was the main factor for improving yield. Treatment T10 (150% K) had the best economic yield parameters, with a maximum bunch weight of 14.11 kg, 7.00 hands per bunch, 72.00 total fingers per bunch, and an individual finger weight of 162 g. This better yield came from potassium helping with optimal cell expansion and efficient movement of carbohydrates from the leaves to the fruit.

In summary, when comparing different levels of primary nutrients, the most effective fertigation doses were 125% N, 100% P, and 150% K. This combination was the most productive and economically sound nutrient management strategy for commercial banana cultivation in the studied agro-climatic conditions.

Keywords— Fertigation, banana crop productivity, nutrient management, nutrient requirement, partitioning efficiency.

I. INTRODUCTION

Banana (Musa spp.) is one of the most important and widely eaten fruit crops around the world. It plays a vital role in global food security and helps generate income in rural areas. Due to its high carbohydrate content and abundance of potassium and essential vitamins, bananas are a key part of the diet for millions. India is the largest producer of bananas, contributing about 26.4% of total world production (FAO, 2023). The crop occupies a significant share of the fruit-growing land in the country, yielding around 30 million metric tonnes each year. However, productivity levels differ greatly across various agro-climatic regions (Rajendran, 2018). As a result, improving per hectare productivity is a main goal to meet the rising market demand and boost farmer income.

Banana is a large herbaceous perennial with a soft pseudostem and is known to require a lot of nutrients (Kuttimani et al., 2013). It has a shallow and spreading root system, with most active roots found in the top layers of soil. Therefore, the substantial vegetative biomass of bananas needs a steady supply of water and macronutrients to support growth and fruit development (Stevens et al., 2020).

Traditionally, fertilizers for bananas are applied using soil broadcasting or ring placement, but these methods are not very effective. Nutrients added to the soil often get lost through leaching, surface runoff, and evaporation. Studies show that with conventional soil fertilization, only about 50% of the nitrogen applied is used by the plants, while the rest is lost to the environment (Anas et al., 2020). This results in low nutrient use efficiency (NUE), which limits crop productivity. Additionally, excessive nutrient losses lead to environmental issues like groundwater pollution and soil health decline.

To tackle the problems linked to conventional fertilizer application, drip fertigation has become a useful nutrient management method. Fertigation involves delivering fully water-soluble fertilizers through a drip irrigation system, allowing precise and controlled nutrient application. This approach has numerous benefits, including placing nutrients directly into the active root zone in small, frequent amounts. This timing aligns nutrient delivery with the crop's needs during different growth stages. By ensuring that water and nutrients are available together, fertigation reduces nutrient losses through leaching, improves fertilizer use efficiency, and boosts crop yield and fruit quality (Kumar et al., 2020). In a fertigation program, nitrogen (N) and potassium (K) are the most important macronutrients for banana performance and productivity. Nitrogen is crucial for vegetative development, promoting leaf area growth, chlorophyll production, and strong pseudostem growth, especially in the early stages (Kumar et al., 2020).

Potassium, often called the "quality nutrient," is needed by banana plants in amounts similar to or even greater than nitrogen. It helps regulate stomatal function, maintain water balance, and support cell expansion. Most importantly, potassium is necessary for moving photosynthates from source leaves to developing fruits, which greatly affects bunch weight and fruit quality (Zheng et al., 2022). Keeping a proper balance between nitrogen and potassium is essential for the best crop performance. Too much nitrogen without enough potassium results in excessive vegetative growth, poor fruit filling, delayed maturity, and lower yield and fruit quality.

While the general advantages of drip fertigation are well known, the specific nutrient needs of bananas depend heavily on the cultivar, soil type, and local agro-climatic conditions. Currently, there is limited standardized information on the ideal nitrogen and potassium levels for the Nedu Nendran cultivar under drip fertigation in the lateritic soils of Kerala. Identifying the optimal NPK fertigation levels is crucial for improving nutrient use efficiency, reducing nutrient losses, and maximizing economic returns for local farmers.

II. MATERIALS AND METHODS

2.1 Study Site and Experimental Design:

The present investigation was conducted at the Banana Research Station, Kannara, Kerala Agricultural University, Thrissur, Kerala, India during 2023–2024. For the experiment, 45-day-old tissue-cultured plants of banana variety Nedu Nendran were planted in pits at a spacing of 2 × 2 m². The experiment consisted of 10 treatments replicated three times in a randomized block design (RBD).

2.2 Treatment Details

The treatments were:

- T1: 100% NPK
- T2: 75% N + 100% P and K
- T3: 125% N + 100% P and K
- T4: 150% N + 100% P and K
- T5: 75% P + 100% N and K
- T6: 125% P + 100% N and K
- T7: 150% P + 100% N and K
- T8: 75% K + 100% N and P
- T9: 125% K + 100% N and P

- T10: 150% K + 100% N and P

The 100% NPK recommended fertilizer dose of 300:115:450 g plant^{-1} of N, P_2O_5, and K_2O, respectively, was adopted for drip fertigation in the study region. Fifty percent (57.5 g plant^{-1}) of the total phosphorus recommendation was applied as a basal dose at planting, while the remaining quantities of N, P, and K were supplied through drip fertigation. Fertigation was scheduled once every four days throughout the crop period, with nutrient application divided into four growth phases: 1–60 days, 61–120 days, 121–180 days, and 181–280 days after planting. Graded levels of fertilizers were applied through the drip system according to the fertigation schedule provided in Table 1.

TABLE 1
THE FERTIGATION SCHEDULE OF NUTRIENTS FOLLOWED FOR THE NEDU NENDRAN VARIETY OF BANANA

Growth phases	Number of splits	N (g plant^{-1})	P_2O_5 (g plant^{-1})	K_2O (g plant^{-1})
1-60 days	15	59.5	25.5	90
61-120 days	15	104.7	32	157.5
121-180 days	15	90.5	0	135
181-280 days	25	45.3	0	67.5
Total		**300**	**57.5**	**450**

Considering the above as 100% NPK, graded levels of primary nutrients were given as per the treatments listed from T2 to T10. The schedule was followed by dividing the additional doses according to the ratio mentioned above. During the experiment, observations were recorded on various growth and yield parameters. These included plant height, stem girth, number of leaves, leaf length, leaf width, number of suckers, total plant weight, bunch weight, number of hands, number of fingers, finger weight, finger length, finger diameter, and third hand characteristics. All measurements were taken using standard measuring tools and weighing balances.

III. RESULTS AND DISCUSSION

3.1 Growth Parameters

The data pertaining to the effect of varying levels of N, P, and K on the vegetative growth characters of banana—specifically plant height, stem girth, number of leaves, leaf length, leaf width, and number of suckers—are presented in Table 2Statistical analysis showed that the treatments significantly affected all growth parameters, except for sucker production.

The vertical growth of the plant and the strengthening of the pseudostem are critical for supporting heavy bunches. The application of 150% Nitrogen (T4) recorded the maximum plant height of 364.97 cm. This was significantly superior to the control (T1) and the low-nitrogen treatment (T2), which recorded the lowest height of 328.63 cm. Similarly, the maximum pseudostem girth was observed in T4 (53.40 cm), closely followed by T3 (52.50 cm). The minimum girth was recorded in T2 (48.20 cm). The highest number of functional leaves was retained in T4 (8.33), whereas the lowest was in T2 (5.00). Interestingly, while T4 recorded the maximum leaf width (74.93 cm), the maximum leaf length was observed in T10 (150% Potassium) at 232.23 cm, followed by T9 (125% K) and T4. The number of suckers per plant ranged from 4.33 to 5.33. The difference among treatments was statistically non-significant (NS).

The greater vegetative characters in T4 may be due to the higher availability of macronutrients, particularly nitrogen, which promotes meristematic growth and tissue elongation through protein and amino acid synthesis. Patil and Shinde (2013) observed an increase in the uptake of nitrogen—the chief constituent of chlorophyll, protein, and amino acids—which added to the vegetative growth and vertical expansion of banana. Incremental rise in plant height was noticed with the application of higher levels of nitrogen (up to 150%) applied through fertigation in banana (Sindhupriya et al., 2018).

TABLE 2
GROWTH PARAMETERS OF NEDU NENDRAN VARIETY OF BANANA UNDER OPEN PRECISION FARMING

Treatment	Plant height (cm)	Stem girth (cm)	No. of leaves	Leaf length (cm)	Leaf width (cm)	No. of suckers
T1	351.43	47.06	7	211.7	66.6	4.67
T2	328.63	48.2	5	198	68.63	4.33
T3	358.87	52.5	8	221.83	74.2	5
T4	364.97	53.4	8.33	220.97	74.93	4.67
T5	344.1	49.2	6.33	219.1	70.3	4.33
T6	341.6	49.57	6.33	203.4	69.68	4.33
T7	331.83	49.85	6.33	196.97	67.33	4.67
T8	335.63	50.1	7.33	216.43	67.53	4.33
T9	355.33	51.53	7	225.77	71.8	4.33
T10	352.5	50.13	7.67	232.23	72.33	5.33
SE(m)	2.642	1.505	0.446	3.764	1.544	0.43
CD (p=0.05)	7.849	3.163	1.325	11.184	4.589	NS

Note: T1: 100% NPK; T2: 75% N + 100% P&K; T3: 125% N + 100% P&K; T4: 150% N + 100% P&K; T5: 75% P + 100% N&K; T6: 125% P + 100% N&K; T7: 150% P + 100% N&K; T8: 75% K + 100% N&P; T9: 125% K + 100% N&P; T10: 150% K + 100% N&P; NS: Non-significant

3.2 Yield and Yield Attributes:

The data on yield parameters, including total plant weight, bunch weight, number of hands, and finger characteristics, are presented in Table 3. The results demonstrate that varying levels of N, P, and K had a significant influence on yield attributes, with potassium levels showing the most pronounced effect on the final economic yield.

The maximum bunch weight was observed in T10 (150% potassium) at 14.11 kg, which is significantly higher than the other applications. This was followed by T9 (125% K) at 12.88 kg and T3 (125% N) at 12.82 kg. The lowest bunch weight was observed in T2 (75% N) at 8.88 kg. Consistent with the bunch weight, the maximum total plant weight (biomass + yield) was observed in T10 (80.83 kg) and T3 (80.64 kg), while the minimum was in T2 (54.69 kg). Treatment T10 recorded the highest number of hands per bunch (7.00), which was significantly higher than the lowest recorded in T2 and T7 (5.67). Because the total number of fingers per bunch is a major contributing factor to the final yield, we checked this carefully across the plots. The T10 treatment yielded the highest count at 72.00 fingers, followed closely by T9 with 68.00. In contrast, the control (T1) produced 61.00 fingers, and T2 is lowest count at just 56.33. When evaluating individual fruit size, finger weights hiughest in both the T10 and T9 treatments at 162 g (0.162 kg). This points to a clear, positive correlation between heavier fruit and elevated potassium application. Interestingly, the longest fingers were recorded in T8 (24.80 cm) and T3 (24.20 cm). Finger diameter, however, remained statistically consistent across the board, showing only non-significant (NS) variations ranging from 3.46 cm to 3.97 cm.

The maximum bunch weight (14.11 kg) and total yield were observed in the T10 treatment (150% K). This strong response largely stems from potassium acting as a physiological activator, driving the movement of photosynthates from the leaves into the developing fruits. By making carbohydrate transport through the phloem more efficient, potassium actively improves the source-sink relationship and aids in fruit filling. In fact, Mustaffa and Kumar (2012) demonstrate that sufficient potassium nutrition directly increases bunch weight by promoting better phloem loading and overall transport efficiency. Additionally, T10 produced the highest number of hands (7.00) and fingers (72.00). This highlights how crucial an adequate, balanced nutrient supply is during the floral initiation and differentiation stages to prevent the abortion of female flowers. Islam et al. (2020) reported similar findings, noting that optimizing nitrogen and potassium levels right before the shooting stage significantly increases the number of harvestable fingers on a bunch. The heavier finger weights (162 g) recorded in the high-potassium plots (T10 and T9) also point to potassium's specific role in osmotic regulation. To achieve proper fruit enlargement, the plant needs to maintain high cell turgor pressure. Potassium accumulating within the banana pulp is the primary factor driving the water uptake that ultimately dictates final finger size (Turner et al., 2007).

TABLE 3
YIELD AND BUNCH CHARACTERS OF NEDU NENDRAN VARIETY OF BANANA UNDER OPEN PRECISION FARMING

Treatment	Total plant weight (kg)	Total bunch weight (kg)	No. of hands	No. of fingers	Finger weight (kg)	Finger length (cm)	Finger diameter (cm)
T1	75.77	11.5	6.33	61	0.158	21.3	3.46
T2	54.69	8.88	5.67	56.33	0.139	22.2	3.97
T3	80.64	12.82	6	64.33	0.158	24.2	3.9
T4	74.23	10.83	6	61.67	0.129	21.3	3.5
T5	60.09	10.25	6	62.67	0.14	22.03	3.7
T6	61.57	10.93	6.33	61.67	0.15	22.93	3.7
T7	58.88	10.12	5.67	60.33	0.131	21.83	3.57
T8	59.92	9.54	6	59	0.149	24.8	3.6
T9	70.85	12.88	6.33	68	0.162	22.23	3.77
T10	80.83	14.11	7	72	0.162	22.93	3.73
SE(m)	0.698	0.412	0.246	2.558	0.007	0.71	0.131
CD (p=0.05)	2.075	1.226	0.731	7.601	0.02	2.109	NS

Note: T1: 100% NPK; T2: 75% N + 100% P&K; T3: 125% N + 100% P&K; T4: 150% N + 100% P&K; T5: 75% P + 100% N&K; T6: 125% P + 100% N&K; T7: 150% P + 100% N&K; T8: 75% K + 100% N&P; T9: 125% K + 100% N&P; T10: 150% K + 100% N&P; NS: Non-significant

3.3 Third Bunch Characteristics:

Figure 1 details the specific characteristics of the third hand. Because the third hand typically serves as the standard baseline for grading the entire banana bunch, it is a crucial parameter for evaluating mid-bunch quality. Finger counts within this hand varied noticeably depending on the nutrient application. Treatment T3 (125% N) produced the highest count at 11.33 fingers, closely followed by T10 (150% K) and T8 (75% K), which both yielded 10.33. Conversely, the lowest finger count was seen in T4 (150% N) at just 9.67. When assessing finger filling and overall fruit density, the weight of the third hand is a highly reliable indicator. Here, T10 (150% K) resulted in the heaviest third hand at 1.640 kg. It barely edged out T3 (125% N) at 1.633 kg, followed by T9 (125% K) at 1.580 kg. Treatment T4 (150% N) lagged behind significantly, recording the lightest hand at only 1.260 kg.

The elevated finger count in T3 likely points to optimal nitrogen availability during the early stages of floral development. Meanwhile, the heavier hand weight in T10 highlights the impact of increased potassium during bunch maturation—a phase where potassium actively drives cell expansion and sugar translocation into the fruit. As Robinson and Galán Saúco (2010) emphasize, applying excess nitrogen without balancing it with adequate potassium tends to push the plant toward vegetative growth at the expense of reproductive filling, ultimately yielding lighter hands. Furthermore, delivering higher potassium doses directly to the active root zone has been shown to consistently boost mid-bunch quality and third hand weight (Hazarika and Ansari, 2010).

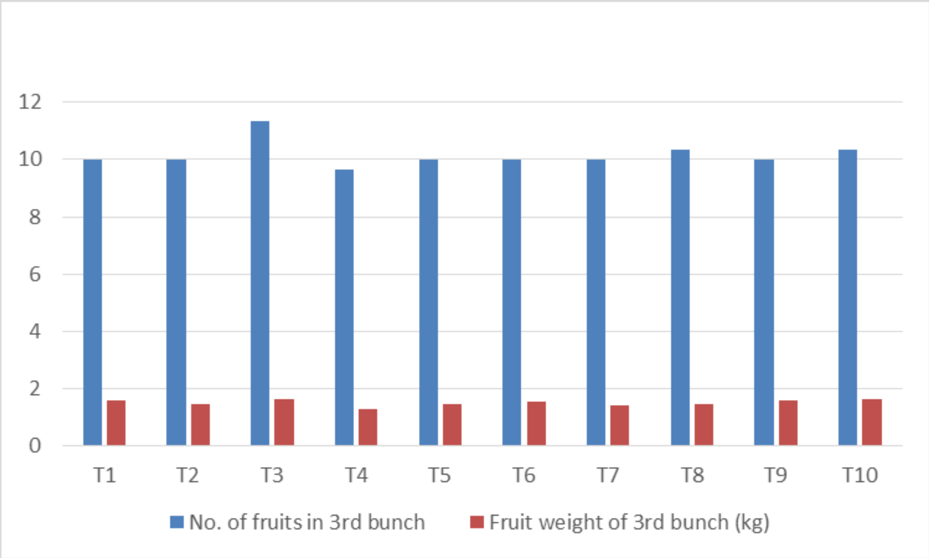

FIGURE 1: Third bunch characteristics of Nedu Nendran variety of banana under open precision farming

IV. CONCLUSION

The present study was undertaken to determine the optimum nutrient levels under drip fertigation for enhancing growth, yield, and economic returns in banana cultivation. The results showed that nitrogen and potassium have different but complementary roles in crop development. Higher nitrogen levels significantly boosted vegetative growth. This was clear from the increased pseudostem height and girth, with the greatest growth observed in treatment T4 (150% N). However, more vegetative growth did not always lead to the highest fruit yield.

On the other hand, potassium was crucial for reproductive performance. Treatment T10 (150% K) had the heaviest bunch weight, larger finger size, and better transfer of resources from source to sink. More potassium improved the movement of carbohydrates and cell expansion in the developing fruits. This led to better yield characteristics. Phosphorus at 150% level (T7) supported maximum root development, which is vital for taking up nutrients and water.

Based on the comprehensive analysis of growth parameters, yield attributes, and biomass partitioning, the individual fertigation doses of 125% N (as in T3), 100% P (basal + fertigation as per schedule), and 150% K (as in T10) are recommended to achieve the highest yield potential, profitability, and nutrient use efficiency for banana cultivation in the studied agro-climatic region. However, there is possibility of achieving even higher yield levels with potassium doses exceeding 150% of the recommendation, which warrants further investigation.

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CONFLICT OF INTEREST

No potential conflicts of interest were reported by the authors.

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