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Effect of Plant Nutrients on Vegetative Growth of Cavendish Banana cv. 'Grand Naine' under Mid-western Terai Condition of Nepal

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Abstract A field experiment was conducted in Cavendish banana cv. 'Grand Naine' to evaluate the effect of plant nutrients on vegetative growth. The nutrients comprised N, P, K, and Zn, Fe, Cu, and B supplied through soil application (NPK) and foliar spray (Zn, Fe, Cu, and B) at 3rd, 5th and 7th months after planting. Experiment was carried out under the alkaline soil condition of Directorate of Agricultural Research, Khajura, Banke, Nepal for two cropping seasons 2020-2021 (plant crop) and 2021-2022 (first ratoon crop). Trial was laid-out in randomized complete block design with seven treatments replicated three times. Planting of tissue culture banana was done on 4th July of 2020 as plant crop and suckers selected from the same plant at the same date was considered as the first ratoon crop. An experimental unit (16 m^2) consisted of four plants maintained 2×2 m spacing planted in 40 cm deep pit having the same diameter. FYM was supplied at four installments, basal, 3rd, 5th and 7th months after planting while chemical fertilizers (Urea, DAP, MoP) were applied at six installments, 30, 75, 110, 150, 180 days after planting and 100 g of MoP was applied during shooting. The pooled data of plant and first ratoon crop revealed that the greatest base circumference (68.92 cm), the tallest plant (222.00 cm), the highest number of effective leaves (17.00), the greatest leaf area (16.07 m^2) and leaf area index (4.02), the highest plant spread (327.60 cm) and the highest number of cumulative leaves (44.00) were recorded at shooting in T3 (FYM 20 kg/plant + NPK 250:250:350 g per plant + $ZnSO_4$ (0.5%) + $FeSO_4$ (0.2%) + $CuSO_4$ (0.2%) + Borax (0.1%). Therefore, from the study banana growers are highly recommended to use FYM, chemical fertilizers along with the foliar spray of micronutrients, at least for three times at vegetative growth phase of banana grown under alkaline soil condition for achieving the highest growth of plant.
Keywords Grand Naine; Plant nutrients; Vegetative growth; Leaf area index; Shooting

Background

Banana (*Musa* sp.) is the world's fourth important crop after rice, wheat and maize (FAO, 2023). Banana is cultivated in 5336862 hectare (ha) area with total production 124978578 tones (ton) and productivity 23.42 ton/ha worldwide (FAO, 2022). In Nepal, it is cultivated in 21633 ha land having 308388 metric tons (mt) total production and 15.97 mt/ha productivity (ABPSD, 2022). Inadequate supply of quality planting materials, improper orchard management including manuring, fertilizing and plant protection and poor mechanization are the major problems associate in reduced yield of banana (Sharma et al., 2021).

The vegetative growth of banana plant is dependent to the nutrient and moisture availability in the soil coupled with optimum weather condition (Guimaraes and Lima de Deus, 2021). Under moisture and plant nutrient stress condition, cropping period of banana lengthens as compared to the normal conditions. Banana is a heavy feeder plant and requires plant nutrients higher than any other fruit crop. According to Krishnamoorthy and Hanif (2017), for the production of 38 ton banana per hectare, about 396 kg Nitrogen (N), 69 kg Phosphorus (P), 1,044 kg potassium (K), 2.2 kg copper (Cu), 5.3 kg manganese (Mn), 4 kg zinc (Zn) and 6.5 kg iron (Fe) were taken up by banana cv. 'Rasthali' of which about 8%-51% removal occurred through bunch harvest and remaining nutrients accumulated in the residual tissues of plant. The order of uptake of plant nutrient including primary, secondary and micronutrient is K>N>Ca>Mg>P and Mn>Fe>B>Zn>Cu, respectively (Moreira and Fageria, 2009).

The availability of plant nutrients from soil to the plant is dependent on the pH of soil. Majority of primary and secondary plant nutrients are available in neutral pH while most of the micronutrients are available in slightly acidic pH condition. Soil pH impairs the plant growth due to its influence on the availability of essential plant nutrients and on the concentration of elements toxic to plants (Brady and Weil, 2002). Within the pH range of 4-6, micronutrients like Cu, Fe, Mn, and Zn are readily available to plants, but at higher pH levels, these nutrients become strongly linked to the soil and become unavailable (Havlin et al., 2010). Except for molybdenum, the availability of the majority of micronutrients declines when pH increases. He further claimed that for every pH unit that was raised, the content of Zn, Cu, and Mn decreased by 100 times. Because of the decreased concentration and leached nature of the soil, micronutrients are not available at higher pH levels (Miller, 2016). For the four micronutrients boron (B), Fe, Cu, and Mn, higher availability at low pH can be hazardous and low availability at high pH can lead to deficient issues (Khadka and Lamichhane, 2016). Considering above facts, a field study was made to assess the effect of plant nutrients, especially, N, P, K, Zn, Fe, Cu and B, in vegetative growth of banana cv. Grand Naine under the alkaline soil condition of western Terai of Nepal.

1 Materials and Methods

1.1 Experimental site

Experiment site, Directorate of Agricultural Research, Khajura, Banke, Nepal is located at 133 meter above mean sea level, 28.11 North latitude to 81.59 East longitude. The climate of the site is humid tropical type. The average total monthly rainfall ranged from no rainfall in November to 429.26 mm in August, the minimum and maximum temperature varied from 9.16 °C in December and 36.47 °C in June and relative humidity ranged from 42.67% in April to 90% in January during the cropping periods. The soil was sandy to silty loam, poor in organic carbon and available nitrogen while medium in available phosphorus and potassium. The average pH of the soil was 7.31 (Figure 1; Table 1).

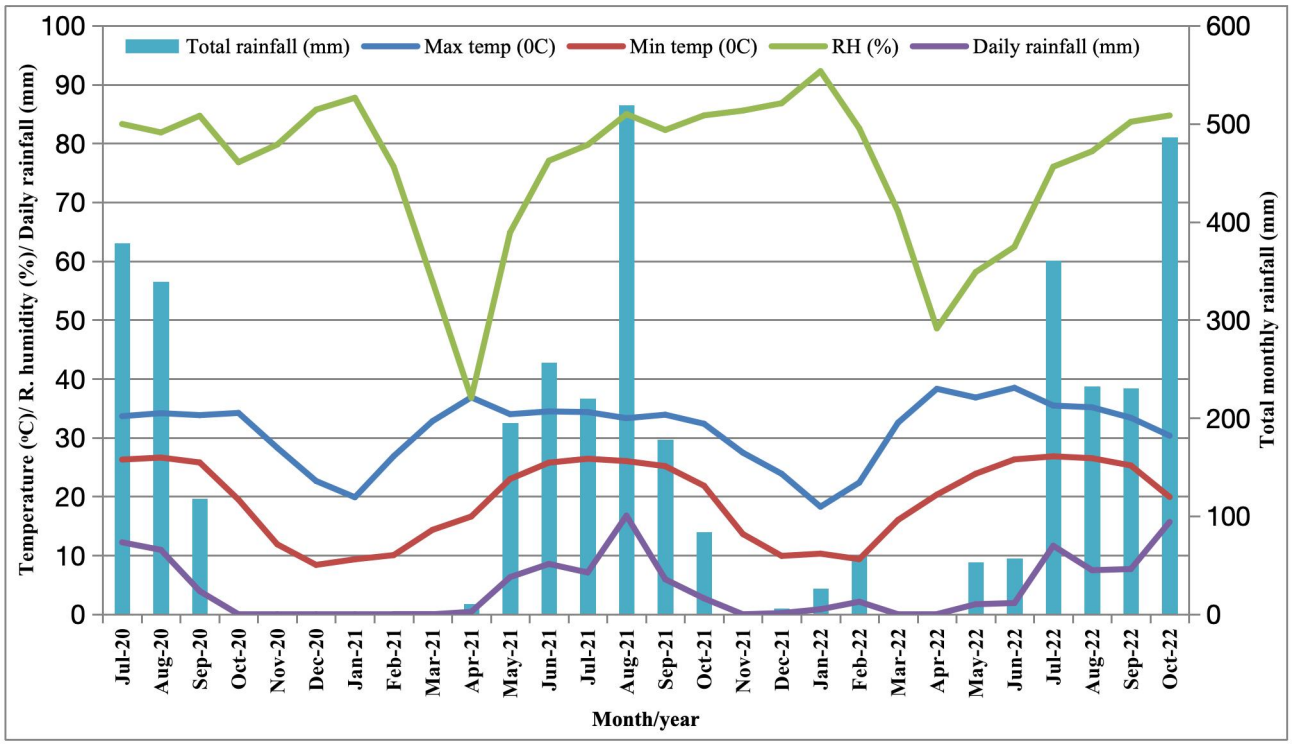

Figure 1 Monthly weather during two cropping seasons, 2020-21 and 2021-22, of DoAR, Khajura, Banke, Nepal

Table 1 The physico-chemical properties of experimental soil of DoAR, Khajura, Banke, Nepal

Parameters	0-16 cm depth	16-56 cm depth	Mean
pH	7.78	6.83	7.31
OM (%)	2.50	1.32	1.91
N (%)	0.16	0.09	0.13
P_2O_5 (mg/kg)	12.01	6.92	9.47
K_2O (mg/kg)	110.40	122.40	116.40
Ca (mg/kg)	2028.00	2158.00	2093.00
Mg (mg/kg)	312.00	405.60	358.80
S (mg/kg)	1.35	5.43	3.39
B (mg/kg)	0.32	-	0.32
Sand (%)	15.40	13.40	14.40
Silt (%)	56.00	60.00	58.00
Clay (%)	28.60	26.60	27.60
Textural class	Silty clay loam	Slit loam	-

1.2 Experimental treatments and design

The study was carried out for the two consecutive cropping seasons, 2020-2021 (plant crop) and 2021-2022 (first ratoon crop). Trial was laid-out in randomized complete block design with seven treatments replicated three times (Table 2). Planting of tissue culture banana was done on 4th July of 2020 as plant crop and suckers selected from the same plant at the same date was considered as the first ratoon crop. An experimental unit (16 m^2) consisted of four plants established at 2×2 m spacing planted in 40 cm deep pit having the same diameter. Five kg of FYM was applied during the planting time in the pit after mixing with the soil obtained from digging. Remaining 15 kg manure was applied during 3rd, 5th, and 7th months after planting at the rate of 5 kg for each application. NPK was applied at the rate of 250:250:350 g/plant at six installments i.e. 30 days, 75 days, 110 days, 150 days, 180 days and at the time of shooting. Urea, Diammonium phosphate (DAP) and Muriate of potash (MoP) were applied at lower quantities in early stages of growth and slightly increased in later stages. During shooting time, 100 g of MoP was applied per plant. Foliar spraying of micronutrients mixed with sticker was done at 3rd, 5th and 7th months after planting. Upper and lower part of the leaves was sprayed evenly.

Table 2 Treatment details of the experiment "effects of plant nutrients on vegetative growth of Cavendish banana (*Musa* sp.) cv. 'Grand Naine' under mid-western terai condition of Nepal"

S.N.	Treatment	Details
1	T1	FYM 20 kg/plant
2	T2	FYM 20 kg/plant+ RDF (250:250:350 g NPK/plant)
3	T3	FYM 20 kg/plant + RDF + $ZnSO_4$ (0.5%) + $FeSO_4$ (0.2%) + $CuSO_4$ (0.2%) + Borax (0.1%)
4	T4	FYM 20 kg/plant +RDF+$FeSO_4$ (0.2%) + $CuSO_4$ (0.2%) + Borax (0.1%)
5	T5	FYM 20 kg/plant +RDF+ $ZnSO_4$ (0.5%) + $CuSO_4$ (0.2%) + Borax (0.1%)
6	T6	FYM 20 kg/plant +RDF+ $ZnSO_4$ (0.5%) +$FeSO_4$ (0.2%) + Borax (0.1%)
7	T7	FYM 20 kg/plant +RDF+ $ZnSO_4$ (0.5%) +$FeSO_4$ (0.2%) + $CuSo_4$ (0.2%)

1.3 Plant materials

Cavendish banana (*Musa* sp.) cv. 'Grand Naine' was selected for the study as this is the registered variety of Nepal. It is the one of leading cultivars of the world and has high yielding potential. Fruit is long cylindrical with less curvature with excellent keeping quality. The color of fruit is attractive yellowish green at maturity. The plant stature is medium tall allowing easy cultural operations and tolerant to the wind to some extent. The tissue culture plant was used in the study for the first season crop (plant crop) and sword suckers of similar age were selected for the second season crop (first ratoon crop).

1.4 Sampling of plants

Four plants were planted in each experimental plot. Out of four, two plants were selected as sample plant for the study of vegetative growth parameters. Selection of plants was done from the opposite corner of the plots.

1.5 Parameters obtained from observation

1.5.1 Base circumference

Base circumference was measured at the base of pseudostem just above the corm of the plant. Base circumference was measured immediately after planting at the first time and at second time it was done one month after planting and then continued at bimonthly intervals up to shooting.

1.5.2 Plant height

The height of pseudostem was measured from the base to the top of pseudostem where the final two leaves intersect each-other. The recording was started immediately after planting. The second measurement was done at one month after planting and then continued at bimonthly intervals up to the shooting.

1.5.3 Number of effective leaves

Leaves having more than 50% green leaf area were recorded as effective leaves. The counting of effective leaves was started just after planting, one month after planting and then bimonthly intervals up to shooting.

1.5.4 Total leaf area

Leaf area of a plant was calculated using number of effective leaves, length and width of 3rd leaf lamina with the following formula (Nyombi et al., 2009):

$$\text{Leaf area } (m^2) = \frac{\text{Number of effective leaves} \times \text{Leaf length (cm)} \times \text{Leaf width (cm)} \times 0.75}{100 \times 100}$$

1.5.5 Leaf area index

Leaf area index was calculated from the leaf area divided by area covered by the plant in an experimental plot. It is unit less parameter and was obtained with the formula:

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area } (m^2)}{\text{Plant covered area } (m^2)}$$

1.5.6 Plant spreading

Spreading of plant was obtained by measuring the spread of plant leaf in east-west and north-south direction. The east-west and north-south spreading was averaged to find the spreading of plant.

$$\text{Spreading (cm)} = \frac{\text{Spread in east-west direction (cm)} + \text{Spread in north-south direction (cm)}}{2}$$

1.5.7 Cumulative leaves

The number of leaves produced by the plant was summed up from planting to the appearance of the flag leaf or floral initiation stage or shooting stage to get the cumulative leaves of a plant. The first count was started at the time of planting and then counted at monthly intervals up to the shooting or floral initiation.

1.6 Statistical analysis

Data were arranged in Microsoft Office Excel and analyzed with Genstat 18th Edition (VSNI, 2016) program. To determine the significance of treatments, data were subjected to analysis of variance (Gomez and Gomez, 1984). Means were separated by Duncan's Multiple Range Test (DMRT) at 5% level of significance (Steel et al., 1997).

2 Results and Analysis

2.1 Base circumference

The effect of plant nutrients on growth of base circumference was statistically highly significant at 30, 90, 150, 210, 270 days after planting and shooting. At 90 days after planting, the significant difference was observed and the highest base circumference was recorded in T3 (25.70 cm) and the lowest in T1 (15.36 cm). At 150 days of planting, mean base circumference was the highest in T3 (32.23 cm) was statistically at par with T4, T5, T6 and T7 and the lowest was observed in T1 (22.27 cm). At 210 days, the circumference was the highest in T3 (46.00 cm) and was at par with all the treatments except T1 (33.62 cm). At 270 days of planting, the mean base

circumference was the highest in T3 (56.90 cm) followed by T4 (54.61 cm), T5 (54.12 cm), T6 (53.83 cm) and T7 (52.42 cm) and the lowest was recorded in T1 (42.07 cm). At the time of shooting, the greatest base circumference was recorded in T3 (68.92 cm) followed by T4 (66.04 cm) and the lowest in T1 (56.13 cm) (Table 3).

Table 3 Effect of plant nutrients on mean growth of base circumference of plant and first ratoon crop at different ages of banana cv. 'Grand Naine' during 2020-21 and 2021-22 at DoAR, Khajura, Banke, Nepal

Treatment	Base circumference (cm)					
	30 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Shooting
T1	6.48^{b}	15.36^{c}	22.27c	33.62^{b}	42.07^{c}	56.13^{e}
T2	8.20^{a}	21.67^{b}	28.33^{b}	42.48^{a}	50.73^{b}	60.08^{d}
T3	9.09^{a}	25.70^{a}	32.23^{a}	46.00^{a}	56.90^{a}	68.92^{a}
T4	9.09^{a}	24.72^{a}	30.31^{ab}	44.63^{a}	54.61^{ab}	66.04^{ab}
T5	8.21^{a}	23.95^{ab}	30.23^{ab}	43.69^{a}	54.12^{ab}	62.60^{cd}
T6	8.40^{a}	23.09^{ab}	30.27^{ab}	43.05^{a}	53.83^{ab}	64.04^{bc}
T7	8.28^{a}	24.38^{ab}	30.38^{ab}	43.08^{a}	52.42^{ab}	61.58^{cd}
Grand mean	8.25	22.70	29.14	42.36	52.10	62.77
CV (%)	7.90	6.30	4.60	5.60	5.20	2.90
P-value	0.006	<0.001	<0.001	<0.001	<0.001	<0.001
CD (P≤0.05)	1.153	2.556	2.409	4.241	4.782	3.244
SEm±	0.529	1.173	1.106	1.946	2.195	1.489

Note: CV= Coefficient of variation, CD (≤0.05) = Critical difference at probability value 0.05, Treatment means followed by common letter (s) within a column are not significantly different at 5% by DMRT, NS= Non-significant, *= Significant at 5%, **= Significant at 1%, *** = Significant at less than 0.1% level, DAP = Days after planting

2.2 Plant height

Effect of plant nutrients on growth of plant height at 30, 90, 150, 210 and 270 days after planting and shooting was found statistically highly significant. At 30 days of planting, significantly the highest growth was observed in T3 (26.57) and was statistically at par with other treatments except T2 (23.77 cm) and T1 (18.14 cm). At 90 days, the greatest plant height was measured in T3 (76.32 cm) and fall statistically at par with T4, T5, T6 and T7 and the minimum height was observed in T1 (46.77 cm). Similarly, at 150 days of planting, T3 (109.26 cm) produced the tallest plant and T1 (76.23 cm) the shortest. At 210 days the tallest plant was measured in T3 (138.80 cm) and the shortest in T1 (97.70 cm) and other treatments were intermediate. At 270 days of planting, T3 (173.60 cm) gave the tallest plant and was at par with all the treatments except T1, which produced the shortest plant height (131.40 cm). Similarly, at shooting maximum plant height was recorded in T3 (222.00 cm) followed by T5 and T6 (213.20 cm) and the lowest plant height was observed in T1 (197.20 cm) (Table 4).

Table 4 Effect of plant nutrients on mean growth of plant height of plant and first ratoon crop at different ages of banana cv. 'Grand Naine' during 2020-21 and 2021-22 at DoAR, Khajura, Banke, Nepal

Treatment	Plant height (cm)					
	30 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Shooting
T1	18.14^{c}	46.77^{c}	76.23^{c}	97.70^{c}	131.40^{b}	197.20^{c}
T2	23.77^{b}	67.35^{b}	99.67^{b}	121.20^{b}	164.40^{a}	207.30^{b}
T3	26.57^{a}	76.32^{a}	109.26^{a}	138.80^{a}	173.60^{a}	222.00^{a}
T4	26.12^{ab}	68.79^{ab}	103.42^{ab}	130.00^{ab}	168.60^{a}	212.80^{ab}
T5	24.71^{ab}	69.26^{ab}	102.62^{ab}	127.80^{ab}	170.90^{a}	213.20^{ab}
T6	24.09^{ab}	68.84^{ab}	102.63^{ab}	128.10^{ab}	175.10^{a}	213.20^{ab}
T7	25.74^{ab}	69.83^{ab}	103.19^{ab}	125.90^{b}	169.60^{a}	211.80^{ab}
Grand mean	24.16	66.74	99.57	124.20	164.80	211.10
CV (%)	5.40	6.80	4.20	5.10	5.00	2.60
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	0.005
CD (P≤0.05)	2.319	8.055	7.374	11.16	14.68	9.58
SEm±	1.064	3.697	3.385	5.12	6.74	4.40

Note: CV= Coefficient of variation, CD (≤0.05) = Critical difference at probability value 0.05, Treatment means followed by common letter (s) within a column are not significantly different at 5% by DMRT, NS= Non-significant, *= Significant at 5%, **= Significant at 1%, *** = Significant at less than 0.1% level, DAP = Days after planting

2.3 Number of effective leaves per plant

The number of effective leaves was non-significant at 30 and 90 days and highly significant at 150, 210, 270 days after planting and shooting. At 30 days, the effective leaves was ranged from 6.67 (T1) to 7.42 (T3 and T4) with mean value 7.11. At 90 days, the effective leaves ranged from 9.25 (T1) to 10.50 (T3 and T7) with a mean value 10.02. At 150 days, the number of effective leaves was significant and the highest leaves was recorded in T3 (11.50) followed by T5 (9.95) and T7 (9.92) and the lowest was observed on T1 (7.83). Again at 210 days, the effect leaves was the highest in T3 (10.92) and the lowest in T1 (6.66). At 270 days, the highest effective leaves was observed in T3 (11.50) followed by T7 (10.62) and the lowest in T1 (7.54). Similarly, at shooting, the highest number of effective leaves was recorded in T3 (17.00) followed by T5 (15.29) and the least in T1 (11.58) (Table 5).

Table 5 Effect of plant nutrients on mean effective leaves number of plant and first ratoon crop at different ages of banana cv. 'Grand Naine' during 2020-21 and 2021-22 at DoAR, Khajura, Banke, Nepal

Treatment	Number of effective leaves (cm)					
	30 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Shooting
T1	6.67	9.25	7.83^{d}	6.66^{d}	7.54^{d}	11.58^{d}
T2	7.25	9.75	8.87^{c}	8.39^{c}	8.96^{c}	13.34^{c}
T3	7.42	10.50	11.50^{a}	10.92^{a}	11.50^{a}	17.00^{a}
T4	7.42	10.00	9.76^{b}	9.58^{b}	10.18^{b}	14.67^{b}
T5	7.33	10.25	9.95^{b}	9.17^{bc}	9.92^{b}	15.29^{b}
T6	6.83	9.92	9.89^{b}	9.17^{bc}	9.93^{b}	15.25^{b}
T7	6.83	10.50	9.92^{b}	9.08^{bc}	10.62^{b}	14.83^{b}
Grand mean	7.11	10.02	9.67	9.00	9.805	14.567
CV (%)	8.40	8.8	3.00	6.10	3.80	3.00
P-value	0.554	0.605	<0.001	<0.001	<0.001	<0.001
CD (P≤0.05)	1.061	1.560	0.5171	0.977	0.6642	0.7810
SEm±	0.487	0.716	0.2373	0.448	0.3048	0.3584

Note: CV= Coefficient of variation, CD (≤0.05) = Critical difference at probability value 0.05, Treatment means followed by common letter (s) within a column are not significantly different at 5% by DMRT, NS= Non-significant, *= Significant at 5%, **= Significant at 1%, *** = Significant at less than 0.1% level, DAP = Days after planting

2.4 Total leaf area

The effect of plant nutrients on total leaf area was non-significant at 30 days while it was highly significant at 90, 150, 210 and 270 days after planting and shooting. At 30 days, the total leaf area of a plant varied from 0.05 m^2 (T1) to 0.13 m^2 (T4) with mean area 0.09 m^2. At 90 days, the highest leaf area was observed in T3 (2.40 m^2) was at par with T4, T5, T6 and T7 and the lowest total leaf area was observed in T1 (0.93 m^2). Similarly, at 150 days, the highest leaf area was found in T3 (3.92 m^2) followed by T7 (3.12 m^2) and the lowest area in T1 (1.43 m^2). At 210 days, the leaf area of T3 (4.86 m^2) was the greatest followed by T4 (3.73 m^2) and the T1 (1.53 m^2) being the lowest in total leaf area. At 270 days, the greatest leaf area was again found in T3 (6.81 m^2) and the lowest in T1 (2.78). At shooting, the highest leaf area was recorded in T3 (16.07 m^2) followed by T6 (12.87 m^2) and the lowest area in T1 (6.99 m^2) (Table 6).

2.5 Leaf area index

At 30 days, the leaf area was non-significantly varied from 0.013 (T1) to 0.032 (T4) with mean index 0.024. At 90 days, the index was significant and the highest was in T3 (0.601) and the lowest in T1 (0.232). At 150 days, significantly the highest index was recorded in T3 (0.980) was followed by T5 and T7 (0.780) and the lowest in T1 (0.358). At 210 days, the highest index was measured in T3 (1.214) followed by T4 (0.932) and lowest being in T1 (0.381). At 270 days, the greatest leaf area index was measured in T3 (1.703) followed by T5 (1.396) and the lowest in T1 (0.695). At shooting, the highest leaf area index was recorded in T3 (4.02) followed by T6 (3.22) and the least in T1 (1.75) (Table 7).

Table 6 Effect of plant nutrients on mean leaf area of plant and first ratoon crop at different ages of banana cv. 'Grand Naine' during 2020-21 and 2021-22 at DoAR, Khajura, Banke, Nepal

Treatment	Total leaf area per plant (m^2)					
	30 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Shooting
T1	0.05	0.93[b]	1.43[d]	1.53[d]	2.78[d]	6.99[d]
T2	0.11	2.04[a]	2.36[c]	2.99[c]	4.03[c]	9.62[c]
T3	0.11	2.40[a]	3.92[a]	4.86[a]	6.81[a]	16.07[a]
T4	0.13	2.09[a]	3.09[b]	3.73[b]	5.37[b]	12.48[b]
T5	0.10	2.14[a]	3.12[b]	3.65[b]	5.58[b]	12.75[b]
T6	0.09	1.98[a]	3.07[b]	3.49[b]	5.38[b]	12.87[b]
T7	0.10	2.13[a]	3.12[b]	3.49[b]	5.48[b]	12.30[b]
Grand mean	0.09	1.96	2.87	3.39	5.06	11.87
CV (%)	23.60	15.50	6.30	7.90	9.90	5.60
P-value	0.051	0.002	<0.001	<0.001	<0.001	<0.001
CD (P≤0.05)	0.041	0.542	0.323	0.475	0.890	1.179
SEm±	0.019	0.249	0.148	0.218	0.408	0.541

Note: CV= Coefficient of variation, CD (≤0.05) = Critical difference at probability value 0.05, Treatment means followed by common letter (s) within a column are not significantly different at 5% by DMRT, NS= Non-significant, *= Significant at 5%, **= Significant at 1%, *** = Significant at less than 0.1% level, DAP = Days after planting

Table 7 Effect of plant nutrients on mean leaf area index of plant and first ratoon crop at different ages of banana cv. 'Grand Naine' during 2020-21 and 2021-22 at DoAR, Khajura, Banke, Nepal

Treatment	Leaf area index					
	30 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Shooting
T1	0.013	0.232[b]	0.358[d]	0.381[d]	0.695[d]	1.75[d]
T2	0.026	0.511[a]	0.591[c]	0.748[c]	1.006[c]	2.41[c]
T3	0.028	0.601[a]	0.980[a]	1.214[a]	1.703[a]	4.02[a]
T4	0.032	0.522[a]	0.772[b]	0.932[b]	1.342[b]	3.12[b]
T5	0.025	0.535[a]	0.780[b]	0.913[b]	1.396[b]	3.19[b]
T6	0.023	0.496[a]	0.768[b]	0.873[b]	1.344[b]	3.22[b]
T7	0.025	0.533[a]	0.780[b]	0.871[b]	1.371[b]	3.08[b]
Grand mean	0.024	0.490	0.7182	0.847	1.265	2.97
CV (%)	23.6	15.5	6.30	7.90	9.90	5.60
P-value	0.051	0.002	<0.001	<0.001	<0.001	<0.001
CD (P≤0.05)	0.01027	0.1355	0.08072	0.1188	0.223	0.2947
SEm±	0.00471	0.0622	0.03705	0.0545	0.102	0.1353

Note: CV= Coefficient of variation, CD (≤0.05) = Critical difference at probability value 0.05, Treatment means followed by common letter (s) within a column are not significantly different at 5% by DMRT, NS= Non-significant, *= Significant at 5%, **= Significant at 1%, *** = Significant at less than 0.1% level, DAP = Days after planting

2.6 Plant spreading

The effect of plant nutrients on mean plant spreading of banana was significant at 30, 150, 210 and 270 days after planting and shooting while non-significant at 90 days after planting. At 30 days, the highest spreading was recorded on T3 (53.47 cm) was statistically at par with all the treatments except T1 which had 40.67 cm spreading. At 90 days, spreading varied from 111.50 cm (T1) to 126.50 cm (T3) with a mean value 122.10 cm. At 150 days, the spreading was the highest in T3 (161.10 cm) was at par with T2, T4, T5 and T6 and the lowest on T1 (125.20 cm). Similarly, at 210 days, spreading was the highest 240.60 cm (T3) and the lowest in T1 (144.70 cm). At 270 days, the spreading was the maximum in T3 (267.20 cm) and was at par with all the treatments except T1 (201.20 cm). At shooting, the widest spreading was observed in T3 (327.60 cm) followed by T4 (314.90 cm) and the smallest in T1 (261.40 cm) (Table 8).

Table 8 Effect of plant nutrients on mean spreading of plant and first ratoon crop at different ages of banana cv. 'Grand Naine' during 2020-21 and 2021-22 at DoAR, Khajura, Banke, Nepal

Treatment	Plant spreading (cm)					
	30 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Shooting
T1	40.67^{b}	111.50^{b}	125.20^{c}	144.70^{c}	201.20^{b}	261.40^{b}
T2	50.63^{a}	125.30^{a}	148.40^{ab}	206.50^{b}	247.70^{a}	305.20^{a}
T3	53.47^{a}	126.50^{a}	161.10^{a}	240.60^{a}	267.20^{a}	327.60^{a}
T4	52.68^{a}	122.50^{a}	155.80^{ab}	218.00^{ab}	253.00^{a}	314.90^{a}
T5	50.00^{a}	122.50^{a}	155.50^{ab}	212.70^{ab}	254.50^{a}	314.10^{a}
T6	50.54^{a}	122.50^{a}	151.40^{ab}	211.20^{ab}	253.40^{a}	313.50^{a}
T7	51.38^{a}	123.70^{a}	146.90^{b}	211.40^{ab}	250.00^{a}	309.70^{a}
Grand mean	49.91	122.10	149.20	206.50	246.70	306.60
CV (%)	5.10	4.10	4.60	8.00	5.90	4.10
P-value	0.001	0.056	<0.001	<0.001	0.004	<0.001
CD (P≤0.05)	4.555	8.89	12.23	29.44	25.89	22.19
SEm±	2.090	4.08	5.62	13.51	11.88	10.18

Note: CV= Coefficient of variation, CD (≤0.05) = Critical difference at probability value 0.05, Treatment means followed by common letter (s) within a column are not significantly different at 5% by DMRT, NS= Non-significant, *= Significant at 5%, **= Significant at 1%, *** = Significant at less than 0.1% level, DAP = Days after planting

2.7 Cumulative leaves

The cumulative leaves production from 30 days to 270 days after planting and shooting was statistically highly significant. At 30 days, the highest number of cumulative leaf was recorded in T3 (8.00) was at par with T4, T5, T6 and T7 and the lowest number was observed in T1 (6.00). At 90 days, the highest number of cumulative leaf was produced in T3 (20.83) followed by T4 (19.25) and the lowest in T1 (14.17). At 150 days, the highest cumulative leaf was recorded in T3 (28.25) followed by T7 (26.75) and the lowest in T1 (19.92). At 270 days, the highest number of cumulative leaf production was observed in T3 (31.25) followed by T7 (29.75) and the lowest number in T1 (22.92). Similarly, at 270 days, the cumulative leaf number was the highest in T3 (36.00) and the lowest in T1 (27.67). At shooting, significantly the highest cumulative leaf number was recorded in T3 (44.00) followed by T7 (42.05) and the lowest in T1 (39.50) (Table 9).

Table 9 Effect of plant nutrients on mean cumulative leaves of plant and first ratoon crop at different ages of banana cv. 'Grand Naine' during 2020-21 and 2021-22 at DoAR, Khajura, Banke, Nepal

Treatment	Number of cumulative leaves per plant					
	30 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Shooting
T1	6.00^{c}	14.17^{c}	19.92^{c}	22.92^{c}	27.67^{c}	39.50^{c}
T2	6.83^{bc}	18.67^{b}	26.00^{b}	29.00^{b}	33.75^{b}	41.75^{b}
T3	8.00^{a}	20.83^{a}	28.25^{a}	31.25^{a}	36.00^{a}	44.00^{a}
T4	7.67^{ab}	19.25^{b}	26.62^{b}	29.62^{b}	34.37^{b}	42.37^{b}
T5	7.58^{ab}	18.58^{b}	26.36^{b}	29.36^{b}	34.11^{b}	42.11^{b}
T6	7.63^{ab}	18.67^{b}	26.40^{b}	29.40^{b}	34.15^{b}	42.15^{b}
T7	7.67^{ab}	18.42^{b}	26.75^{b}	29.75^{b}	34.50^{b}	42.50^{b}
Grand mean	7.34	18.37	25.75	28.75	33.50	42.05
CV (%)	7.00	3.70	2.70	2.40	2.10	1.80
P-value	0.007	<0.001	<0.001	<0.001	<0.001	<0.001
CD (P≤0.05)	0.919	1.196	1.247	1.247	1.247	1.322
SEm±	0.422	0.549	0.572	0.572	0.572	0.607

Note: CV= Coefficient of variation, CD (≤0.05) = Critical difference at probability value 0.05, Treatment means followed by common letter (s) within a column are not significantly different at 5% by DMRT, NS= Non-significant, *= Significant at 5%, **= Significant at 1%, *** = Significant at less than 0.1% level, DAP = Days after planting

3 Discussion

Considering the difficulties of nutrient availability, especially micronutrient, in the neutral to alkaline soil pH condition, a field study was carried out to observe effect of plant nutrients on vegetative growth of banana cv. 'Grand Naine' at DoAR, Khajura, Banke, Nepal and the study results revealed that the most of the growth parameters including base circumference, plant height, leaf area, leaf area index, spreading and leaf number was recorded significant from 30 days after planting to the shooting date. Out of seven treatments (Table 1), T1 (FYM 20 kg/plant) produced the lowest and T3 [FYM 20 kg, NPK 250:250:350 g/plant and $ZnSO_4$ 0.5% + $FeSO_4$ 0.2% + $CuSO_4$ (0.2%) + Borax (0.1%)] produced the greatest growths whereas treatments T4-T7 (supplying one micronutrient less than T3) showed intermediate growth rate of the vegetative parameters of plant of treatments T1 and T3 (Table 3; Table 4; Table 5; Table 6; Table 7; Table 8; Table 9). The lowest growth achieved in T1 was reasonable since plants were supplied no NPK and micronutrient which is required most for the optimum growth of the plant. Similarly, the growth rate of plants of the treatment T2 was higher in comparison to T1 for the reason that NPK improved the growth of root and shoot systems and better photosynthetic activities which ultimately supported growth but lower than the T3 because there was use of four types of micronutrient in T3. The lower vegetative growths of T1 and T2 might be attributed to the low availability of the micronutrient in neutral to slightly higher pH (Khadka and Lamichhane, 2016; Miller, 2016). The average growth of base circumference was 11.95 cm in T3 whereas it was 9.93 cm in T1 per two months from 30 days to 270 days after planting (Table 3). The average bimonthly growth of plant height (36.76 cm), cumulative leaf (7.75), leaf area (1.68 m^2), leaf area index (0.42) and plant spreading (53.43 cm) was the highest in T3 followed by T4-T7 and the lowest was observed in T1 (Table 4).

The improved vegetative growth of banana supplied with macro as well as micronutrients was due to the synergistic effect as N, P, K, Ca, Mg, Mn, Fe, B, Zn and Cu are the key nutrients of banana (Moreira and Fageria, 2009). The N, P, K, Ca and Mg have principal role on root and shoot growth and photosynthetic activities whilst micronutrients take parts in different biosynthetic activities of different enzymes and hormones. Zinc is involved in the biosynthesis of Indole-3-acetic acid through its involvement in the synthesis of tryptophan, a precursor of auxin (Ram and Bose, 2000; Alloway, 2008), resulted maximum growth of root, and increased absorption of nutrients consequential enhanced vegetative growth (Gonmei et al., 2022). Accelerated activation of several enzymes and physiological activities by the micronutrients is the result of encouraged plant growth including spread (Das and Mohan, 1993; Singh and Singh, 2002). According to Das (2018) zinc and manganese functions in several enzyme systems as bridges to connect the enzyme with the substrate upon which it is meant to act. In leaves, the content of Ca, Zn, Cu and B increases as there is greater soil water availability coupled with greater temperature (Guimaraes and Lima de Deus, 2021) therefore, higher growth during the summer rainy season in banana was observed was due to more available nutrient to the plant (Figure 1).

The present findings are also supported by the number of researchers. Among them, Borate et al. (2019) found 170.41 cm plant height, 56.29 cm girth, 12.24 leaves with (Zn 0.5%, Fe 0.2%, Cu 0.2% and B 0.1%) foliar spray at 5th, 7th and emergence of final hand) on 'Grand Naine' banana supporting the present results. In Robusta banana, Kumar and Jeyakumar (2001) sprayed $ZnSO_4$ (0.5%), $FeSO_4$ (0.2%), $CuSO_4$ (0.2%) and H_3BO_3 (0.1%) at 3rd, 5th and 7th month after planting and found increased pseudostem girth (59.80) and number of leaves (17.80) as in present results. Nodal et al. (2021) found soil application of micronutrients i.e. 25 kg $ZnSO_4$, 25 kg $FeSO_4$, 10 kg $CuSO_4$ and 10 kg Borax per hectare produced the tallest plant (407.57 cm), the greatest pseudostem girth 91.78 cm and the highest number of leaves (14.457) in 'Udhayam' banana. Krishnamoorthy and Hanif (2017) conducted a field experiment and found 206 cm plant height, 62 cm girth, 16 leaves and 4.66 leaf area index with the foliar application of Zn, Fe, Cu and B in banana. In Red banana Arthi and Shakila (2023) reported that foliar spray of 2% NRB Banana Shakti (4.8% Fe, 5.3% Zn, 2.8% B, 2.4% Cu and 4.6% Mn) at 45 days intervals started from 90 days of planting produced the greatest plant height (304.06 cm), girth (72.27 cm), number of functional leaves (16.56) and leaf area (8.28). In another study done in 'Grand Naine' banana by Rahate et al. (2020) recorded 204.60 cm plant height, 62.19 cm girth, 12.17 leaves and 3.25 suckers per plant at 270 days after planting with 200:100:200 g NPK and 20 g micronutrient mixture (Fe, Cu, Mn and Zn) per plant. With $ZnSO_4$

(0.5%), $FeSO_4$ (0.2%), $CuSO_4$ (0.2%) and Borax (0.1%) foliar spray at 5th and 7th months after planting, Thakur et al. (2023) recorded 199.00 cm height, 56.13 cm girth and 18.32 leaves per plant at 270 days after planting in banana which also support the present results.

4 Conclusion

Under the alkaline soil condition, availability of the most of the micronutrients (except molybdenum) is limited and results poor growth and development of banana plant hampering ultimate yield and fruit quality attributes. Therefore, to address the problem, a field study was carried on effect of plant nutrients on vegetative growth of banana cv. 'Grand Naine' under the alkaline soil condition of DoAR, Khajura, Banke, Nepal and found that the greatest base circumference (68.92 cm), the tallest plant (222.00 cm), the highest number of effective leaves (17.00), the greatest leaf area (16.07 m^2) and leaf area index (4.02), the highest plant spread (327.60 cm) and the highest number of cumulative leaves (44.00) at shooting in plants supplied with FYM 20 kg + NPK 250:250:350 g per plant + $ZnSO_4$ (0.5%) +$FeSO_4$ (0.2%)+ $CuSO_4$ (0.2%) + Borax (0.1%). Hence, from the study banana growers are highly recommended to use FYM, chemical fertilizers along with the foliar spray of micronutrients, at least for three times at 3rd, 5th and 7th months after planting in banana orchard grown under alkaline soil condition for the highest growth of plants.

Authors' contributions

BC was the principal investigator, responsible for designing field experiment, data collection, literature review and write-up of the manuscript. AKS, AS, and KMT were responsible for designing, monitoring the field experiment and overall guidance of the experiment. All authors read and approved the final manuscript.

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