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Research Article

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Effect of Plant Nutrients on Fruit Yield and Quality of Cavendish Banana (*Musa* sp.) cv. 'Grand Naine'

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Abstract

A field experiment was conducted to evaluate the effect of plant nutrients on yield and fruit quality of 'Grand Naine' banana under alkaline soil conditions for the two cropping seasons 2020-2021 and 2021-2022 at Directorate of Agricultural Research (DoAR), Khajura. The trial was laid out in a randomized complete block design consisting of seven treatments replicated three times having four plants in an experimental plot. Planting of tissue culture banana was done at 2×2 m spacing on 4th July 2020 and suckers selected from the same plant on the same date were taken as the first ratoon crop. Farmyard manure was applied at four, chemical fertilizers at six, and micronutrients at three installments. The pooled results revealed that the longest bunch (114.30 cm), the highest number of hands (10.08) and finger number per bunch (185.80) and second hand (21.50), the heaviest bunch (25.74 kg) and second-hand weight (3.28 kg), the highest finger length (21.08 cm), diameter (3.85 cm) and weight (156.20 g) and bunch yield (64.35 mt/ha), the highest TSS (20.20%), TSS: TA ratio (47.10) and total sugar (12.55%) and the lowest TA (0.43%) were registered in T3 (20 kg FYM, 250:250:350 g NPK along with foliar spray of four types of micronutrients viz. Zn, Fe, Cu and B at 3rd 5th and 7th months of planting. Hence, from the study banana growers are recommended to use FYM, chemical fertilizers along with a foliar spray of micronutrients, at least three times in the vegetative growth stage of bananas for higher yield and improved quality of fruits.

Keywords : Grand Naine, micronutrients, bunch weight, total soluble solid, titratable acidity

Introduction:

Banana (*Musa* sp.) is the world's fourth most important crop after rice, wheat, and maize and is cultivated in a 5,336,862 ha area with a total production of 124,978,578 mt and productivity is 23.42 mt/ha worldwide (FAO, 2022). In Nepal, it is cultivated in 21,633 ha of land, total production is 308,388 mt and the productivity is 15.97 mt/ha (ABPSD, 2022). Inadequate supply of quality planting materials, improper orchard management including manuring, fertilizing, and plant protection, and poor mechanization are the major problems associated with reduced yield of banana (Sharma et al., 2021).

Optimal growth and fruit production of banana is highly dependent on the nutrients present in the soil. Moreira and Fageria (2009), claimed that N, P, K, Mg, and Cu have a higher rate of re-translocation in bananas and the order of main nutrient and micronutrient uptake is K>N>Ca>Mg>P and Mn>Fe>B>Zn>Cu, respectively. Soil pH impairs plant growth due to its influence on the availability of essential plant nutrients and the concentration of elements toxic to plants (Brady and Weil, 2002). Within the pH range of 4-6, micronutrients like copper, iron, manganese, and zinc are readily available to plants, but at higher pH levels, they become securely linked to the soil and unavailable to them (Havlin et al., 2010). Except for molybdenum, the availability of the majority of micronutrients declines when pH increases and 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, iron, copper, and manganese, higher availability at low pH can be hazardous, and low availability at high pH can lead to deficient issues (Khadka and Lamichhane,

2016).

Because the soil in the DoAR's horticultural block of Khajura, Banke is alkaline (Table 1), the current study's goal was to determine how micronutrients affected banana fruit yield and quality in this environment.

Materials and Methods:

The study was conducted on 'Grand Naine' banana for the two consecutive crop seasons 2020-2021 (plant crop) and 2021-2022 (first ratoon crop) planted at 2×2 m spacing in a 40 cm deep pit having the same diameter. Five kg of FYM was applied during the planting time. Planting was done on 4th July 2020 and the first ratoon crop was selected on the same date in 2021 and the trial was completed in 2022. The remaining manure was applied during the 3rd, 5th, and 7th months after planting at the rate of 5 kg for each application. N:P:K 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 flowering. Urea, DAP, and MoP were applied at lower quantities in the early stages of growth and increased in later stages. During shooting time, 100 g of MoP was applied per plant. A foliar spray of micronutrients was done at 3rd, 5th and 7th months after planting. Intercultural operations were followed as per the recommendations.

Experimental site

The experiment site, Directorate of Agricultural Research, Khajura, Banke, Nepal is located at 133 meters above mean sea level, 28.11^0 North latitude to 81.59^0 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^{0}C in December and 36.47^{0}C in June and relative humidity ranged from 42.67% in April to 90% in January during the cropping periods (Figure 1). The soil's physical and chemical properties are given in Table 1.

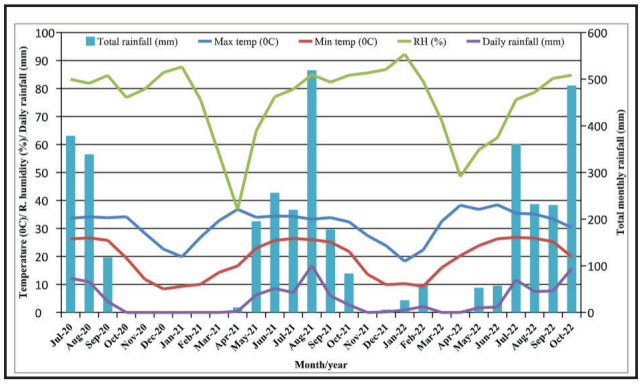

Figure 1: Monthly weather during two cropping seasons, 2020-21 and 2021-22, of DoAR, Khajura, Banke, Nepal

Experimental treatments and design

Table 2 : Treatment details of the experiment, effects of nutrients on fruit yield, and quality of Cavendish banana (Musa sp.) cv. 'Grand Naine'

Treatment	Treatment detail
T1	FYM 20 kg/plant
T2	FYM 20 kg/plant+ RDF (250:250:350 g NPK/plant)
T3	FYM 20 kg/plant+RDF+$ZnSO_4$ (0.5%)+$FeSO_4$ (0.2%)+$CuSO_4$ (0.2%) +Borax (0.1%)
T4	FYM 20 kg/plant+RDF+$FeSO_4$ (0.2%)+$CuSO_4$ (0.2%)+Borax (0.1%)
T5	FYM 20 kg/plant +RDF+$ZnSO_4$ (0.5%)+$CuSO_4$ (0.2%)+Borax (0.1%)
T6	FYM 20 kg/plant+RDF+$ZnSO_4$ (0.5%)+$FeSO_4$ (0.2%)+Borax (0.1%)
T7	FYM 20 kg/plant+RDF+$ZnSO_4$ (0.5%) +$FeSO_4$ (0.2%)+$CuSO_4$ (0.2%)

Data collection, measurement, and statistical analysis

Table 1 : The 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	Silt loam	

Yield and its attributing characters like bunch length were measured from the base to the tip of the bunch. Finger length, diameter, and weight were calculated as the average of 10 fingers from the second hand of the bunch. Bunch weight and yield were calculated from the average of 4 plants of an experimental plot. Fruit quality was analyzed in DoAR, Khajura, and the National Food Research Center, Khumaltar. Data were arranged in Microsoft Office Excel and analyzed with the 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).

Results:

Fruit yield attributes:

Bunch length and number of hands per bunch:

The length of the bunch was non-significant in plant crop, first ratoon crop, and pooled data. The number of hands per bunch was statistically significant. T4 and T7 produced the highest number of hands (8.67) and they were at par with other treatments except T1 in the plant crop while it was non-significant in the first ratoon crop and differed from 7.50 (T1) to 12.70 (T3) with a mean value of 10.31. The pooled data showed a similar pattern of the plant crop and the highest number of hands was observed in T3 (10.08) and was statistically at par with other treatments except T1 (6.50) (Table 3).

Table 3 : Effect of plant nutrients on bunch length and number of hands per bunch of plants and first ratoon crop of banana cv. 'Grand Naine' during 2020-21 and 2021-22 at DoAR, Khajura, Banke, Nepal

Treatment	Bunch length (cm)			Number of hands per bunch		
	Plant crop	First ratoon crop	Pooled	Plant crop	First ratoon crop	Pooled
T1	99.80	104.30	102.10	5.50b	7.50	6.50b
T2	99.40	121.30	110.40	8.17a	9.67	8.92a
T3	99.60	129.00	114.30	8.00a	12.17	10.08a
T4	103.80	124.20	114.00	8.67a	10.67	9.67a
T5	99.00	124.20	111.60	7.83a	10.67	9.25a
T6	96.70	117.80	107.30	8.33a	10.50	9.42a
T7	109.40	117.80	113.60	8.67a	11.00	9.83a
Grand mean	101.10	119.80	110.40	7.88	10.31	9.10
CV (%)	8.70	8.00	4.80	8.40	14.50	10.00
F value	0.69^{NS}	2.05^{NS}	2.11^{NS}	8.25^{**}	2.81^{NS}	5.29^{**}
CD (P≤0.05)	15.62	16.94	9.42	1.175	2.654	1.617
SEm±	7.17	7.78	4.32	0.539	1.218	0.742

Number of fingers per bunch and second hand:

The number of fingers per bunch was significant in the plant crop and non-significant in the first ratoon crop while pooled data was highly significant. In plant crops, the highest number of fingers per bunch was recorded in T3 (151.80) while it was the lowest in T1 (85.70). In pooled data, the highest number of fingers was 185.80 (T3) which was statistically at par with T2 (168.20) and T4 (160.20). On the second hand, the highest number of fingers was recorded in T3 (21.33) in the plant crop while it was the highest in T4 (23.83) in the first ratoon crop which was statistically at par with T2, T4, T5, and T7. In pooled data, the highest number of fingers was recorded in T3 (21.50) (Table 4).

Weight of bunch and second hand:

Bunch weight and weight of second hand were statistically significant in plant crop, first ratoon crop, and pooled data. Significantly the highest bunch weight was produced in T3 (28.05 kg) which was statistically at par with T4 (24.67 kg) and the lowest was in T1 (11.86 kg) in plant crop. In the first ratoon crop, the highest bunch weight was observed in T3 (23.43 kg) followed by T6 (19.58 kg), and the lowest in T1 (13.49 kg). In pooled data, the maximum bunch weight was recorded in T3 (25.74 kg) followed by T4 (21.84 kg), and the lowest in T1 (12.68 kg). Similarly, the weight of the second hand was the highest in T3 (3.03 kg) in plant crop, first ratoon crop (3.54 kg), and pooled data (3.28 kg). The lowest second hand weight was produced in T1 (Table 5).

Finger length and diameter:

The length of the finger was significantly different among the treatments in plant crops while it was non-significant in the first ratoon crop. In plant crops, the longest finger (21.76 cm) was observed in T6 which was statistically at par with T3, T4, T5, and T7. In pooled data, the longest finger was recorded in T3 (21.08 cm) while the shortest was in T1 (18.02cm). The finger diameter was highly significant in the plant and first ratoon crop. The highest diameter was observed in T3 and the smallest diameter in T1 in plant crop, first ratoon crop, and pooled data (Table 6).

Finger weight and bunch yield:

The weight of individual fingers in the plant and first

Table 4 : Effect of plant nutrients on the number of fingers per bunch and second hand of plant and first ratoon crop of banana cv. 'Grand Naine' during 2020-21 and 2021-22 at DoAR, Khajura, Banke, Nepal

Treatment	Number of fingers per bunch			Number of fingers in second-hand		
	Plant crop	First ratoon crop	Pooled	Plant crop	First ratoon crop	Pooled
T1	85.70b	136.70	111.20c	14.67c	18.17c	16.42e
T2	135.20a	201.30	168.20ab	18.67ab	23.50a	21.08a
T3	151.80a	219.70	185.80a	21.33a	21.67ab	21.50a
T4	136.00a	184.30	160.20ab	17.00bc	23.83a	20.42ab
T5	122.20a	179.80	151.00b	15.33c	20.83abc	18.08cd
T6	124.50a	177.80	151.20b	14.33c	19.83bc	17.08de
T7	129.30a	163.20	149.60b	16.50bc	22.00ab	19.25bc
Grand mean	126.40	180.40	153.009	16.83	21.40	19.12
CV (%)	16.00	15.60	10.00	10.10	8.20	4.30
F value	3.05*	2.66NS	6.65**	6.41**	3.93*	17.41***
CD (P≤0.05)	36.04	50.10	27.24	3.021	3.110	1.469
SEm±	16.540	23.00	12.500	1.386	1.427	0.674

Table 5 : Effect of plant nutrients on the weight of bunch and second hand of plant and first ratoon crop of banana cv. 'Grand Naine' during 2020-21 and 2021-22 at DoAR, Khajura, Banke, Nepal

Treatment	Bunch weight (kg)			Weight of second hand (kg)		
	Plant crop	First ratoon crop	Pooled	Plant crop	First ratoon crop	Pooled
T1	11.86e	13.49c	12.68e	1.87c	1.99c	1.93d
T2	18.14d	17.83b	17.99d	2.38abc	2.24bc	2.31cd
T3	28.05a	23.43a	25.74a	3.03a	3.54a	3.28a
T4	24.67ab	19.00b	21.84b	2.87ab	3.43a	3.15ab
T5	23.39bc	17.94b	20.67bc	2.05c	3.04ab	2.54bcd
T6	22.20bcd	19.58b	20.89bc	2.24bc	3.11ab	2.67abc
T7	20.18cd	17.58b	18.88cd	2.34abc	3.33a	2.83abc
Grand mean	21.22	18.41	19.81	2.40	2.95	2.68
CV (%)	10.50	7.30	6.50	15.80	17.40	14.20
F value	16.39***	14.65***	28.80***	3.66*	4.09*	4.60*
CD (P≤0.05)	3.96	2.379	2.300	0.6726	0.916	0.674
SEm±	1.818	1.092	1.056	0.309	0.420	0.309

Table 6 : Effect of plant nutrients on finger length and diameter of banana cv. 'Grand Naine' during 2020-21 and 2021-22 at DoAR, Khajura, Banke, Nepal

Treatment	Finger length (cm)			Finger diameter (cm)		
	Plant crop	First ratoon crop	Pooled	Plant crop	First ratoon crop	Pooled
T1	17.91c	18.14	18.02d	3.09b	2.63b	2.86d
T2	20.28b	19.16	19.72c	3.75a	3.27a	3.51bc
T3	20.94ab	21.22	21.08a	3.96a	3.75a	3.85a
T4	21.35ab	19.73	20.54ab	3.86a	3.39a	3.63bc
T5	21.09ab	19.49	20.29abc	3.63a	3.28a	3.45c
T6	21.76a	19.42	20.59ab	3.86a	3.50a	3.68ab
T7	20.73ab	19.79	20.26bc	3.67a	3.57a	3.62bc
Grand mean	20.58	19.56	20.07	3.69	3.34	3.51
CV (%)	2.90	5.10	2.10	4.70	7.40	3.30
F value	13.14***	2.49NS	16.81***	8.46***	6.36**	22.41***
CD (P≤0.05)	1.077	1.792	0.746	0.305	0.437	0.206
SEm±	0.494	0.822	0.342	0.140	0.201	0.095

ratoon crop was significantly different among the treatments. In plant crops, the highest finger weight was produced in T4 (169.60 g) followed by T7 (154.30 g), was statistically at par with T2, T3, and T6. In first ratoon crop, the highest finger weight was recorded in T3 (159.80 g) followed by T5 (143.30 g), and the lowest in T1 (114.80 g). In pooled data maximum finger weight was found in T3 (156.20 g) was statistically at par with T6 (145.60 g) and T7 (144.20 g). The highest bunch yield was recorded in T3 (70.13 mt/ha) in plant crop which was followed by T4 (61.68 mt/ha) and the lowest in T1 (29.66 mt/ha). Similarly, in first ratoon crop, the highest yield was produced by T3 (58.57 mt/ha) followed by T6 (48.94 mt/ha), and the lowest in T1 (33.72 mt/ha). The pooled data showed T3 produced the maximum bunch yield (64.35 mt/ha) followed by T4 (54.60 mt/ha) and the lowest yield was found in T1 (31.69 mt/ha). The mean yield of the first ratoon crop is low (46.02 mt/ha) as compared to the plant crop (53.00 mt/ha) (Table 7).

Fruit quality attributes:

Moisture content and pH of ripe fruit:

The moisture content of fruit was highly significant in plant crops, first ratoon, and pooled data. The highest moisture was found in T2 (78.62%) followed by T6 (78.36%) and the lowest in T1 (72.31%) in the plant crop. The first ratoon crop followed a similar trend and the highest moisture was recorded in T2 (82.70%) followed by T4 (81.89%) and the lowest moisture was observed in T1 (77.60%). The pooled data exhibited the highest moisture content in T2 (80.66%) followed by T6 (79.45%) and the lowest in T1 (74.95%). In plant crops, pH was the highest in T6 (5.02) followed by T2 (4.95), and the lowest pH was recorded in T4 (4.58). In the first ratoon crop, this was non-significant and varied from 4.5 in T1 to 4.90 in T2 and T3 with a mean value of 4.79. Pooled data exhibited the highest pH in T2 (4.92)

Table 7 : Effect of plant nutrients on finger weight and bunch yield of banana cv. 'Grand Naine' during 2020-21 and 2021-22 at DoAR, Khajura, Banke, Nepal

Treatment	Finger weight (g)			Bunch yield (mt/ha)		
	Plant crop	First ratoon crop	Pooled	Plant crop	First ratoon crop	Pooled
T1	118.40c	114.80c	116.60d	29.66e	33.72c	31.69e
T2	146.90ab	118.30c	132.60c	45.36d	44.57b	44.97d
T3	152.70ab	159.80a	156.20a	70.13a	58.57a	64.35a
T4	169.60a	114.50c	142.10bc	61.68ab	47.51b	54.60b
T5	139.80bc	143.30ab	141.60bc	58.48bc	44.86b	51.67bc
T6	160.00ab	131.20bc	145.60ab	55.51bcd	48.94b	52.22bc
T7	154.30ab	134.10bc	144.20abc	50.46cd	43.94b	47.2cd
Grand mean	148.80	130.90	139.80	53.00	46.02	49.53
CV (%)	8.90	9.90	4.70	10.50	7.30	6.50
F value	4.59*	5.02**	10.64***	16.39***	14.65***	28.80***
CD (P≤0.05)	23.580	23.020	11.710	9.900	5.947	5.750
SEm±	10.82	10.57	5.37	4.540	2.729	2.639

Table 8 : Effect of plant nutrients on moisture content and pH of ripe banana cv. 'Grand Naine' during 2020-21 and 2021-22 at DoAR, Khajura, Banke, Nepal

Treatment	Moisture content (%)			pH of fruit pulp		
	Plant crop	First ratoon crop	Pooled	Plant crop	First ratoon crop	Pooled
T1	72.31d	77.60e	74.95e	4.61cd	4.50	4.56c
T2	78.62a	82.70a	80.66a	4.95a	4.90	4.92a
T3	72.88cd	81.47b	77.17d	4.75b	4.90	4.83ab
T4	74.51b	81.89ab	78.2c	4.58d	4.80	4.69bc
T5	74.03bc	79.42d	76.73d	4.65cd	4.80	4.72bc
T6	78.36a	80.53c	79.45b	5.02a	4.80	4.91a
T7	74.78b	79.88cd	77.33d	4.7bc	4.80	4.75ab
Grand mean	75.07	80.50	77.78	4.75	4.79	4.77
CV (%)	1.00	0.60	0.60	1.10	3.70	1.90
F value	34.75***	40.28***	47.58***	31.33***	1.69NS	6.10**
CD (P≤0.05)	1.304	0.833	0.834	0.0939	0.3189	0.1623
SEm±	0.598	0.382	0.383	0.0431	0.1464	0.0745

Total soluble solid, titratable acidity, and TSS:TA:

followed by T6 (4.91) and the lowest pH in T1 (4.56) (Table 8).

The effect of plant nutrients on the total soluble solid, titratable acidity, and TSS:TA ratio was significant in the case of the plant crop and the pooled data, while it was non-significant in the case of the ratoon crop. Significantly, the highest TSS was recorded in treatment T3 (20.21%) followed by T7 (18.19%) which was statistically at par with T1, T2, T4, T5, and T6 and the lowest in T1 (17.36%) in the plant crop. In the first ratoon crop, it was non-significant and varied from 17.17% (T1) to 20.19% (T3) with a mean value of 18.12%. In pooled data, it was significant and the highest in T3 (20.20%) was followed by T4 (18.15%) and the lowest was in T1 (17.27%). Significantly, the highest titratable acidity was observed in T1 (0.48%) followed by T7 (0.46%), and was at par with T5 (0.45%) in the case of the plant crop. Titratable acidity was non-significantly varied from 0.42% (T5) to 0.53% (T2) with the average data 0.47% in the first ratoon crop. The pooled data of plant and first ratoon crop was significant and showed the highest titratable acidity in T1 (0.49%) which was statistically at par with T2 (0.48%) and T7 (0.45%) and the lowest (0.43%) in T3 and T5 (Table 9).

The TSS:TA ratio of ripe banana fruit was statistically highly significant in plant crop and pooled data and non-significant in the first ratoon crop. In the case of the plant crop, the highest ratio was recorded in T3 (48.46) followed by T4 (43.84), and the lowest ratio was observed in T1 (36.50) which was statistically at par with T2, T5, and T6 and T7 respectively. In the first ratoon crop, the ratio was non-significantly varied from 33.29 (T2) to 45.74 (T3) with a mean value of 39.50. The pooled data was highly significant among the treatments. The highest ratio was found in T3 (47.10) and was followed by T5 (41.70) and the lowest ratio was recorded in T1 (35.22) and was at

Table 9 : Effect of plant nutrients on total soluble solid and titratable acidity of ripe banana fruit cv. 'Grand Naine' during 2020-21 and 2021-22 at DoAR, Khajura, Banke, Nepal

Treatment	Total soluble solid (%)			Titratable acidity (%)		
	Plant crop	First ratoon crop	Pooled	Plant crop	First ratoon crop	Pooled
T1	17.36b	17.17	17.27b	0.48a	0.52	0.49a
T2	17.65b	17.50	17.57b	0.44bc	0.53	0.48ab
T3	20.21a	20.19	20.20a	0.42c	0.44	0.43c
T4	18.12b	18.18	18.15b	0.41c	0.47	0.44bc
T5	17.68b	18.33	18.01b	0.45ab	0.42	0.43c
T6	17.53b	17.69	17.61b	0.44bc	0.44	0.44bc
T7	18.19b	17.77	17.98b	0.46ab	0.45	0.45abc
Grand mean	18.11	18.12	18.11	0.44	0.47	0.45
CV (%)	5.20	6.40	4.50	3.7	11.6	5.5
F value	3.25*	2.21NS	4.33*	5.63**	1.82NS	3.33*
CD (P≤0.05)	1.668	2.060	1.437	0.02944	0.0964	0.04459
SEm±	0.765	0.945	0.660	0.01351	0.0443	0.02046

Table 10 : Effect of plant nutrients on TSS: TA ratio of ripe fruit of banana cv. 'Grand Naine' during 2020-21 and 2021-22 at DoAR, Khajura, Banke, Nepal

Treatment	TSS: TA ratio		
	Plant crop	First ratoon crop	Pooled
T1	36.50c	33.94	35.22c
T2	40.16bc	33.29	36.72bc
T3	48.46a	45.74	47.10a
T4	43.84ab	39.22	41.53b
T5	39.37bc	44.03	41.70b
T6	40.23bc	40.39	40.31bc
T7	39.96bc	39.80	39.88bc
Grand mean	41.22	39.50	40.35
CV (%)	7.00	12.10	7.10
F value	5.33**	2.83NS	5.37**
CD (P≤0.05)	5.129	8.52	5.107
SEm±	2.354	3.91	2.344

par with T2 (36.72), T6 (40.31), and T7 (39.88) (Table 10).

Total sugar and reducing sugar content:

The effect of plant nutrients on total sugar and reducing sugar content of bananas was statistically non-significant in plant crops and first ratoon crops however pooled data was significant. In the first ratoon crop, it varied from 11.15% (T1) to 13.54% (T4) with an average value of 12.54%. In pooled data, the highest total sugar content was recorded in T3 (12.55%) followed by T4 (12.28%), T2 (11.84%), T5 (11.76%), T6 (11.37%), and the lowest content was found in T1 (10.44%). The reducing sugar content was significant and the highest was recorded in T4 (2.69%) which was statistically at par with T6 (2.25%) and T7 (2.14%) and the lowest reducing sugar content was found in T1 (0.78%) in plant crop. In the first ratoon crop, the reducing sugar content was the maximum in T7 (0.60%) followed by T6 (0.56%), and the lowest was recorded on T3 (0.46%) which was statistically at par with T1 (0.47%), T2 (0.50%) and T5 (0.50%). In pooled data, the highest reducing sugar was recorded on T4 (1.62%) which was statistically at par with T6 (1.40%) and T7(1.37%), and the lowest was found in T1 (0.63%) (Table 11).

Table 11 : Effect of plant nutrients on total sugar and reducing sugar content of ripe banana cv. 'Grand Naine' during 2020-21 and 2021-22 at DoAR, Khajura, Banke, Nepal

Treatment	Total sugar content of fruit pulp (%)			Reducing the sugar content of pulp (%)		
	Plant crop	First ratoon crop	Pooled	Plant crop	First ratoon crop	Pooled
T1	9.73	11.15	10.44c	0.78d	0.47c	0.63d
T2	10.84	12.84	11.84ab	1.99bc	0.50c	1.25bc
T3	11.86	13.23	12.55a	1.57c	0.46c	1.01c
T4	11.02	13.54	12.28a	2.69a	0.55b	1.62a
T5	11.26	12.26	11.76ab	1.89bc	0.50c	1.19bc
T6	10.20	12.54	11.37abc	2.25ab	0.56ab	1.40ab
T7	9.90	12.23	11.06bc	2.14abc	0.60a	1.37ab
Grand mean	10.69	12.54	11.61	1.90	0.52	1.21
CV (%)	9.10	6.80	5.20	17.20	4.70	13.80
F value	1.92^{NS}	2.50^{NS}	4.25^{*}	10.11^{***}	13.27^{***}	11.01^{***}
CD (P≤0.05)	1.728	1.526	1.080	0.583	0.043	0.297
SEm±	0.793	0.700	0.496	0.267	0.019	0.136

Discussion:

Yield attributes:

Average bunch length (114.30 cm), number of hands per bunch (10.08), number of fingers per bunch (185.80) and number of fingers in second hand (21.50), weight of bunch (25.74 kg) and weight of second hand (3.28 kg), finger length (21.08 cm), finger diameter (3.80 cm), finger weight (156.20 g) and yield of bunch (64.35 mt/ha) were higher in T3 when compared to T1, T2 and other treatments (T4, T5, T6 and T7) having one nutrient less as compared toT3. The higher value of yield and yield attributing parameters were due to the synergistic effect of plant nutrients in bananas. The pH level of the study site was slightly alkaline and the availability of micronutrients to the plant from soil may be limited. In this context yield attributing parameters in the treatment T3 (combined FYM, chemical fertilizers, and four micronutrients foliar spray) were higher as compared to others. As mentioned earlier, different micronutrients have a specific role in catalyzing biochemical reactions, and biosynthesis of important enzymes, hormones, or other compounds required for optimum growth and development of plants. Zinc has a role in IAA synthesis (Alloway, 2008) which is responsible for plant root and shoot growth and ultimately affects the yield; iron promotes photosynthesis and chlorophyll development (Mamatha. 2007) therefore has an important participation in the assimilation of photosynthates and growth of finger and yield finally; copper catalyzes the photosynthesis and synthesis of chlorophyll (Ram and Bose, 2000) so, have an important role in growth and development of yield attributing parameters and boron helps in uptake of calcium, IAA metabolism, root growth and metabolism of RNA (Sala, 2011; ASK, 2012; Pandey and Gupta, 2013) therefore has important position in plant growth and development and enhancement of yield parameters.

The present results were also supported by the number of researchers. The highest bunch weight (23.15 kg) and number of hands per bunch (12.75) were obtained by Kumar and Jeyakumar (2001) with the combined spray of Zn, Fe, Cu, and B at the 3rd, 5th, and 7th months after planting. According to Patel et al. (2010), foliar spray of ZnSO4 (0.5%) and FeSO4 (0.5%) produced the highest results, with bunches weighing 23.85 kg, being 93.50 cm long, and having 11.70 hands. The addition of Cu and B in the present study may be the cause of the greater yield. The present findings regarding yield and yield parameters that contributed to yield were better than those of Borate

et al. (2019), who reported 16.91 fingers per hand, 15.24 cm of finger length, 131.30 g of finger weight, 7.54 hands per bunch, 130.72 fingers per bunch and 19.88 kg of bunch weight. Along with the recommended quantity of NPK (200:50:400 g/plant), Jeyabaskaran and Pandey (2008) obtained the highest bunch weight with soil applications of Fe (5 g) at 3 months and foliar applications of Zn (0.5%) and B (10 ppm) at 3rd, 5th and 7th months after planting. Premalatha et al. (2020) recorded higher length (23.05 cm) finger weight (282.64 g), and bunch yield (12.76 kg) as compared to other treatments with spraying micronutrient combinations at 2nd, 3rd, and 6th months after planting. These results partially supported the present findings. In a study conducted by Pathak et al. (2011), bananas had the highest number of fingers and hands, longest bunch and finger length, greatest finger diameter, and maximum bunch weight, when applied $ZnSO_4$ (0.5%) and $FeSO_4$ (0.5%) in banana. Bananas supplied with 160:50:390 g NPK applied at the 3rd, 5th, and 7th months after planting along with banana special 30 kg/ha (magnesium 1310 mg, calcium 400 mg, sulfur 120 mg, zinc 3.5 mg, boron 2.7 mg, iron 160 mg, cytokinin 200 mg, amino acids 0.23 mg/l) and Banana Shakti 12.5 kg/ha (boron 2.5%, copper 2.4%, iron 4.75%, manganese 4.5%, and zinc 5.25%) two times foliar spray at fruit development stage produced 45.83 mt and 44.28 mt yields (Jagadeeswari et al., 2018). The results are lower than the present findings this difference could be explained by cultural practices and spacing. According to Sallam et al. (2002), Zn, Cu, and B together increased fruit yield (18.0 kg/plant), fruit length (23.5 cm), and fruit diameter (3.15 cm), all of which are consistent with the present findings.

Fruit quality attributes:

Average moisture content, pH, total soluble solid (TSS), titratable acidity (TA), and TSS:TA ratio of ripe banana fruit were variable in different treatments. The highest moisture content (80.66%) and pH (4.92) were recorded in T2 while T1 showed the lowest level of moisture (74.95%) and pH (4.56). The maximum TSS (20.20%), minimum TA (0.43%), and the highest TSS:TA ratio (47.10) were recorded in T3. Similarly, total sugar and reduced sugar content of ripe bananas were also not showing clear trends in different treatments and registered the highest in T3 (12.55%) and was at par with T4 (12.28%), T2 (11.84%), T5 (11.76%), T6 (11.37%) and non-reducing sugar contained was the highest in T4 (1.62%) (Table 11).

The present findings are also in agreement with the number of researches. Ningavva et al. (2014) found the higher value of TSS (28.50%), total sugar (18.97%), reducing sugar (15.97%) and non-reducing sugars (2.93%), titratable acidity (0.29%) and sugar to the acid ratio (65.41) in the treatment (225:135:280 g NPK with a combination of foliar spray of $ZnSO_4$ (0.5%)+boron (0.2%) at 4th and 5th months after planting) as compared to present results, may be due to variation in study site, doses of fertilizers used and exclusion of $FeSO_4$ and $CuSO_4$. Yadav et al. (2011) also found the maximum TSS and other quality parameters with 200:90:200 g NPK/ plant along with 40g Zn-EDTA, 20 g $MnSO_4$, 5 g $CuSO_4$, and 10 g borax per plant as soil application. Ghanta and Mitra (1993) sprayed 0.3% Zn, 0.1% Cu, and 0.2% B at 3 and 5 months after planting and found the highest TSS, total sugars, reducing sugars, and sugar-acid ratio which is in line with the present findings. Pathak et al. (2011) reported the maximum sugar acid ratio (41.698), non-reducing sugar (10.040%) also showed considerable improvement in total soluble solids (25.53°Brix) and total sugar (17.241%) content of pulp under foliar spraying of Fe (0.5%) and Zn (0.5%). Similarly, Panigrahi et al. (2018) reported that maximum total soluble solids, reducing sugar, non-reducing sugar, total sugar, pulp: peel ratio, and minimum acidity percent under the treatment (RDF+$ZnSO_4$ (0.5%)+$FeSO_4$ (0.5%)). Kumar and Jeyakumar, 2001 reported in Robusta banana that spray of $ZnSO_4$ (0.5%), $FeSO_4$ (0.2%), $CuSO_4$ (0.2%), and H_3BO_3 (0.1%) at 3, 5 and 7th month after planting resulted in the highest TSS (19.15%) in the ripe fruit as compared to the single spray or soil application of the nutrients supporting the present study.

Conclusion:

Banana is a profitable horticultural crop that can be continued for 6-7 cycles without significant reduction in yield. Soil pH plays a significant role in determining the yield and fruit quality of bananas, as it affects the availability of major and micronutrients. High soil pH conditions make micronutrients unavailable to the banana, necessitating foliar application at different stages of plant growth. A foliar spray of $ZnSO_4$ (0.5%), $FeSO_4$ (0.2%), $CuSO_4$ (0.2%), and Borax (0.1%) produced the longest bunch (114.30 cm), highest number of hands (10.08) and fingers per bunch (185.80) and fingers per second hand (21.50), the highest weighed bunch (25.74 kg) and second hand weight (3.28 kg), maximum finger length (21.08 cm), diameter (3.85 cm), weight (156.20 g), bunch yield (64.35 mt/ha), the highest TSS (20.20%), TSS:TA ratio (47.10) and total sugar (12.55%), and the lowest TA (0.43%). Therefore, banana growers in alkaline areas should supply micronutrients through foliar spray in the 3rd, 5th, and 7th months after planting, along with FYM and chemical fertilizers, for optimal yield and quality fruit

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The authors declare no conflict of interest. Basant Chalise was the principal researcher, overseeing the field experiment, data collection, literature review, and manuscript writing. Arjun Kumar Shrestha, Arvind Srivastava, and Kalyani Mishra Tripathi designed, monitored, and guided the research, with all authors reading and approving the manuscript for publication.

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