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Soil and plant nutrient status and growth parameters of banana cv. Nendran (*Musa* AAB) as influenced by organic nano NPK formulation

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Abstract
To evaluate the effect of soil application of organic nano NPK formulation on soil and plant nutrient status and growth parameters in banana cv. Nendran, a field experiment was laid out in the Instructional Farm of College of Agriculture, Vellayani, Thiruvananthapuram from December 2020 to November 2021 in RBD with eight treatments and three replications. The treatments were T_1 (15 g nano NPK in 2 splits), T_2 (15 g nano NPK in 6 splits), T_3 (30 g nano NPK in 2 splits), T_4 (30 g nano NPK in 6 splits) T_5 (45 g nano NPK in 2 splits), T_6 (45 g nano NPK in 6 splits), T_7 (soil test-based Package of Practices (POP) recommendation of KAU) and T_8 was 'control'. The study revealed that the application of 45 g granular organic nano NPK in 6 splits along with 10 kg FYM and 100 g lime per plant per year (T_6) increased the total number of functional leaves, soil organic carbon and dehydrogenase activity and enhanced the soil nutrient status and improved the nutrient uptake by the plants.

Keywords: Organic nano NPK, banana, dehydrogenase, nutrient uptake

1. Introduction
Banana is a highly nutritious and easily digestible fruit crop with high productivity and is rich in potassium. Leaves of banana are widely used as plates. Among the commercial banana cultivars, Nendran is unique and is very popular in Kerala. Mature unripe fruit of Nendran is used as a vegetable. Being a nutrient exhaustive crop, Nendran requires high nutrient doses more frequently which increase labour cost and cost of production. Use of organic nano formulations is a viable alternative. Since these fertilizers deliver nutrients to crops in a controlled release manner, quantity can be substantially reduced thus minimizing environmental damage and maintain soil quality. Hence, this study was carried out to evaluate the effect of soil application of organic nano NPK formulation on growth parameters of banana cv. Nendran (*Musa* AAB), soil nutrient status and plant nutrient uptake.

2. Materials and Methods
The research work was carried out in the Instructional Farm of College of Agriculture, Vellayani, Thiruvananthapuram, Kerala during 2020-2021. The commercially available granular organic nano NPK (TAG NANO NPK) formulation was used as the nano NPK source for the field experiment. Before the experiment, sample of the formulation was analyzed for the total nutrient content (N, P, K, Ca, Mg and S), pH, EC, organic carbon and humic acid using the standard procedures as listed in the Table 1.
The experimental site was located at 8°25'38" North latitude and 76°59'14" East longitude and at an altitude of 19 m above MSL. The major soil type of the site was laterite and with sandy clay loam texture. It belongs to the Vellayani series and is moderately acidic with a pH of 5.9. Before initiation of experiment, soil samples collected from the field were analyzed for the pH, EC, organic carbon, dehydrogenase enzyme and available nutrients (N, P, K, Ca, Mg, and S) using the standard procedures as listed in the Table 2.

Table 1: Methods for analysis of granular organic nano NPK formulation

Sl. No.	Parameter	Method	Reference
1.	pH	pH meter method	Jackson (1973)
2.	Electrical conductivity	Conductivity meter method	Jackson (1973)
3.	Organic Carbon	Walkley and Black's rapid titration method	Walkley and Black (1934)
4.	Humic acid	Extraction using mild alkali	McBride (1994)
5.	Total Nitrogen	Micro Kjeldahl digestion and distillation	Jackson (1973)
6.	Total Phosphorus	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using spectrophotometer	Jackson (1973)
7.	Total Potassium	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using flame photometer	Jackson (1973)
8.	Total Calcium and Magnesium	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using Versenate titration method	Hesse (1971)
9.	Total Sulphur	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and turbidimetry	Massoumi and Cornfield (1963)

Table 2: Methods used for soil analysis

Sl. No	Particulars	Method adopted	Reference
1.	Soil reaction (pH)	pH meter with glass electrode	Jackson (1973)
2.	Organic Carbon	Walkley and Black titration method	Jackson (1973)
3.	Electrical conductivity	Soil water suspension of 1:2.5 and read in EC meter	Jackson (1973)
4.	Dehydrogenase enzyme	Spectrophotometric method	Casida *et al.* (1964)
5.	Nitrogen	Alkaline permanganate method	Subbiah and Asija (1956)
6.	Phosphorus	Bray's colorimetric method	Jackson (1973)
7.	Potassium	Ammonium acetate method	Jackson (1973)
8.	Ca and Mg	Versenate titration method	Hesse (1971)
9.	Sulphur	$CaCl_2$ extraction method	Massoumi and Cornfield (1963)

Uniform sized healthy suckers of banana cv. Nendran were used as planting material for the field experiment. The field experiment was laid out in RBD with eight treatments and three replications. The plot size was 24 m^2 and six plants were maintained in each plot at a spacing of 2 x 2 m. The treatment plots were separated by channels of 1 m width. The experiment was conducted with combinations of three fertilizer doses (N_1, N_2 and N_3) and two times of application (S_1 and S_2) as detailed below.

a) Fertilizer dose (N)

1) N_1- 15g organic nano NPK formulation per plant
2) N_2- 30g organic nano NPK formulation per plant
3) N_3- 45g organic nano NPK formulation per plant

b) Time of application (S)

1) S_1- 2 splits (2 and 4 months after planting)
2) S_2- 6 splits (1,2,3,4,5 months after planting and just after complete emergence of bunch)

Treatment combinations comprised of T_1 (N_1S_1), T_2 (N_1S_2), T_3 (N_2S_1), T_4 (N_2S_2), T_5 (N_3S_1), T_6 (N_3S_2), T_7 (KAU Package of Practices Recommendations -133.86:28.8:338.4g N:P_2O_5:K_2O per plant (based on soil test result) in six splits) and T_8 (control). Organic manure (10 kg FYM per plant) was applied (KAU, 2016) uniformly to all the treatments including the control as basal dose. Lime was applied @ 100g per pit based on the soil analysis report in all the pits two weeks prior to planting of suckers. Observations on vegetative parameters were recorded. After harvest, soil samples were collected from each plot and were used for analysis of pH, EC, Organic Carbon, dehydrogenase enzymes and available nutrients (N, P, K, Ca, Mg and S). The analysis was done using the standard procedures mentioned in Table 2. Rhizome, pseudostem, leaves and fruit were collected from the sample plants in each plot. The collected samples were chopped, dried and powdered before the estimation of N, P, K, Ca, Mg and S. The standard procedures used for the estimation of nutrient content are shown in Table 3. Finally, the nutrient uptake was calculated by using the values of per cent nutrient content of each plant part and the values of dry matter production and was expressed in kg ha^{-1}.

Table 3: Estimation of plant nutrient status

Sl. No.	Parameters	Methods	Reference
1	Nitrogen	Modified Kjeldahl method	Jackson (1973)
2	Phosphorus	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using Vanado molybdate yellow colour method	Jackson (1973)
3	Potassium	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using flame photometer	Jackson (1973)
4	Calcium and Magnesium	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using Versenate titration method	Hesse (1971)
5	Sulphur	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and turbidimetry	Massoumi and Cornfield (1963)

Statistical analysis of observed data was done by applying the technique of analysis of variance for Randomized Block Design (Panse and Sukhatme, 1985) [21]

3. Results and Discussion

3.1 Analysis of granular organic nano NPK formulation.

The data on analysis of organic nano NPK formulation revealed that it had a

pH of 7.79, EC of 0.14 dSm-1, and contained 2.35 per cent Organic Carbon, 19.19 per cent humc acid, 1.97 per cent N, 1.82 per cent P, 2.96 per cent K, 0.33 per cent Ca., 0.28 per cent Mg and 0.62 per cent S.

Subramanian and Rahale (2009) reported that the adsorptive sites of nano sized particles act as reservoir of nutrient ions. The present analytical report of the formulation is in conformity with the results of Nibin (2019) [20], who concluded that the formulation had a pH of 7.68 and an EC of 0.141 dS m^{-1} and Organic Carbon and humic acid contents were 2.25 per cent and 16.73 per cent respectively. He also found that the formulation contained 1.96 per cent N, 1.76 per cent P, 2.75 per cent K, 0.37 per cent Ca, 0.30 per cent Mg and 0.59 per cent S.

3.2 Effect of organic nano NPK formulation on the biometric characters

3.2.1 Height *of pseudostem*

Significant difference in pseudostem height was noticed among the treatments at different stages of crop growth as shown in Table 4. At 2 MAP, pseudostem height ranged from 83.28 cm in T_1 (15 g nano NPK in 2 splits) to 143.72 cm in T_7 (soil test-based KAU POP recommendation). At 4, 5 and 6 MAP, T_7 recorded the highest pseudostem height and the control (T_8) recorded the lowest.

At harvest stage, the highest pseudostem height (291.11 cm) was observed in T_7 which was on par with T_6 (45 g nano NPK in 2 splits) and T_4 (30 g nano NPK in 6 splits) and the lowest value (173 cm) was recorded in T_1 (15 g nano NPK in 2 splits).

Table 4: Effect of treatments on pseudostem height and pseudostem girth

Treatments	Pseudostem height (cm)				Pseudostem girth (cm)			
	2MAP	4MAP	6MAP	At harvest	2 MAP	4 MAP	6 MAP	At harvest
T_1 (15 g nano NPK in 2 splits)	110.67	158.72	163.22	173.00	21.63	28.83	33.62	38.67
T_2 (15 g nano NPK in 2 splits)	111.83	176.33	206.22	229.44	22.49	33.05	38.98	48.67
T_3 (15 g nano NPK in 2 splits)	101.67	144.72	181.89	200.89	25.73	31.67	35.44	43.41
T_4 (15 g nano NPK in 2 splits)	121.33	174.00	228.67	250.39	26.55	36.03	41.24	49.31
T_5 (15 g nano NPK in 2 splits)	106.50	168.95	206.22	207.39	25.82	35.33	39.74	49.31
T_6 (15 g nano NPK in 2 splits)	118.89	195.94	202.89	258.39	30.02	38.33	45.21	53.05
T_7 (Soil test-based POP recommendation)	143.72	244.58	252.45	291.11	31.37	43.46	51.82	54.95
T_8 (control)	83.277	119.78	150.00	196.16	20.33	28.25	32.58	36.03
SEm(±)	6.803	8.206	15.97	16.15	0.25	1.49	1.23	0.34
CD (0.05)	20.634	24.89	48.43	48.98	0.76	4.52	3.74	1.02

The pseudostem height was found to be the highest with the application of soil test-based POP recommendation in 6 splits along with 10 kg FYM and 100 g lime plant $^{-1}$ year^{-1} (T_7) wherein the height showed a consistent increase from 2 MAP. At harvest, the pseudostem height was on par with T_6 (45 g nano NPK in 6 splits along with 10 kg FYM and 100 g lime plant $^{-1}$ year^{-1}). Increased plant height might be attributed to the higher nitrogen level. High concentration of nitrogen promotes vegetative growth and improves plant height. Kumar *et al.* (2003) [12] made a similar observation in banana that the plant height in banana was influenced by higher levels of nitrogen. This is also in agreement with Prakashmany (2002) [23], who recorded increased plant height in banana cultivar Nendran with application of fertilizers as per KAU POP recommendation.

3.2.2 Girth of pseudostem

The pseudostem girth was recorded at different stages *viz*., 2 MAP, 4 MAP, 6 MAP and at harvest. The effect of different treatments on the girth of pseudostem was analyzed statistically and the data are presented in Table 4. Throughout the growth period, pseudostem girth showed highest values in the treatment T_7 (soil test-based POP recommendation) ie., 31.37 cm at 2 MAP, 43.46 cm at 4 MAP and 51.82 cm at 6 MAP. The plants in the control plot (T_8) recorded the lowest during all these stages of crop growth.

According to Krishnan and Shanmugavelu (1979) [10], plants with thicker pseudostem are desirable as they reflect on bunch size and other related characters. In the present study, the treatments exerted significant influence on the pseudostem girth. At all stages of plant growth, the highest pseudostem girth was noticed in plants which received soil test-based POP recommendation in 6 splits along with 10 kg FYM and 100 g lime plant $^{-1}$ year^{-1} (T_7) and it was followed by T_6 (45 g nano NPK in 6 splits) at all stages of plant growth. The combined application of N, P and K fertilizers in different splits along with FYM might have made available all the major nutrients at critical stages of plant growth. This finding is in conformity with the results of Prakashmany (2002) [23] who reported that the combined application of N, P and K increases the rate of photosynthesis, which in turn increase the meristematic activity and pseudostem girth in banana cv Nendran.

3.2.3 Number of functional leaves and Leaf Area Index

Statistical analysis revealed significant difference in the total number of functional leaves and LAI among the different treatments at different stages of growth (Table 5).

The total number of functional leaves ranged from 7.54 in T_3 (30 g nano NPK in 2 splits) to 7.73 in T_5 (45 g nano NPK in 2 splits) at 2 MAP, 8.07 in T_8 (control) to 10.48 in T_6 (45 g nano NPK in 6 splits) at 4 MAP and 9.28 in T_8 (control) to 13.05 in T_6 (45 g nano NPK in 6 splits) at 6 MAP.

During harvest, T_6 (8.69) recorded the maximum number of leaves while the control (T_8) recorded the least (6.04). At harvest stage, the maximum LAI was in T_6 (2.10) and it was on par with T_7 (2.09), T_4 (2.04), T_3 (1.88) and T_2 (1.83). Here, the minimum value was recorded by control (0.88).

Table 5: Effect of treatments on the number of functional leaves and Leaf Area Index

Treatments	Number of functional leaves				Leaf Area Index			
	2MAP	4MAP	6MAP	At harvest	2MAP	4MAP	6MAP	At harvest
T_1 (15 g nano NPK in 2 splits)	7.39	8.49	10.30	7.26	0.50	0.84	1.36	1.39
T_2 (15 g nano NPK in 2 splits)	7.13	8.62	10.33	6.44	0.59	1.03	1.84	1.83
T_3 (15 g nano NPK in 2 splits)	5.75	8.33	10.32	8.43	0.37	1.06	1.54	1.88
T_4 (15 g nano NPK in 2 splits)	7.38	8.65	10.66	8.25	0.69	1.22	1.84	2.04
T_5 (15 g nano NPK in 2 splits)	7.73	9.15	11.29	8.39	0.53	1.33	1.77	1.77
T_6 (15 g nano NPK in 2 splits)	7.05	10.48	13.05	8.69	0.58	1.63	2.43	2.10
T_7 (Soil test-based POP recommendation)	7.98	10.24	12.25	7.92	0.81	1.86	2.74	2.09
T_8 (control)	7.10	8.07	9.28	6.04	0.50	0.80	1.10	0.88
SEm(±)	0.09	0.064	0.07	0.06	0.07	0.19	0.14	0.10
CD (0.05)	0.42	0.19	0.21	0.19	0.21	0.58	0.43	0.30

The number of functional leaves showed an increasing trend upto 6 MAP in all the treatments and thereafter it showed a declining trend. Application of nano fertilizer has been effective in producing more number of leaves, leaf area and LAI. Higher nitrogen rates might have resulted in vigorous vegetative growth of the plants and split application of nutrients made available the nitrogen and other major nutrients throughout the critical stages of crop growth. Earlier also, similar findings have been reported. Parida *et al*. (1994) [22] reported that the uptake and accumulation of more amount of nitrogen in leaves increased the phosphorus content which accelerated the protein synthesis and meristematic activities and thus increased the LAI in banana. Kumar and Nalina (2001) [11] also revealed that the number and life of functional leaves increased by the application of higher doses of nitrogen and potassium in banana.

3.2.4 Soil analysis before and after the experiment

Soil of the experimental site was analysed before and after the experiment and the results are presented in Table 6. Before the experiment, It was found that the soil had a pH of 5.9 and it was moderately acidic in nature. The EC of the soil was normal (0.06 dSm^{-1}) with medium organic carbon composition of 1.05 per cent. Dehydrogenase enzyme activity of the soil was 23.31 µg of TPF released g^{-1} soil 24 h^{-1}. The available major plant nutrients in the soil were in the order of 156.99 kg h^{-1} N, 113.3 kg h^{-1} P_2O_5, 154 kg h^{-1} K_2O, 350 mg kg^{-1} Ca, 102 mg kg^{-1} Mg and 14.66 mg kg^{-1} S.

After harvest, significant variation in soil pH was observed due to the influence of different treatments. It was found to be the highest in T_6 (6.85) and the lowest in the control (5.55). The electrical conductivity of soil after harvest was the highest in T_6 (0.115 dS m^{-1}) and was on par with T_4 (0.112 dSm^{-1}). The lowest EC value was observed in T_8(control) (0.061 dS m^{-1}). The highest soil organic carbon content after harvest was recorded in T_6 (1.82 per cent) and it was significantly different from all other treatments. The control (T_8) had the lowest organic carbon content (1.06 per cent). The dehydrogenase enzyme activity was found to be the highest in T_6 (41.88 µg of TPF released g^{-1} soil 24 h^{-1}). It was significantly superior to all other treatments. This was followed by T_4 (37.55 µg of TPF released g^{-1} soil 24 h^{-1}). Here also, the control (T_8) recorded the lowest (24.27 µg of TPF released g^{-1} soil 24 h^{-1}).

Table 6: Effect of treatments on soil pH, EC, organic carbon and dehydrogenase enzyme status after harvest

Treatments	pH	EC (dS m^{-1})	Organic carbon (per cent)	Dehydrogenase enzyme (µg of TPF released g^{-1} soil 24 h^{-1})
T_1 (15 g nano NPK in 2 splits)	6.31	0.084	1.19	28.72
T_2 (15 g nano NPK in 2 splits)	6.43	0.092	1.32	31.36
T_3 (15 g nano NPK in 2 splits)	6.36	0.084	1.26	32.90
T_4 (15 g nano NPK in 2 splits)	6.63	0.112	1.71	37.55
T_5 (15 g nano NPK in 2 splits)	6.64	0.103	1.64	35.45
T_6 (15 g nano NPK in 2 splits)	6.85	0.115	1.82	41.88
T_7 (Soil test-based POP recommendation)	6.12	0.108	1.15	31.69
T_8 (control)	5.55	0.061	1.06	24.27
SEm(±)	0.05	0.002	0.02	0.20
CD (0.05)	0.14	0.005	0.06	0.62

3.2.5 Soil available primary and secondary nutrients (N, P, K, Ca, Mg, S)

The data on soil available primary and secondary nutrients were statistically analysed and the results are presented in Table7.

The highest soil available N after harvest was found in T_6 (191.96 kg ha^{-1}), which significantly differed from all other treatments. It was followed by T_4 (183.69kg ha^{-1}). The lowest N content was obtained in control (151.47 kg ha^{-1}). The highest soil available P was found in T_6 (127.81 kg ha^{-1}) and it was followed by T_4 (122.68 kg ha^{-1}). The lowest soil P content (71.89 kg ha^{-1}) was recorded in the control (T_8). The highest soil available K content was found in T_6 (227.38 kg ha^{-1}). This was followed by T_4 (195.51 kg ha^{-1}) and was on par with T_5 (193.59). The control (T_8) had the lowest soil available K content (122.24 kg ha^{-1}).

Table 7: Effect of treatments on the status of soil primary and secondary nutrients after harvest

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})	S (mg kg^{-1})
T_1 (15 g nano NPK in 2 splits)	163.58	93.27	169.163	326.74	82.70	12.38
T_2 (15 g nano NPK in 2 splits)	173.21	98.62	182.97	347.89	90.44	18.51
T_3 (15 g nano NPK in 2 splits)	168.36	105.17	176.41	352.85	88.26	15.74
T_4 (15 g nano NPK in 2 splits)	183.69	122.68	195.51	385.44	104.77	23.26
T_5 (15 g nano NPK in 2 splits)	176.66	118.78	193.59	377.95	98.95	19.57
T_6 (15 g nano NPK in 2 splits)	191.96	127.81	227.38	368.14	120.65	29.81
T_7 (Soil test-based POP recommendation)	163.41	103.44	163.46	310.07	86.84	9.66
T_8 (control)	151.47	71.89	122.24	331.81	76.82	6.97
SEm(±)	0.81	0.99	0.83	5.21	1.26	0.49
CD (0.05)	2.46	3.01	2.52	15.80	3.82	1.50

The Ca content in soil was the highest in T_4 (385.44 mg kg^{-1}) and was on par with T_5 (377.95 mg kg^{-1}). The lowest Ca content was recorded in T_1 (326.74 mg kg^{-1}). The highest soil available Mg was recorded in T_6 (120.65 mg kg^{-1}) and it was significantly different from all other treatments. This was followed by T_4 (104.77 mg kg^{-1}). The lowest Mg content was found in control (76.82 mg kg^{-1}). The soil available S was found to be the highest in T_6 (28.81 mg kg^{-1}) and was significantly superior to all other treatments. This was followed by T_4 (23.26 mg kg^{-1}). Control (6.97 mg kg^{-1}) had the lowest soil available S.

Earlier, Liu *et al.* (2006) [15] observed that application of nano formulations in the soil improved the soil physical properties and they concluded that it could be due to the interaction between naturally available granular organic minerals and nano composites. In bhindi, Nibin (2019) [20] reported that combined application of nano NPK formulations resulted in the highest organic carbon content, pH, dehydrogenase enzyme activity, primary nutrient status and Ca in the postharvest soil. These results are in line with the present study.

Mineralization and nitrogen availability for plant use was high in organic source with low C:N ratio and with high nitrogen concentration (Cordovil *et al*., 2005) [3]. Slow release of nutrients was found with application of organic compounds as compared with conventional fertilizers (Ramesh *et al*., 2009) [25]. But the chemical composition of organic nutrient source and the nature of microorganisms present in the soil decided the amount of nitrogen released from the source (Mohanty *et al*., 2013) [18].

Bulluck *et al.* (2002) [1] reported the increased availability of Ca, K and Mg in soil in association with application of organic sources. The soil K availability was high in treatments which receiving organic manures as compared with control (Srinivasan *et al*., 2016) [27]. Activity of soil microbes accelerated with the application of organic manures which contain available carbon compounds which intern increased the availability of OC in the soil (Leno, 2017) [14]. He also concluded that Vellayani soil series contain higher amount of P (180 kg ha^{-1}) and application of organic nutrient sources increased the amount of mineralized P in the soil. Soil application of organic nano NPK formulation at the rate of 25 kg ha^{-1} along with FYM gave highest EC that may be due to the release of bases and soluble components from organic nano NPK formulation to the soil in a faster rate (Nibin, 2019) [20].

3.2.6 Plant uptake of primary and secondary nutrients (N, P, K, Ca, Mg, S)

The statistically analysed data on plant uptake of primary (N, P and K) and secondary (Ca, Mg and S) nutrients after harvest are presented in Table 8.

The uptake of N by the plants at harvest was found to be the highest in T_6 (218.03 kg ha^{-1}) and was on par with T_7 (203.63 kg ha^{-1}). Control (120.85 kg ha^{-1}) recorded the lowest uptake. P uptake by the plants was found to be the highest in T_6 (46.08kg ha^{-1}). This was followed by T_4 (41.87 kg ha^{-1}), which was on par with T_7 (41.51 kg ha^{-1}). The lowest P uptake was found in control (25.55 kg ha^{-1}). The plant uptake of K was highest in T_6 (354.14 kg ha^{-1}) and this was on par withT_5 (330.85 kg ha^{-1}). The control recorded the lowest K uptake (201.36 kgha^{-1}).

The plant uptake of Ca was highest in T_6 (123.43 kg ha^{-1}) and this was significantly different from other treatments. This was followed by T_7 (111.21 kg ha^{-1}). The lowest Ca uptake was found in the control (75.43 kg ha^{-1}). The plant uptake of Mg was highest in T_6 (26.51 kg ha^{-1}) and this was followed by T_7 (25.16 kg ha^{-1}). The control recorded the lowest uptake (17.94 kg ha^{-1}). The plant uptake of S was found to be highest in T_6 (24.33 kg ha^{-1}). This was followed by T_7 (22.53 kg ha^{-1}), which was on par with T_4 (22.14 kg ha^{-1}). The lowest S uptake was noted in the control (12.22 kg ha^{-1}).

Nano fertilizers provide nutrients to plants in an available form, thus facilitating enhanced nutrient uptake by plants. In the present study, the highest uptake of primary and secondary nutrients was observed in treatments which received 45 g nano NPK in 6 splits along with 10 kg FYM and 100 g lime plant $^{-1}$ year^{-1}.

Table 8: Effect of treatments on uptake of primary and secondary nutrients by plant after harvest

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca (kg ha^{-1})	Mg (kg ha^{-1})	S (kg ha^{-1})
T_1 (15 g nano NPK in 2 splits)	145.54	28.22	257.82	79.76	18.53	14.85
T_2 (15 g nano NPK in 2 splits)	175.62	34.21	296.89	95.74	20.60	17.21
T_3 (15 g nano NPK in 2 splits)	153.00	31.63	271.66	85.21	18.50	16.28
T_4 (15 g nano NPK in 2 splits)	189.66	41.87	324.06	107.32	23.86	22.14
T_5 (15 g nano NPK in 2 splits)	188.99	38.44	330.85	90.09	21.75	19.22
T_6 (15 g nano NPK in 2 splits)	218.03	46.08	354.14	123.43	26.51	24.33
T_7 (Soil test-based POP recommendation)	203.63	41.51	324.73	111.21	25.16	22.53
T_8 (control)	120.85	25.55	201.36	75.43	17.94	12.22
SEm(±)	6.05	0.33	7.92	0.12	0.32	0.23
CD (0.05)	18.35	1.00	24.03	0.36	0.97	0.69

Thangaselvahai *et al*. (2009) [30] concluded that N, P and K were the major nutrients for plant growth and reproduction but their uptake was found to be high during leaf and pseudostem growth. Vegetative growth was directly proportional to rate of leaf production and leaf production, unfolding and its longitudinal growth was influenced by nitrogen uptake by the plant (Gonge *et al*., 2015) [4]. The bunch weight was dependent on the number of leaves produced upto four months in banana (Hazarika *et al*., 2015) [5]. The flower setting was influenced by healthy and strong rhizome and root system in banana and application and availability of P in soil was necessary for that (Kalaivanan *et al*., 2014) [8].
The K absorbed by plant during reproductive phase by banana utilized for better translocation of assimilates towards bunch resulted in the increased finger size, yield and quality (Kuttimani *et al*., 2013) [13]. Banana requires K in higher rate for increased fruit size and quality. The banana pseudostem contain high concentration of K as compared with other plant parts. The K absorbed after six months of plant growth might be deposited in banana pseudostem.
Ca and Mg were mainly deposited in rhizome, pseudostem and leaves and their uptake were continued after six months of plant growth (Raghupathi *et al*., 2002) [24]. Growth and yield of banana positively influenced by the application of Mg and S (Mostafa and Abd El-Kader, 2006) [19]. With the application of organic manures, the uptake of Mg and S increased leading to better yield by banana cv. Nendran (Leno, 2017) [14].
Nano fertilizers have high surface areas, and this can provide a chance for maximum reactivity and increase both the nutrient availability and plant NUE (Siddiqi and Husen, 2017) [26]. Unlike most of the conventional synthetic fertilizers, they are soluble in water and hence increase the dispersion of nutrients in soil and availability of nutrients to plants. Several studies have proved that nutrient uptake by plants can be enhanced through nano fertilizer application.
The highest uptake of primary and secondary nutrients by the plants in the present study might be due to the particle size of nano fertilizer which helped in the easy absorption by the roots. The larger surface area and slow-release nature helped in the availability of nutrients throughout the cropping period because of split application. Nibin (2019) [20] also reported that the combined application of granular and liquid organic nano NPK formulations in bhindi at the rate of 12.5 kg ha^{-1} and 0.4 per cent respectively along with FYM showed the highest uptake of primary and secondary nutrients by the plants.

4. Conclusion
Application of 45 g granular organic nano NPK in 6 splits along with 10 kg FYM and 100 g lime per plant per year increased the total number of functional leaves, soil organic carbon and dehydrogenase activity and enhanced the soil nutrient status and improved the nutrient uptake by the plants.

5. References

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