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Standardization of stage-wise requirement of nutrients in banana cv. Grande Naine (AAA)

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ABSTRACT

A field trial was conducted during 2009-2010 at College Orchard, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, to standardize stage-wise requirement of nutrients in banana cv. Grand Naine (AAA). Treatment T_{16} where application of 100% RDF (165:52.5:495g NPK plant^{-1}) at 4 critical growth stages, i.e., 40:52.5:25, 30:0:35, 30:0:25 and 0:0:15% at the 3rd, 5th, 7th and 9th months after planting (MAP), respectively, recorded maximum plant height, pseudostem girth and leaf area index. Maximum bunch weight of 32.15kg was recorded in T_{16}. Higher yield was attributed to more number of (i) hands per bunch, (ii) fingers per hand and (iii) per bunch, besides the higher average weight of the finger. Better quality fruits, with higher TSS, total sugars, low acidity and better sugar:acid blend, were obtained in T_{16}. In treatment T_{16}, where 100% RDF was applied, increased N, P, and K content were seen in the index leaf of the crop. Lower soil-available nutrients, viz., N, P, K, at the higher level of split-application at critical stages of the crop revealed, that, the nutrients applied were utilized efficiently. This was reflected in the better yield and quality obtained. Economics were worked out which indicated T_{16} as giving the highest cost:benefit ratio (1:3.97).

Key words: Banana, Grande Naine, stage-wise nutrient requirement, yield, quality, cost:benefit ratio

INTRODUCTION

Banana, the second largest fruit crop in the world in terms of cultivation, produced in the tropical and subtropical regions, is recognized as the fourth most important food commodity in terms of gross value next only to paddy, wheat and milk products. India is the largest producer of banana in the world, accounting for about 25% of the global output. Its availability round-the-year at a reasonable cost, and its ready acceptance by all sections of the society, make it a very popular fruit. Peninsular India, especially the states of Tamil Nadu, Kerala and Karnataka, constitute an area of great diversity of both the banana and the plantain. Over five lakh small- and medium- farmers depend on banana cultivation for livelihood in our country. Though the farmers spend huge amounts on fertilizer, only 50% of the potential crop yield is realized owing to poor fertilizer use efficiency. With a growing population and enhanced awareness among public about health and nutritional aspects of banana, the country's requirement in the next 20 years is expected to go up to 25 million tonnes. This volume of production can be achieved through increased productivity while ensuring better fertilizer use efficiency. Banana is a voracious feeder of nutrients; therefore, addition of mineral fertilizer stands to have a major effect on yield potential. Banana requires high amounts of K than N or P to ensure high yield and quality. It is estimated that a crop of 50 tonnes of banana in one hectare removes 320kg N, 32kg P_2O_5 and 925kg K_2O every year. Hence, it is of paramount importance to maintain a high degree of soil fertility by timely and judicious application of NPK for achieving good fruit yield and quality in banana. In Tamil Nadu, nutrients are applied in three split doses during the 3rd, 5th and 7th month after planting (MAP) @ 110:35:330g/NPK/plant/year; But, under tropical conditions, soil nutrients are leached/ lost rapidly due to various factors. Therefore, it is important to apply nutrients at the critical stages of crop growth in small doses, at shorter intervals, to minimize loss of nutrients and cost of production. Though extensive information is available on nutrient requirement in banana, very little work has been done on stagewise nutrient requirement in this crop. This necessitates research on application of nutrients at various stages of crop growth to derive maximum benefit from a given quantity of

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the nutrient. With this background, the present study was undertaken to standardize stagewise nutrient requirement in banana cv. Grand Naine under Coimbatore conditions to achieve improved yield and quality.

MATERIAL AND METHODS

Soil parameters

A field experiment was conducted at the College Orchard, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, during 2009-2010. Soil type in the experimental field was clayey-loam, and its initial status revealed that it was alkaline (pH 8.41), medium in EC (0.32 dSm^{-1}), available N (216.7kg ha^{-1}), available K (453.60kg ha^{-1}) and low in available P (18.32kg ha^{-1}). The experiment was laid out using tissue-culture derived banana cv. Grand Naine (AAA). Drip irrigation was provided to the experimental plot.

Experiment details

The treatments consisted of three nutrient levels (L_1: 60% recommended dose of fertilizer, L_2: 80% recommended dose of fertilizer, and L_3: 100% recommended dose of fertilizer) and four stages of nutrient application (3rd month, 5th month, 7th month and 9th month after planting). Per cent nutrients applied at each stage are given hereunder:

Treatment	Per cent nutrient level / stage of growth							
	3 MAP* (Vegetative stage)		5 MAP (Flower-bud initiation stage)		7 MAP (Pre-flowering/ flowering stage)		9 MAP (Flowering/ bunch stage)	
	N	K_2O	N	K_2O	N	K_2O	N	K_2O
S_1	10	10	40	20	30	30	20	40
S_2	20	15	30	25	30	30	20	30
S_3	30	20	20	30	30	30	20	20
S_4	40	25	30	35	30	25	0	15
S_5	50	30	20	40	20	30	10	0
S_6	50	20	30	40	20	40	0	0

*MAP: Months after planting

A total of 19 treatments, viz., T_1 - L_1S_1, T_2 - L_1S_2, T_3 - L_1S_3, T_4 - L_1S_4, T_5 - L_1S_5, T_6 - L_1S_6, T_7 – L_2S_1, T_8 - L_2S_2, T_9 - L_2S_3, T_{10} - L_2S_4, T_{11} - L_2S_5, T_{12} - L_2S_6, T_{13} - L_3S_1, T_{14} - L_3S_2, T_{15} - L_3S_3, T_{16} - L_3S_4, T_{17} - L_3S_5, T_{18} - L_3S_6 and T_{19} – Control (Recommended dose of fertilizer @ 165: 52.5: 495g of NPK/plant/year in 4 splits at 2nd, 4th, 6th and 8th MAP) and phosphorus was applied as a single dose, i.e., at 3rd MAP. The above-stated treatments were tested in Randomized Block Design, with four replications. Each treatment was spread over a net area of 12.96m^2, enclosing nine plants. All the recommended agronomic practices and plant protection measures were applied for raising the crop.

Data analysis

Observations on morphological characters, viz., pseudostem height and girth, leaf area index, and bunch characters, viz., bunch weight, number of hands and fingers, and, average weight of finger, were recorded as per standard procedures. Total soluble solids (TSS) were determined by using a hand refractometer. Total sugars, total acidity and Vitamin C were estimated using standard methods (AOAC, 1960). For soil nutrient analysis, soil samples were collected before planting and at harvest. Available nitrogen in the soil was estimated by the alkaline permanganate method (Subbiah and Asija, 1956), available phosphorus in soil estimated using Klett Summerson colorimeter with a red filter (Olsen *et al*, 1954), and, available potassium in the soil was estimated upon extraction with neutral N ammonium acetate using a flame photometer (Hanway and Heidal, 1952). For plant nutrient analysis, functional leaves were used at different stages of growth. Nitrogen content was estimated by Microkjeldahl method (Piper, 1966) and phosphorus content in the leaf was estimated using triple acid extract by vanadomolybdate phosphoric yellow colour method (Jackson, 1973). Potassium content was estimated by flame photometry (Jackson, 1973). Statistical analysis of the data was done as per Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Morphological parameters

Potential yield in banana can be achieved only by applying adequate doses of fertilizer at critical stages of plant growth. Banana crop requires a larger quantity of potassium, moderate quantity of nitrogen and a relatively lower dose of phosphorus for optimal growth and yield (Norris and Ayyar, 1942). Data on the influence of different levels of nutrients applied during various growth stages on growth characteristics in our study are presented in Table 1. Progressive increase in plant height and girth of the pseudostem from 3rd MAP up to shooting was observed in all the treatments. Among the treatments, T_{16} (with 100% of RDF at four different stages) registered maximum plant height and girth at 7th, 9th MAP, and at harvest.

Increases in plant height and girth may be attributed to an increase in utilization of nutrients, more specifically, nitrogen. Improved nitrogen absorption ultimately led to

Table 1. Effect of various levels of fertilizer at different growth stages on growth parameters in banana cv. Grande Naine

Treatment	Plant height (m)					Plant girth (cm)					Leaf area index				
	3 MAP*	5 MAP	7 MAP	9 MAP	At harvest	3 MAP	5 MAP	7 MAP	9 MAP	At harvest	3 MAP	5 MAP	7 MAP	9 MAP	At harvest
T_1	0.76	1.64	1.78	1.86	1.87	25.21	49.25	57.188	65.42	66.72	0.46	2.43	2.56	4.39	2.75
T_2	0.79	1.74	1.81	1.92	1.95	26.42	50.61	59.683	66.63	69.21	0.48	2.48	2.69	5.04	2.82
T_3	0.78	1.72	1.79	1.92	1.96	26.19	50.37	59.467	66.63	67.63	0.48	2.48	2.60	5.00	2.81
T_4	0.77	1.71	1.82	1.89	1.92	25.98	49.98	59.271	66.50	67.25	0.48	2.45	2.59	4.76	2.77
T_5	0.82	1.75	1.83	1.94	1.97	26.77	50.94	59.717	67.25	69.63	0.49	2.53	2.71	5.13	2.84
T_6	0.83	1.78	1.87	1.95	1.98	27.06	51.45	60.292	68.21	70.21	0.49	2.55	2.73	5.17	2.88
T_7	0.83	1.83	1.88	2.04	2.04	27.35	51.91	60.717	68.96	70.92	0.49	2.70	2.82	5.41	2.94
T_8	0.84	1.84	1.95	2.03	2.05	27.67	52.34	60.758	70.58	71.46	0.50	2.71	2.82	5.43	2.94
T_9	0.83	1.82	1.89	2.01	2.04	27.19	51.83	60.642	68.46	70.58	0.49	2.61	2.75	5.40	2.93
T_{10}	0.84	1.87	1.91	2.03	2.06	27.71	52.38	61.096	70.92	71.46	0.51	2.72	2.84	5.55	2.95
T_{11}	0.85	1.92	1.99	2.06	2.08	27.90	53.19	61.396	71.50	71.83	0.51	2.79	2.95	5.71	3.14
T_{12}	0.85	1.93	1.98	2.05	2.07	28.02	55.57	61.396	71.33	71.54	0.52	2.86	2.91	5.68	3.14
T_{13}	0.85	1.95	2.03	2.06	2.10	28.15	55.98	62.588	71.83	72.25	0.52	2.95	3.12	5.92	3.15
T_{14}	0.85	1.96	2.06	2.07	2.15	28.90	56.63	62.833	72.17	72.46	0.53	2.97	3.13	5.93	3.17
T_{15}	0.85	2.01	2.02	2.06	2.10	29.40	57.31	62.202	71.63	72.17	0.54	3.00	3.05	5.80	3.15
T_{16}	0.86	2.01	2.13	2.16	2.18	29.83	57.36	64.117	74.75	75.25	0.54	3.02	3.19	6.50	3.26
T_{17}	0.92	2.02	2.05	2.07	2.09	30.27	59.90	62.846	72.88	72.68	0.58	3.05	3.14	6.05	3.22
T_{18}	0.87	2.08	2.09	2.12	2.12	30.17	62.39	63.108	73.33	73.30	0.56	3.14	3.15	6.26	3.25
T_{19}	0.85	1.91	1.97	2.05	2.06	27.77	53.10	61.292	70.96	71.46	0.51	2.73	2.86	5.57	3.02
SEd	3.74	11.48	9.61	4.91	0.10	1.38	4.31	1.50	2.54	0.04	0.05	0.27	0.24	0.58	0.24
CD *(p=0.05)*	7.49	23.01	19.26	9.85	0.20	2.78	8.65	3.00	5.09	0.08	(NS)	0.54	0.49	1.17	0.47

*MAP: Months After Planting

formation of complex nitrogenous substances like amino acids and proteins for building new tissues (Childers, 1966). Application of N at the critical growth stages, viz., early vegetative stage, flower-bud initiation and differentiation stage, and, post-shooting stage had a great influence on growth and development, plant health and yield. Increases in plant height and girth from application of nitrogen and potassium is commonly noticed in banana (Basagarahally, 1996; Shakila and Manivannan, 2001; Nalina, 2002); while, phosphorus increased the girth when applied along with K (Jagirdar and Ansari, 1966).

Lowest plant height and stem girth were observed in treatment T_1. This could be due to an insufficient supply of nitrogen and potassium at the initial stages of plant growth. Reddy *et al* (2002) reported that increases in plant height and girth may be largely due to a regular supply of higher doses of nitrogen and potassium. Though banana requires nutrient supplementation throughout its growing period, application of N and K prior to shooting, especially, during flower-bud initiation (4^{th}-6^{th} MAP) ensures uninhibited growth, and has a greater influence on bunch-size, number of fingers and hands per bunch, and ultimately, the yield (Simmonds, 1982).

Leaf area index (LAI) is critical for maximum utilization of photosynthetically active radiation (PAR). In banana, optimum LAI should be 4 to 4.5. LAI was higher when the plants were under T_{17} at 3^{rd} MAP; T_{18} at 5^{th} MAP, and T_{16} at 7^{th}, 9^{th} MAP and at harvest. Rapid development in leaf area was associated with higher accumulation of most of the nutrients applied. In the present study too, LAI increase was rapid between the 7^{th} and 9^{th} MAP as a result of 100% RDF applied at the four critical stages (T_{16}). Baruah and Mohan (1991) showed that higher potassium application increased LAI considerably in banana cv. Jahaji (AAA group).

Yield parameters

Influence of various levels of nutrients applied at different growth stages on yield and quality is presented in Table 2. Among the treatments, T_{16} (NPK @ 165:52.5:495g per plant at four stages of growth) registered maximum bunch-weight (32.15kg), followed by T_{14} (27.96 kg) and T_{13} (27.77 kg). Increase in yield may be attributed to improved morphological traits such as plant height, girth and number of functional leaves. Better LAI, faster rate of leaf production and higher nutrient-uptake by plants were also observed in this treatment (T_{16}). This is in conformity with Shakila (2000) and Nalina (2002). Increased yield in treatment T_{16} could be due to application of optimum quantity of fertilizers, well-spread at the four different critical stages of crop growth. This may lead to an increase in dry matter

Table 2. Effect of various levels of fertilizer at different growth stages on yield and fruit quality in banana cv. Grande Naine

Treatment	Bunch weight (Kg)	No. of hands (bunch^{-1})	No. of fingers in 2nd hand	No. of fingers (bunch^{-1})	Average finger weight (g)	TSS (%)	Acidity (%)	Ascorbic acid (mg 100 g^{-1})	Total sugars (%)	Sugar/ acid ratio
T_1	24.06	8.75	17.21	162.63	147.36	12.30	0.22	11.56	15.80	71.81
T_2	25.62	9.13	18.67	169.45	157.51	15.10	0.19	12.04	16.30	85.78
T_3	24.29	9.13	18.17	165.89	154.19	14.90	0.20	11.93	16.27	81.35
T_4	25.11	8.92	17.33	163.12	150.38	14.40	0.21	11.62	16.00	76.19
T_5	25.63	9.21	19.25	169.60	158.88	15.20	0.18	12.37	16.67	92.61
T_6	25.65	9.33	19.67	170.23	159.96	15.50	0.18	12.43	16.83	93.50
T_7	26.65	9.46	19.71	180.00	161.15	15.60	0.17	12.69	17.50	102.94
T_8	26.73	9.54	19.83	180.59	161.99	15.70	0.17	12.93	18.20	107.05
T_9	26.32	9.33	19.71	170.52	161.10	15.50	0.18	12.57	17.22	101.87
T_{10}	26.73	9.67	19.96	173.39	165.00	15.85	0.17	13.62	15.73	126.46
T_{11}	27.66	9.79	20.21	181.10	176.19	16.50	0.16	14.36	17.20	135.78
T_{12}	27.56	9.75	20.13	177.07	171.13	15.90	0.16	14.05	16.73	101.87
T_{13}	27.77	9.83	20.63	184.11	181.65	16.50	0.15	14.85	18.97	126.46
T_{14}	27.96	9.96	21.04	184.83	185.79	16.75	0.14	14.89	19.01	135.78
T_{15}	27.67	9.79	20.63	181.79	176.19	16.50	0.15	14.49	18.90	126.00
T_{16}	32.15	10.18	21.50	191.09	190.00	**17.20**	**0.11**	**15.07**	**20.23**	**183.90**
T_{17}	28.18	10.00	21.13	185.98	186.87	16.90	0.14	14.92	19.10	136.42
T_{18}	30.27	10.33	21.50	186.01	188.25	16.90	0.13	14.92	19.97	153.61
T_{19}	27.31	9.75	20.04	176.31	170.08	15.90	0.18	14.02	18.43	102.38
SEd	0.76	0.33	1.45	0.28	4.13	0.02	0.007	0.023	0.05	7.86
CD *(p=0.05)*	1.52	NS	2.91	0.56	8.29	0.04	0.015	0.046	0.10	16.45

at harvest, contributing ultimately to suoerior bunch and finger characters. Another plausible explanation is the timely availability of required amounts of nutrients for flower-bud initiation, a finding corroborated by Basagarahally (1996).

In the present study, a low yield obtained at lower levels of nutrients applied (T_1) is probably due to lower uptake of nutrients, consequently lower dry-matter production, As banana requires large amounts of potassium before and during the reproductive stage, application of 60% RDF is adequate for accelerating growth and development. Kholi *et al* (1985) reported that application of nitrogen increased biomass production in the leaves, rachis and flower buds, whereas, lack of N supply confined biomass production to the rhizome and pseudostem. In the present investigation, lower nutrient levels led to reduced leaf size, delayed flowering, reduced fruit number per bunch and fruit size.

Highest yield in terms of bunch weight (32.15kg plant^{-1}) was observed in T_{16}. This increase was also associated with a corresponding increase in number of hands per bunch (10.18) and number of fingers per bunch (191.09).

In any production system, the primary objective is to attain maximum fruit yield per unit area without affecting fruit quality. Fruit quality in banana is judged mainly by sugar content and acidity in the pulp. A marked effect on fruit quality was observed with application of adequate amount of nutrients. Higher levels of TSS (17.20%), ascorbic acid (15.07mg/100g), total sugars (20.23%), sugar/ acid ratio (183.90) and lower acidity (0.11%) were recorded in fruits under T_{16}. Higher fruit-quality, especially sugar content, can be explained on the basis of the role of nutrients, particularly potassium, involved in carbohydrate synthesis, breakdown and translocation of starch, synthesis of protein, and, in neutralization of physiologically important organic acids (Tisdale and Nelson, 1966). Several investigations have more firmly established the involvement of K^+ in carbohydrate synthesis and its absolute requirement for the activity of the enzyme, starch synthetase (Greenberg and Preiss, 1965).

Increased level of potassium reduced the acidity in the pulp. This may be due neutralization of organic acids from a high K^+ level in the tissues (Tisdale and Nelson, 1966; Ram and Prasad, 1988).

Leaf nutrient content

Leaf nutrient concentration in the banana plant provides information on plant nutrient status, and reflects the optimum leaf concentration of major nutrients aiding in growth and development in the banana crop. The present study, maximum N content was registered in treatment T_{16} at the 7th (3.46%), T_{13} at the 9th (3.49%) MAP and at harvest (Table 3). This may be due to an optimum availability of N

Table 3. Effect of various levels of fertilizer at different growth stages on leaf nutrient concentration in banana cv. Grande Naine

Treatment	Nitrogen (%)				Phosphorus (%)				Potassium (%)			
	5 MAP*	7 MAP	9 MAP	At harvest	5 MAP	7 MAP	9 MAP	At harvest	5 MAP	7 MAP	9 MAP	At harvest
T_1	2.46	2.53	2.97	2.97	0.172	0.497	0.635	0.137	3.41	3.67	4.42	3.75
T_2	2.62	2.78	2.91	2.82	0.184	0.509	0.649	0.141	3.54	3.74	4.39	3.73
T_3	2.12	2.83	2.89	2.81	0.181	0.504	0.642	0.140	3.42	3.69	4.20	3.69
T_4	2.71	2.91	2.76	2.59	0.179	0.498	0.639	0.138	3.55	3.69	4.34	3.71
T_5	2.85	2.83	2.87	2.76	0.189	0.509	0.651	0.145	3.55	3.81	4.24	3.67
T_6	2.86	2.96	2.62	2.73	0.192	0.511	0.653	0.147	3.42	3.81	4.18	3.72
T_7	2.97	3.05	3.25	3.14	0.196	0.514	0.657	0.149	3.60	3.87	4.53	3.83
T_8	2.99	3.06	3.21	3.11	0.197	0.514	0.657	0.151	3.61	3.92	4.56	3.84
T_9	2.89	3.06	3.19	3.09	0.194	0.514	0.654	0.149	3.56	3.82	4.51	3.79
T_{10}	3.01	3.15	3.11	3.03	0.198	0.516	0.657	0.151	3.72	3.96	4.47	3.78
T_{11}	3.04	3.12	3.18	3.06	0.211	0.517	0.663	0.155	3.81	4.03	4.43	3.78
T_{12}	3.07	3.16	3.09	3.05	0.213	0.517	0.662	0.153	3.67	4.01	4.46	3.79
T_{13}	3.09	3.22	3.49	3.37	0.213	0.519	0.671	0.156	3.84	4.11	4.52	3.81
T_{14}	3.12	3.23	3.42	3.29	0.213	0.520	0.674	0.156	3.85	4.11	4.63	4.04
T_{15}	3.14	3.25	3.39	3.23	0.214	0.518	0.664	0.156	4.02	4.09	4.59	3.91
T_{16}	3.18	3.46	3.29	3.15	0.215	0.524	0.698	0.164	4.10	4.21	4.58	4.10
T_{17}	3.21	3.32	3.39	3.22	0.215	0.521	0.678	0.158	3.68	4.17	4.69	3.89
T_{18}	3.24	3.39	3.29	3.17	0.217	0.521	0.684	0.159	4.09	3.97	4.58	3.84
T_{19}	3.16	3.39	3.26	2.73	0.204	0.516	0.659	0.151	4.10	4.17	4.58	3.87
SEd	0.005	0.004	0.004	0.005	0.002	0.0009	0.002	0.002	0.005	0.004	0.004	0.003
CD (p=0.05)	0.012	0.009	0.008	0.009	(NS)	(NS)	(NS)	(NS)	0.009	0.008	0.008	0.006

*MAP: Months After Planting

in the soil, favouring higher absorption and translocation by roots. Lower content of N in the higher dose of applied fertilizer, viz., T_1 to T_6, could be due to the osmotic effect, which may have hindered uptake of N and supply of nitrogen converted from the nitrate to the ammoniacal form. Also, per cent dose of fertilizer applied was lower than in $T_{16.}$

Phosphorus content in various plant parts at different growth stages in banana cv. Grand Naine revealed that in leaves, this nutrient increased linearly until shooting. This may be due to an increased physiological activity in the plant as development proceeded. Decrease in P content in leaves at harvest could be related to mobilization of stored assimilates to the fruit. P content was maximum in leaf lamina at the shooting stage. This indicates that P absorbed during earlier stages accumulates in the midrib and leaf lamina, thereby serving as a source during peak vegetative stages for higher photosynthetic activity. P content in the leaves decreased at harvest showing that metabolites containing P were translocated to the fruit. A higher demand for P at the early stages and at flowering (Veerannah *et al*, 1976) and reduction in P at harvest (Twyford and Walmsley, 1974) have been reported. In the present investigation, K content in leaves at different stages indicates that this nutrient accumulated in the vegetative parts until shooting, highlighting that K concentration increased with increased physiological activity during the developmental processes. Decrease in K content during harvest was probably due to an increased catalytic activity of K in reproductive parts for mobilizing metabolites from the vegetative part (despite substantial post-shooting uptake from the soil). Veerannah *et al* (1976) reported similar results in banana cv. Robusta. Among the treatments, T_{16} recorded highest K content at the 5th (4.10%) and 7th (4.21%) MAP. This may be due to an increase in the available form of K in the soil solution.

Soil nutrient status

In the present investigation, available N, P and K were estimated at planting and at harvest to study soil nutrient status under various treatments (Table 4). Initial soil N status was found to be 216.70kg/ha. Available N in the soil at harvest under different treatments was significantly variable. Treatment T_1 (572.55kg/ha), followed by T_4 (486.65kg/ha), recorded high amounts of available N, as, 20% was applied at the 9th MAP which was perhaps not fully utilized by the plant (since, at 9th MAP, no vegetative growth occurs, and only bunch-development and fruit-filling takes place). Lesser amount of soil N was recorded in T_{16} (118.15kg/ha) due to application of N upto the pre-flowering stage (7th MAP). Thus, the plant was able to utilize N optimally for production of the vegetative parts. Treatment T_{16} recorded higher bunch yield and had 509kg ha^{-1} available N (which had been applied

Table 4. Effect of various levels of fertilizer on soil NPK (kg/ha) during harvest in banana cv. Grande Naine

Treatment	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
T1	572.55	121.67	626.64
T2	453.65	112.57	497.46
T3	460.25	114.71	532.75
T4	486.65	118.63	573.70
T5	381.76	108.36	475.6
T6	375.48	105.45	457.89
T7	286.38	98.62	430.23
T8	276.89	97.83	429.48
T9	345.89	104.23	453.76
T10	265.70	97.20	420.76
T11	221.65	91.67	385.78
T12	228.45	93.30	385.85
T13	183.45	87.57	372.83
T14	176.65	83.27	358.70
T15	198.32	89.61	372.94
T16	118.15	76.25	270.6
T17	169.97	82.56	343.67
T18	168.35	78.56	295.78
T19	249.75	96.81	419.53
SEd	2.34	0.24	1.63
CD *(p=0.05)*	4.66	N	3.27

in three splits). This may be due to utilization of N, by the plant during its critical stages of growth, in three split applications. This may have facilitated optimum N concentration in the soil for the entire cropping period. Therefore, residual nutrients in the soil may be subjected to lower loss.

Phosphorus estimated at the initial stages and at harvest revealed that available P in the soil showed a decreasing trend, which may be due to a continuous uptake of this nutrient by the plant. However, differences among treatments were not significant. Uptake of P was also influenced substantially by potassium application. Application of fertilizers also altered available K in the soil. Available K in the soil at harvest showed a decreasing trend with time, and the quantity applied. Among the various treatments, available K in soil was lower in T_5 (475.6kg/ha) and T_6 (457.89kg/ha) at 60% RDF; in T_{11} (385.78kg/ha) and T_{12} (385.85kg/ha) at 80% RDF, and, in T_{18} (295.78kg/ha) at 100% RDF at harvest.

K content in soil in T_{16} treatment was lower than in treatment T_{19} (in which the same dose of fertilizer was applied in four equal splits). Higher application of potassium in the early stages improved growth, yield and quality attributes. As, the time of application and stage of plant growth determines uptake and translocation of K, application of this nutrient at four critical stages may have provided optimal availability of K in the soil, throughout the growth period, and facilitated better growth. Similarly, higher K uptake for bunch-development and finger-filling also resulted in lower levels of K in soil at harvest.

Application of 100% RDF in T_{16} (165:52.5:495 g NPK plant^{-1} at 4 critical growth stages, i.e., 40:100:25, 30:0:35, 30:0:25, 0:0:15% at 3rd, 5th, 7th and 9th MAP, respectively) recorded highest cost:benefit ratio (1:3.97). The highest gross and net returns realized were because of highest yield. As, the cost of cultivation was also equal to that in the Control, application of fertilizer this way was found to be economically more viable.

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