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Research Article

Total N, P & K uptake by main and ratoon banana crop cv.Grand Naine under different levels of planting distances, irrigation and fertigation

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Abstract

A field experiment was conducted to evaluate the effect of different levels of planting distances, irrigation and fertigation levels on available and total N ,P & K uptake by main & ratoon banana crop cv.Grand Naine (Musa AAA). Maximum leaf and fruit N, P and K uptake were recorded at D_3 (1.25x1.25m) Application of irrigation at a rate of 764.30 mm per year during main crop substantially improved available soil nitrogen, phosphorus and potassium. In the ratoon crop, irrigation at a rate of 1187.10 mm per year was observed to be most economical and effective in maintaining higher available soil nitrogen, phosphorus and potassium. In the both main and ratoon crops, 80 per cent of the recommended fertigation dose (160 N:32 P :192 K g per plant per year) performed well in maintaining medium level of available soil nitrogen and potassium and higher level of phosphorus. Hence, fertigation with 80 per cent of the recommended dose was found to be optimum and economical. Main and ratoon crops grown at D_1 x I_1 x F_3 and D_1 x I_2 x F_3, respectively showed the lowest nutrient uptake by leaf and fruit that consequently reduced the total uptake. On the other hand, same combinations were superior to the control treatment in terms of total uptake and were found to be optimum and viable options to adopt for the respective crops in order to avoid unnecessary extra nutrient uptake that might increase the vegetative growth and extended the total crop duration. Main and ratoon crops grown under different treatment combinations (using drip and fertigation system) were superior to the crop grown under the control treatment (using surface irrigation and conventional application of solid fertilizers) as regards to total nutrient uptake.

Keywords: soil nitrogen, phosphorus and potassium, banana crop, fertigation dose.

Introduction

Banana has wide adaptability to soil condition but its performance vary with soil types, lime concentration, nutrient status and drainage. In heavy soils, time taken for cropping is longer as compared to light soil. The information on the soil factor is vital for the banana production which needs attention for maximizing the production with available resources.

Banana is a surface feeder and a nutrient exhausting crop; hence large quantities of major nutrients especially nitrogen and potassium are necessary for proper growth, high yield, improved fruit quality and economic cultivation of this crop. Further they reported that, about 50 t /ha /year of fresh fruit removed about 60 kg phosphorus, 1500 kg potassium 215 kg calcium and 140 kg/ha magnesium. This is achieved by applying organic manure and/or more efficiently by mineral fertilizers which supply nutrients in concentration and readily available form (Walmsley and Twyford, 1976). Balanced fertigation at every crop stage is a key factor for optimum yield of banana. The dwarf varieties are very particular to higher doses of fertilizers particularly nitrogen at the early stages of growth (Ramaswamy and

Muthukrishnan, 1973 and Dagade, 1986). Soil compaction affects the development of field-grown bananas. It reduces the size of banana plants and bunches, delays flowering and reduces the number of suckers produced. Soil compaction also upset banana plant nutrition by reducing uptake of N, P, K and Ca, and promoting uptake of Mn (Dorel, 1993). Patel *et al*. (1999) reported that nitrogen and potassium had significant effects only on finger and pulp weight. The combined application of 300 g N and 300 g K gave the highest bunch weight.

Malo and Campel (1914) reported that in soil with low fertility, banana should be fertilized frequently for maximum production. Freiberg (1954) reported that nitrogenous sources and super phosphate were beneficial and that K increased the weight of fruit but has little or no effect on number of hand on the fruit stalk. Butler (1960) showed that relatively fertile regions required only nitrogen for improvement of banana growth and yields where as other regions required phosphate or potash fertilizers in addition to nitrogen because of low content and availability of these minerals. In Canary Islands, Baillon *et al.* (1932) observed that all parts of the banana plant contained high K-content. Approximately 772 g of K_2O, 166 g of N and 35 g of P_2O_5 were removed from the soil by the mature plant and fruits. Banana generally requires high amounts of mineral nutrients for growth and fruit production, and these nutrients are only partly supplied by the soil. The large quantities of nutrients have to be replenished in order to maintain soil fertility and to permit the continuous production of high yields. The research conducted so far in banana is done either taking into consideration a single or two aspects of production technology. Precision farming technique is lacking. To achieve this, the studies conducted to determine the total N, P & K uptaked by main and ratoon banana crop cv.Grand Naine under different levels of planting distances, irrigation and fertigation

Materials and Methods

The experiment was conducted during 2003-2005 at Precision Farming Development Centre, Dr. Annasaheb Shinde College of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, India. The experiment was laid out in split-split plot design, with 27 treatment combinations besides control (Table 2), replicated thrice with three plants in each replication. Guard rows were provided on all sides of the plots.

Treatment details

I) **Main factors** : 3 levels of planting distances (D):

II)

D_1 1.75 x 1.75 m (3265 plants/ha)
D_2 1.5 x 1.5 m (4444 plants/ha)
D_3 1.25 x 1.25 m (6400 plants/ha)

II) Sub factors : 3 levels of irrigation through drip (I):

I_1 0.4 PE
I_2 0.6 PE
I_3 0.8 PE

III) Sub-sub factors: 3 levels of (Water soluble NPK fertilizers through drip (F):

F_1 120 % RD (240 N: 48 P: 288 K g/plant/year)
F_2 100 % RD (200 N: 40 P: 240 K g/plant/year)
F_3 80 % RD (160 N: 32 P: 192 K g/plant/year)

IV) Control: 1.5 x 1.5 m planting distance (4444 plants/ha), surface irrigation with application of recommended fertilizers dose (RD) in solid form.

The soil of the experimental plots was prepared to a fine tilth by cross wise ploughing followed by harrowing with disk harrow. Field was made free from organic residues of the previous crop or weed .Furrow then irrigated and farm yard manure (FYM) 10 kg was mixed for each hill .Tissue cultured plants of banana cv. Grand Naine were used as planting material. Banana planting was done on 31 July, 2003 and thereafter recommended package of cultural practices were followed. The special horticulture practices viz., earthing up, desuckering, propping removal of floral buds etc. were carried out as usual. Drip and surface irrigation was scheduled on the basis of pan evaporation (PE) .The time of operation of drip irrigation system was decided by knowing the average discharge of microtube per plant.

Two types of fertilizers i.e., normal solid fertilizers and water soluble fertilizers were used .The recommended fertilizer dose(R F D) of solid fertilizers (200N: 40 P2O5 : 240 K2O g per plant per year) was applied for control treatment by ring method.

Out of 25 per cent N through organic fertilizers (10 kg FYM at the time of planting and 75 per cent through inorganic fertilizers in four equal split doses at 45,90 and 210 days after planting .Phosphorus 40 g per plant was applied at the time of planting and 240 g K2O was applied in four equal split doses at the time of planting 165, 255 and 300 days after planting .Fertilizers for the treatment combinations were applied through drip irrigation system (fertigation).Weighed quantity of water soluble fertilizers and urea was added in water and injected in the lateral line as per treatments. Application of water soluble fertilizer through drip irrigation system was scheduled at monthly intervals spread over a period of 10 months, starting from one month after setting of suckers. The following fertilizers grades were used during experimentation (Table1).

Table 1. Fertilizers grades used during experimentation

Fertilizer grade	Type of Fertilizer	Nutrient levels N:P:K	Purpose
Urea NH2_CO_NH2	**N S F**	46:0:0	For full nitrogen requirement
Single superphosphate P_2O_5	**N S F**	0 : 16 : 0	For full phosphorus
Muriate of potash KCl	**N S F**	0 : 0 : 60	For full potassium requirement
NPK	**W S F**	19 : 19 : 19	For full P and part of N and K requirement
Urea	**W S F**	46 : 0 : 0	To cater remaining N left out.
K	**W S F**	0 : 0 : 50	To cater remaining K left out.

WSF,Water-soluble fertilizer **NSF**,Normal solid fertilizer

For soil sampling “V” shaped cut was made to a depth of 30 cm at each sampling spot. About 1.5 cm thick slices of soil were removed and collected in clean polythene bags. Samples of the same treatment were mixed thoroughly and quantity was reduced by quartering for analysis. Soil samples were collected thrice i.e. before the planting of main crop and after harvesting of main and ratoon crops. The soil type was clayey with 199.75, 16.95 and 526.30 kg available NPK, respectively.

The available nitrogen in the soil was estimated by Alkaline potassium permanganate method and the values were expressed as kg/ha (Subbiah and Asija, 1956). The available phosphorus in the soil was estimated using Klett Summerson Colorimeter with red filter at 600 nm (Olsen *et al*., 1954) and computed values were expressed as kg/ha.The available potassium in the soil was estimated using flame photometer. The soil extract with neutral normal ammonium acetate was used. The values were expressed as kg/ha (Hanway and Heidal, 1952).

For tissue analysis, leaf samples were collected from both sides of the midrib in the mid portion of the third leaf (Hewitt, 1955) at shooting stage. In order to avoid the variation in the maturity indices in the bunch, the representative fruit sample of fingers was collected from third hand and analysed. Both leaf and fruit samples were dried and grinded. The samples (0.2 g) were digested with 1:1 mixture of concentrated H_2SO_4 and H_2O_2 (30%) in digestion unit and the digested extract was used to determine the concentration of nitrogen, phosphorus and potassium in leaf tissue and in fruits for main and ratoon crops. The nitrogen content was estimated by micro-Kjeldahl method (Jackson, 1973) and expressed in percentage. The phosphorus content was estimated in a triple acid extract by adopting Vanadomolybdate phosphoric yellow colour method as outlined by Jackson (1973). The potassium content was estimated by reading the flame photometer value of triple extract as outlined by Jackson (1973).

Results and Discussion

Leaf and fruit nutrient uptake in banana plant provides information on the nutrient status of the plant and it also indicates whether the plants are properly utilizing the applied nutrients.

Maximum leaf and fruit N, P and K uptake were recorded at D_3 planting distance in main and ratoon crops(Table.2). This might be due to high plant population under HDP shared limited fertilizer dose as compared to the crop grown under the widest planting distance with less plant population which shared the same fertilizer dose. On the other hand, maximum leaf and fruit N, P and K uptake and subsequently total uptake under D_3 planting distance (HDP) could be correlated with higher amount of nutrients which have been removed to fulfill the requirement of higher production per unit area due to high population under D_3 planting distance compared to D_1 and D_2 planting distance. Generally, the crop grown under closed planting distance has lengthy (long) crop duration and stays for long period on the field. The long duration of staying in the field might be enough to remove more amount of N, P and K from the soil, and thus maximum N, P and K uptake observed in present study. By adopting fertigation and narrow planting density (2500 plant per ha) Mahalakshmi (2000) reported high yield (85.22 t/ha).Under high density planting higher yield(148.60 t /ha) was obtained.

Comparison of three levels of irrigation regarding their efficiency and effectiveness, I_1 irrigation level, in both main and ratoon crop registered substantial increase in N, P and K uptake by leaves, fruits and subsequent total uptake(Table .2). Hegde and Srinivas (1989) reported that decrease in frequency of irrigation through drip method caused increase in N concentration in organic matter besides high water use efficiency compared to surface method of irrigation.

In both main and ratoon crops, supplied with F_1 fertigation level (120% RDF) tended to increase leaf and fruit N, P and K uptake(Table .2) , which was expected result due to the application of higher fertigation dose that subsequently resulted in higher leaf and fruit N, P and K uptake in relation to other treatments. Nutrient uptake (N, P and K) was also higher with 100 g N through fertigation compared to direct soil application. Fruit yields were highest with 300 g N/plant fertigation but the differences were non-significant above 100 g N. However, yields increased with soil applied N upto 200 g both in main and ratoon crops (Srinivas, 1997).

From these experimental results, it appears that all treatment combinations in main and ratoon crops, respectively, performed well in respect of leaf and fruit N, P and K uptake as compared to control treatment. This is in accordance with the finding of Hegde and Srinivas (1990). These finding are also in conformity with those obtained by Arscott (1970) who reported that leaf nitrogen content of Cavendish banana was significantly higher when applied through drip irrigation than those plants to which fertilizer had been applied by conventional method.

In the present investigation, the combination D_1 x I_1 x F_3 and D_2 x I_2 x F_2 in main and ratoon crops, respectively, were found to be superior in respect of N (80 and 88%), P (125 and 146%) and K (35 and 57%) total uptake as compared to control treatment (Table 3). This result are in conformity with the finding of Baillon *et al*. (1932). This result showed that lower irrigation level is required during main crop (August) whereas there is slight increase in water requirement in ratoon crop trial (March). This might be due to high temperature during the ratoon crop season. These results are in agreement with those obtained by Arscott *et al*. (1965) who reported that total consumptive use of water varied greatly with the climatic and environmental condition, when temperature was 71°F, water requirement was 7.00 mm per day, and when temperature was 82°F, and water requirement was 9.2 mm per day.

The applied nutrients at any stage should be properly reflected in terms of available nutrients in soil so that the plant could absorb these nutrients without any hindrance. In this context, the estimation of soil available N, P and K content will be much useful to the horticulturists.

In the present study, soil available N, P and K estimated after main crop harvested were lower at D_1 (1.75 x 1.75 m) widest planting distance. This might be due to heavy bunch weight and more number of suckers obtained from the individual plant at the widest planting distance in main crop (Table 4).

Table 2. Effects of planting distances, irrigation and fertigation levels on total N, P and K uptake by main and ratoon banana crops.

Treatments	Main crop			Ratoon crop		
	Total Nitrogen Uptake (Kg/ha)	**Total Phosphorus uptake (Kg/ha)**	**Total Potassium uptake (Kg/ha)**	**Total Nitrogen uptake (Kg/ha)**	**Total Phosphorus uptake (Kg/ha)**	**Total Potassium uptake (Kg/ha)**
A) Planting istances						
D_1 (1.75 x 1.75 m)	526.60[c]	82.20[c]	752.10[c]	338.90[c]	61.40[b]	573.60[c]
D_2 (1.50 x 1.50 m)	580.00[b]	89.12[b]	931.80[b]	357.50[b]	60.49[c]	651.10[b]
D_3 (1.25 x 1.25 m)	831.40[a]	127.30[a]	1377.00[a]	548.40[a]	93.63[a]	106.10 [a]
Control	**317.40**	**42.10**	**609.90**	**205.50**	**29.70**	**467.90**
S.E.±	5.158	0.26	1.49	3.72	0.15	1.27
CD (0.05%)	20.26	1.03	5.88	14.64	0.61	5.00
B) Irrigation levels						
I_1 (40% of PE)	716.90[a]	112.50[a]	1071.00[a]	439.80[a]	80.83[a]	785.70[a]
I_2 (60% of PE)	568.80[c]	86.76[c]	967.10[c]	380.20[b]	62.57[c]	727.70[c]
I_3 (80% of PE)	652.30[b]	99.32[b]	1023.00[b]	424.80[a]	72.12[b]	772.40[b]
Control	**317.40**	**42.10**	**609.90**	**205.50**	**29.70**	**467.90**
S.E. ±	8.25	0.57	2.23	7.06	0.47	1.81
C.D. (0.05%)	25.4	1.78	6.87	21.78	1.47	5.59
C) Fertigation levels						
F_1 (240 **N** :48 **P** :288 **K** g/plant/year) (120 % of the recommended dose)	751.90[a]	125.10[a]	1129.00[a]	474.30[a]	91.25[a]	837.70[a]
F_2 (200 **N** :40 **P** :240 **K** g/plant/year) (100 % of the recommended dose)	606.80[b]	87.59[b]	962.80[b]	391.20[b]	63.33[b]	728.20[b]
F_3 (160 **N** :32 **P** :192 **K** g/plant/year) (80 % of the recommended dose)	579.30[c]	85.94[c]	969.20[b]	379.30[b]	60.94[c]	720.00[c]
Control	**317.40**	**42.10**	**609.90**	**205.50**	**29.70**	**467.90**
SE±	9.01	0.50	2.84	6.58	0.41	2.31
C.D. (0.05%)	25.86	1.46	8.17	18.8	1.18	6.6
CV %	17.25	12.66	14.50	18.24	12.98	15.80

In each column means followed by different letters are significantly different at the 5% level using Duncan's Multiple test.

Table 3. Interaction effects of planting distances, irrigation and fertigation levels (D x I x F) on total N,P and K uptake by main and ratoon banana crops.

Treatments	Main crop			Ratoon crop		
	Total Nitrogen uptake (Kg/ha)	Total Phosphorus uptake (Kg/ha)	Total Potassium uptake (Kg/ha)	Total Nitrogen uptake (Kg/ha)	Total Phosphorus uptake (Kg/ha)	Total Potassium uptake (Kg/ha)
Planting distances, irrigation and fertigation levels interactions (D x I x F)						
D_1 x I_1 x F_1	301.30^{k}	37.33^{r}	514.10^{r}	207.70^{l}	29.98^{r}	454.70^{o}
D_1 x I_1 x F_2	667.30^{fg}	116.40^{f}	889.60^{kl}	410.20^{efgh}	85.12^{g}	646.30^{j}
D_1 x I_1 x F_3	570.00^{h}	94.70^{hi}	822.60^{n}	330.80^{ijk}	65.16^{k}	563.20^{m}
D_1 x I_2 x F_1	665.20^{fg}	109.20^{g}	888.00^{kl}	416.40^{efg}	80.96^{h}	656.20^{j}
D_1 x I_2 x F_2	335.50^{k}	38.79^{r}	525.00^{r}	241.00^{l}	27.67^{r}	401.00^{p}
D_1 x I_2 x F_3	436.50^{j}	76.15^{o}	718.10^{q}	328.70^{ijk}	61.02^{l}	590.70^{kl}
D_1 x I_3 x F_1	664.20^{fg}	98.50^{h}	864.20^{lm}	380.80^{fghij}	73.97^{ij}	654.80^{j}
D_1 x I_3 x F_2	584.40^{gh}	89.79^{jkl}	794.80^{o}	367.30^{ghijk}	66.20^{k}	589.50^{kl}
D_1 x I_3 x F_3	515.20^{hij}	79.05^{no}	752.30^{p}	367.10^{ghijk}	62.57^{kl}	605.80^{k}
D_2 x I_1 x F_1	788.40^{de}	128.10^{e}	1131.00^{g}	484.10^{d}	91.49^{f}	814.20^{h}
D_2 x I_1 x F_2	757.50^{de}	126.80^{e}	1115.00^{gh}	497.90^{cd}	101.20^{e}	902.60^{f}
D_2 x I_1 x F_3	531.20^{hi}	66.65^{pq}	855.00^{m}	318.30^{jk}	38.87^{q}	515.10^{n}
D_2 x I_2 x F_1	542.00^{hi}	68.53^{p}	825.40^{n}	349.80^{hijk}	46.82^{nop}	590.10^{kl}
D_2 x I_2 x F_2	536.30^{hi}	94.22^{hij}	900.20^{k}	387.60^{fghi}	73.03^{j}	734.30^{i}
D_2 x I_2 x F_3	551.90^{hi}	81.79^{mn}	936.40^{j}	215.10^{l}	44.76^{op}	561.50^{m}
D_2 x I_3 x F_1	538.70^{hi}	85.51^{lm}	940.50^{j}	301.00^{k}	50.41^{n}	587.20^{kl}
D_2 x I_3 x F_2	508.80^{hij}	81.30^{mn}	871.50^{lm}	309.10^{k}	50.42^{n}	574.00^{lm}
D_2 x I_3 x F_3	465.20^{ij}	69.13^{p}	811.50^{no}	354.60^{ghijk}	47.41^{no}	580.60^{lm}
D_3 x I_1 x F_1	1217.00^{a}	225.00^{a}	1688.00^{b}	717.00^{a}	160.60^{a}	1197.00^{b}
D_3 x I_1 x F_2	794.00^{de}	68.62^{p}	1103.00^{h}	407.90^{efgh}	46.58^{nop}	838.40^{g}
D_3 x I_1 x F_3	825.10^{d}	148.90^{d}	1524.00^{d}	584.20^{b}	108.60^{d}	1140.00^{c}
D_3 x I_2 x F_1	911.50^{c}	165.10^{c}	1587.00^{c}	677.70^{a}	130.10^{c}	1285.00^{a}
D_3 x I_2 x F_2	559.00^{h}	83.55^{mn}	1251.00^{e}	438.90^{def}	55.69^{m}	907.90^{f}
D_3 x I_2 x F_3	581.50^{gh}	63.62^{q}	1072.00^{i}	366.50^{ghijk}	43.02^{p}	822.20^{gh}
D_3 x I_3 x F_1	1139.00^{b}	208.30^{b}	1724.00^{a}	733.90^{a}	156.90^{b}	1299.00^{a}
D_3 x I_3 x F_2	718.60^{ef}	88.88^{kl}	1216.00^{f}	460.90^{de}	64.10^{kl}	959.50^{e}
D_3 x I_3 x F_3	736.60^{ef}	93.41^{ijk}	1231.00^{ef}	548.30^{bc}	77.13^{i}	1101.00^{d}
Control	**317.40**	**42.10**	**609.90**	**205.50**	**29.70**	**467.90**
SE±	27.04	1.52	8.54	19.74	1.23	6.95
CD (0.05)	77.57	4.38	24.51	56.63	3.54	19.95
CV %	17.25	12.66	14.50	18.24	12.98	15.80

In each column means followed by different letters are significantly different at the 5% level using Duncan's multiple test.

Table 4. Effects of planting distances, irrigation and fertigation levels on soil available N, P and K after harvest of main and ratoon banana crops.

Treatments	After Main crop harvest			After Ratoon crop harvest		
	Soil Nitrogen (Kg/ha) status	**Soil Phosphorus (Kg/ha) status**	**Soil Potassium (Kg/ha) status**	**Soil Nitrogen (Kg/ha) status**	**Soil Phosphorus (Kg/ha) status**	**Soil Potassium (Kg/ha) status**
A) Planting distances						
D_1 (1.75 x 1.75 m)	139.40[b]	14.75[c]	337.90 [c]	169.40 [b]	15.50[c]	281.90 [c]
D_2 (1.50 x 1.50 m)	170.20[a]	15.25[b]	374.00 [b]	190.20 [a]	16.00[b]	318.00 [b]
D_3 (1.25 x 1.25 m)	161.70[a]	15.47[a]	391.40 [a]	171.70[b]	16.22[a]	335.40 [a]
Control	**84.67**	**16.80**	**504.00**	**112.89**	**17.90**	**448**
S.E.±	4.49	0.03	1.09	4.49	0.03	1.19
CD (0.05%)	17.67	0.04	4.30	16.77	0.14	5.30
B) Irrigation levels						
I_1 (40% of PE)	168.30[a]	14.97[c]	363.40[b]	188.30[a]	15.72[c]	307.40[b]
I_2 (60% of PE)	140.80[a]	15.47[a]	378.30[a]	160.80[a]	16.22[a]	322.30[a]
I_3 (80% of PE)	162.20[a]	15.04[b]	361.50[b]	182.20[a]	15.79[b]	305.50[b]
Control	**84.67**	**16.80**	**504.00**	**112.89**	**17.90**	**448.00**
S.E. ±	9.40	0.01	1.93	9.41	0.01	1.93
C.D. (0.05%)	28.99	0.04	5.96	29.79	0.03	5.96
C) Fertigation levels						
$\mathbf{F_1}$ (240 **N** :48 **P** :288 **K** g/plant/year) (120 % of the recommended dose)	156.20[c]	14.74[b]	343.50[c]	176.20[c]	15.49[b]	287.50[c]
$\mathbf{F_2}$ (200 **N** :40 **P** :240 **K** g/plant/year) (100 % of the recommended dose)	158.00[a]	15.38[a]	382.00[a]	178.00[a]	16.13[a]	326.00[a]
$\mathbf{F_3}$ (160 **N** :32 **P** :192 **K** g/plant/year) (80 % of the recommended dose)	157.10[b]	15.35[a]	377.70[b]	177.10[b]	16.10[a]	321.70[b]
Control	**84.67**	**16.80**	**504.00**	**112.89**	**17.90**	**448.00**
SE±	0.29	0.01	1.49	0.39	0.02	1.50
C.D. (0.05%)	0.84	0.04	4.29	0.74	0.05	4.40
CV %	16.98	19.66	12.11	18.87	15.57	12.49

In each column means followed by different letters are significantly different at the 5% level using Duncan's Multiple test.

Soil available N, P and K estimated after ratoon crop harvested were medium at normal planting distance (1.50 x 1.50 m) (Table 4). This result might be due to vigour growth, bunch weight, number of fingers per hand and number of fingers per bunch obtained at normal planting distance.

The results of this experiment showed that lower irrigation level I_1 40% PE (764.26 mm per year for main) and (791.33 mm per year for ratoon) recorded minimum soil available phosphorus and potassium content(Table 4). While, different irrigation levels had no significant effect on soil available nitrogen content in main as well as in ratoon crop. This result might be due to high uptake of N, P and K observed previously at I_1 irrigation level in the present study. It was also revealed that higher soil available N, P and K were maintained at I_2 (1186.99 mm per year) irrigation level after ratoon crop had been harvested (Table 4). This finding confirmed the data previously observed in the present experiment regarding less N, P and K total uptake at I_2 irrigation level.

In the present investigation, soil available nitrogen and potassium were maintained high level at F_3 (80% of RDF) and F_2 (100% of RDF) fertigation level in main crop and ratoon crops, respectively (Table 4). From these experimental results, it appears that F_3 and F_2 fertigation levels in main and ratoon crop are the optimum level for maintaining soil fertility without leaving unnecessary more fertilizer in soil or heavily exhaustion to soil available nutrients. Regarding higher soil available phosphorus remained in soil might be due to less requirement of phosphorus in banana. This agrees with Volk (1930) who observed that satisfactory growth occurred in area having only 0.1-0.2 m of available P_2O_5 in soil. Veerannah *et al*. (1976) also reported that lesser content of phosphorus in leaf at shooting in banana is quite expected as the demand for phosphorus was more only at early stage of growth.

In the present study, maximum soil available phosphorus and potassium were observed under control treatment which might be due to the lower nutrient uptake under surface irrigated treatment as previously recorded. Less soil available nitrogen in control treatment might be also due to vigorous growth that represented in more number of functional leaves and more number of suckers per plant. In the present investigation, banana grown under control treatment required longer crop duration with an extended the vegetative growth period in utilizing the available nitrogen from soil and subsequently decreased the soil available nitrogen.

From these experimental results, it appeared that treatment combinations D_1 x I_1 x F_3 and D_2 x I_2 x F_2 in main and ratoon crops respectively, had maintained relatively low soil available N, P and K in relation to other treatment combinations (Table 5). This result might be due to high use efficiency of additional and available nutrient in soil.

Table 5. Interaction effects of planting distances, irrigation and fertigation levels (D x I x F) on soil available N, P and K after harvest of main and ratoon banana crops.

Treatments	After Main crop harvest			After Ratoon crop harvest		
	Soil Nitrogen (Kg/ha) status	Soil Phosphorus (Kg/ha) status	Soil Potassium (Kg/ha) status	Soil Nitrogen (Kg/ha) status	Soil Phosphorus (Kg/ha) status	Soil Potassium (Kg/ha) status
Planting distances, irrigation and fertigation levels interactions (D x I x F)						
D_1 x I_1 x F_1	152.60^{h}	16.86^{a}	498.40^{b}	182.60^{def}	17.8^{a}	442.40^{b}
D_1 x I_1 x F_2	151.60^{h}	13.25^{n}	263.20^{o}	181.60^{f}	14.00^{n}	207.20^{o}
D_1 x I_1 x F_3	152.10^{h}	14.30^{k}	313.60^{jk}	182.10^{ef}	15.05^{k}	257.60^{jk}
D_1 x I_2 x F_1	120.20^{m}	13.20^{n}	268.80^{no}	150.20^{l}	13.95^{n}	212.80^{no}
D_1 x I_2 x F_2	120.00^{m}	16.85^{a}	459.20^{c}	150.20^{l}	17.60^{a}	403.20^{c}
D_1 x I_2 x F_3	120.30^{m}	15.15^{h}	302.40^{kl}	150.20^{l}	15.90^{h}	246.40^{kl}
D_1 x I_3 x F_1	144.30^{j}	13.55^{m}	257.60^{o}	174.30^{hi}	14.30^{m}	201.60^{o}
D_1 x I_3 x F_2	147.40^{i}	14.60^{j}	324.80^{ij}	177.40^{g}	15.35^{j}	268.80^{ij}
D_1 x I_3 x F_3	145.80^{ij}	15.00^{i}	352.80^{g}	175.80^{gh}	15.75^{i}	296.80^{g}
D_2 x I_1 x F_1	163.10^{ef}	14.65^{j}	330.40^{hi}	183.10^{def}	15.40^{j}	274.40^{hi}
D_2 x I_1 x F_2	166.20^{cd}	14.55^{j}	341.60^{gh}	186.20^{bc}	15.30^{j}	285.60^{gh}
D_2 x I_1 x F_3	164.60^{de}	15.50^{ef}	420.00^{de}	184.60^{cde}	16.25^{ef}	364.00^{de}
D_2 x I_2 x F_1	165.20^{de}	15.55^{e}	431.20^{d}	185.20^{cd}	16.30^{e}	375.20^{d}
D_2 x I_2 x F_2	168.30^{c}	15.35^{g}	268.80^{no}	188.30^{b}	16.10^{g}	212.80^{no}
D_2 x I_2 x F_3	166.70^{d}	15.45^{efg}	380.80^{f}	186.70^{bc}	16.20^{efg}	324.80^{f}
D_2 x I_3 x F_1	178.80^{b}	15.40^{fg}	386.40^{f}	198.90^{a}	16.15^{fg}	330.40^{f}
D_2 x I_3 x F_2	179.80^{b}	15.40^{fg}	386.40^{f}	199.80^{a}	16.15^{fg}	330.40^{f}
D_2 x I_3 x F_3	179.30^{b}	15.40^{fg}	420.00^{de}	199.30^{a}	16.15^{fg}	364.00^{de}
D_3 x I_1 x F_1	188.20^{a}	14.10^{l}	280.00^{mn}	198.40^{a}	14.85^{l}	224.00^{mn}
D_3 x I_1 x F_2	188.60^{a}	16.35^{b}	520.80^{a}	198.20^{a}	17.10^{b}	464.80^{a}
D_3 x I_1 x F_3	188.90^{a}	15.15^{h}	302.40^{kl}	198.00^{a}	15.90^{h}	246.40^{kl}
D_3 x I_2 x F_1	133.80^{l}	15.00^{i}	347.20^{g}	143.80^{n}	15.75^{i}	291.20^{g}
D_3 x I_2 x F_2	136.90^{k}	16.20^{c}	459.20^{c}	146.90^{m}	16.95^{c}	403.20^{c}
D_3 x I_2 x F_3	135.40^{kl}	16.45^{b}	487.20^{b}	145.40^{mn}	17.20^{b}	431.20^{b}
D_3 x I_3 x F_1	159.90^{g}	14.40^{k}	291.20^{lm}	169.90^{k}	15.15^{k}	235.20^{lm}

Table 5 (Contd…)

Treatments	After Main crop harvest			After Ratoon crop harvest		
	Soil Nitrogen (Kg/ha) status	**Soil Phosphorus (Kg/ha) status**	**Soil Potassium (Kg/ha) status**	**Soil Nitrogen (Kg/ha) status**	**Soil Phosphorus (Kg/ha) status**	**Soil Potassium (Kg/ha) status**
D_3 x I_3 x F_2	163.10[ef]	15.85[d]	414.40[e]	173.10ij	16.60[d]	358.40[e]
D_3 x I_3 x F_3	161.50[fg]	15.75[d]	420.00[de]	171.50 [jk]	16.50[d]	364.00[de]
Control	**84.67**	**16.80**	**504.00**	**112.89**	**17.90**	**448.00**
SE±	0.88	0.04	4.48	0.88	0.04	4.48
CD (0.05)	2.54	0.13	12.87	2.54	0.13	12.87
CV %	16.98	19.66	12.11	18.87	15.57	12.49

In each column means followed by different letters are significantly different at the 5% level using Duncan's Multiple test.

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