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Nutrient use and dynamics under different fertigation scheduling for banana (*Musa paradisiaca*) cultivation in vertisol

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ABSTRACT

Field experiment was conducted at Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra) for three consecutive years (2008-2011) to study the nutrient availability, uptake and movement in vertisol under drip fertigation for banana (*Musa paradisiaca* L.) cv Grand naine. The drip fertigation @ 100, 80 and 60 per cent of recommended dose through water soluble fertilizers (WSF) applied in two schedules and results were compared with three control treatments. The drip fertigation @ 100 per cent recommended dose scheduled as per crop growth stages showed 46.22 per cent increase in yield (82.94 tonnes/ha). However, it was on par with 80% fertigation treatment (79 tonnes/ha) whereas, 60 per cent fertigation (Schedule as per crop growth stages) resulted into 40 per cent fertilizer saving and 24.5 per cent increase in yield over surface irrigation (57.40 tonnes/ha). The drip fertigation relatively improved the nutrients availability and uptake as compared to band placement of dry fertilizers. The study indicated that application of water soluble fertilizers through drip as per the growth stages proved superior as compared to uniform splits for periodical availability of nutrients, uptake and nutrient movement in soil than conventional fertilizers. The maximum movements of nutrients in vertisol were recorded for 100 and 80% fertigation using water soluble fertilizers. The N was moved up to 45 cm laterally and 60 cm vertically. P was moved up to 30 cm laterally and 40 cm vertically and K movement was up to 45 cm laterally and 60 cm vertically during the crop growth. The 100% fertigation, also registered higher economical parameters, however the difference with 80% fertigation was non significant.

Key words: Drip fertigation, Nutrient availability and uptake, Nutrient movement, Water soluble fertilizers

The popularity of drip for banana (*Musa paradisiaca* L.) has also raised the opportunities for improved fertilizer management through drip fertigation because of the very high fertilizer demand of banana crop. Fertigation has some special advantages in irrigated agriculture since it provides the most effective way of supplying nutrients to the plant roots (Thangaselvabai *et al.* 2009). The fertilizer use efficiency by traditional fertilizer application using soil manipulation was observed to be only 30-35% because of loss of nutrients, e.g. volatilization, evaporation and loss of P and K by fixation in the soil (Sathya *et al.* 2008). High fertilizer use efficiency with substantial improvement in phenological characteristics, bunch characteristics, yield and substantial saving of fertilizer up to 30% over conventional fertilizers application could be obtained by drip fertigation to banana (Kavino *et al.* 2004, Nalina *et al.* 2009, Kumaran and Muthuvel 2009).

The concentration of primary nutrients in different parts of banana plant has reported highest under fertigation. The distribution of nutrients added to the soil from drip emitters is also likely to differ markedly by source and level of application (Pan *et al.* 2011). Urea is relatively mobile in soil tends to be more evenly distributed within the wetted profile. The movement of P was found to be both in horizontal and vertical direction near the outlet when applied as urea phosphate. Common K source such as muriate of potash is also readily soluble in water and its distribution in the wetted volume may be more uniform due to interaction with binding sites (Pawar *et al.* 2014, Solaimalai *et al.* 2005). However, while performing fertigation it should be noted that without using proper schedule the costly water soluble fertilizers may leach deep below root zone and fix in the soil profile or lost in the atmosphere by volatilization making it non-available to the plants. Hence, present investigation was aimed to explore appropriate fertigation scheduling on the basis of plant need and its impact on soil fertility status, nutrient uptake and dynamics to optimize fertilizer use.

MATERIALS AND METHODS

The field experiment was conducted for three years (2008 to 2011) at research farm of Interfaculty Department

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of Irrigation Water Management, Mahatma Phule Krishi Vidyapeeth Rahuri. Agro-climatically, the area falls under the scarcity zone of Maharashtra with annual average rainfall of 520 mm which is mostly erratic and uncertain in nature. The soil was clayey in texture (23.5% coarse sand, 26% silt and 50.5% clay) having 80 cm depth. The bulk density of soil was 1.27 g/cm^3 and electrical conductivity was 0.32 dS/m. The hydraulic conductivity and organic carbon was 1.0 cm/hr and 0.65% respectively. The soil was alkaline in reaction with pH as 8.20. The available nitrogen, phosphorus and potassium was 175.0, 18.20 and 530.0 kg/ha, respectively. The soil was having good drainage with moisture content at field capacity, permanent wilting point and available water content was 42.40, 20.27 and 22.25 per cent, respectively. Three arrangements of fertigation doses (100, 80 and 60% of recommended dose) under two different schedules A (T_1 to T_3) and B (T_4 to T_6), N fertigation only (T_7), drip with conventional practice of fertilizer application (T_8) and drip with conventional practice of irrigation and fertilizer application (T_9) were evaluated in Randomized Block Design (RBD).

Under schedule A, all the fertilizers were applied in 18 uniform splits at an interval of 15 days, as most of the progressive farmers were adopting fertigation by applying equal doses for easy operation; whereas in schedule B, the fertilizers were applied in 18 fortnightly splits apportioned on the basis of nutrient requirement of crop during different growth stages (Table 1). In N fertigation (T_7), the entire N was applied through urea in 18 equal splits of 15 days interval whereas; P and K were applied conventionally. In conventional practice of fertilizer application N was applied in two uniform splits, at planting and another at 120 DAP, P as basal and K in four equal splits at 30, 165, 255 and 300 days after planting through soil.

The recommended dose of fertilizer for banana was applied as 200:40:200; N: P_2O_5: K_2O g/plant. The fertigation was done using water soluble fertilizers, viz. Urea (46:0:0), Urea phosphate (17:44:0) and MOP (0:0:60). In conventional application fertilizers were applied using urea, single super phosphate and muriate of potash. The tissue culture banana saplings (cv Grand naine) of 2 to 2½ months old were planted at spacing of 1.5 × 1.5 m twice during the 1st week of December 2007 and 2009 and were harvested during the November 2008 and 2010, respectively. The first ratoon (suckers) was allowed from 2nd fortnight of November 2008 and was harvested during the month of October 2009.

The schedule of fertigation was maintained as per treatments finalized for each crop. In drip fertigation, the fertilizers were applied along with water using Automized Fertijet System (Galcon, Israel). The drip irrigation system was operated at every alternate day to meet out crop water requirement using climatological approach as given by Allen *et al.*(1997). The lateral lines of 16 mm diameter LLDPE pipes were laid along the crop rows with online drippers of 4 lph discharge capacity. The spacing between two adjacent laterals and emitters within plot was 1.5 m and 0.75 m, respectively. In conventional method of irrigation, 80 mm depth of irrigation was applied at 75 mm cumulative pan evaporation.

The soil samples were collected periodically (90, 180 and 270 days after planting (DAP) and at harvest) for nutrient availability and uptake. The uptake of major nutrients was worked out by multiplying dry matter accumulation to N, P and K concentration (Jackson 1985) in leaves, shoot and fruit. The plant samples were digested (diacid extract) as per the standard procedure given by Parkinson and Allen (1975).

The nutrient movement was recorded for two years (one plant and ratoon banana) at 90, 180, 270 days after planting (DAP) and at harvest by collecting samples at 0, 15, 30, 45 and 60 cm laterally and 0, 20, 40, 60, 80 and 100 cm vertically from emitter for each drip irrigation treatment. The movement of nutrient was assured by comparing the available nutrients at particular location with initial nutrient status and if the nutrient availabilities at any location under study was found more by at least 10% than initial status; the nutrient was considered to be moved up to that point at that time.

Table 1 Proportion of nutrients to be applied in fortnightly splits (Schedule B)

Month	% N	% P	% K
First 2 months (4 splits)	15	30	10
3-4 months (4 splits)	40	50	20
5-6 months (4 splits)	25	20	30
7 months (4 splits)	20		30
8-9 months (2 splits)			15

RESULTS AND DISCUSSION

Yield of banana

The banana yield data (Table 2) pooled over three years was found to be ranged between 57.40 tonnes/ha to 82.94 tonnes/ha. The maximum yield of 82.94 tonnes/ha was obtained in T_4, where 100% recommended dose of fertilizer was apportioned as per growth stages in 18 splits. The yield under T_4 was significantly superior over all other

Table 2 Yield of banana as influenced by different treatments (2007-2010)

Treatment	Yield (tonnes/ha)			
	2008-09	2009-10	2010-11	Pooled mean
T_1	83.73	75.76	78.02	79.17
T_2	75.81	67.80	73.36	72.32
T_3	72.91	64.45	66.10	67.82
T_4	87.84	79.14	81.84	82.94
T_5	83.31	74.84	78.81	79.00
T_6	75.79	66.79	69.44	70.67
T_7	80.69	72.97	69.28	74.31
T_8	75.34	65.78	68.02	69.71
T_9	64.91	56.04	51.26	57.40
SE ±	2.82	1.801	1.63	2.69
CD (P = 0.05)	7.47	5.381	4.89	6.02

treatments except T_1 (100% WSF in uniform 18 splits at an interval of 15 days) and T_5 (80% WSF in 18 splits as per growth stages) and was 46.22% more than conventional method of irrigation and fertilizer application. The drip irrigation (T_8) produced (69.71 tonnes/ha) 17.66% more yield than surface irrigation (57.40 tonnes/ha). The overwhelming performance of drip irrigation over surface irrigation was due to the application of right quantity of water at right time and at right place which resulted in appropriate moisture content in root zone. This supports the work of Dinesh Kumar and Pandey (2008) that optimum moisture content in soil promoted the physiological process and increased the growth of banana plant.

Nutrient movement

Nitrogen mobility

The N mobility (average of 2 years data) was found to be varied considerably with period from planting in all the treatments (Table 3). It was minimum at 90 DAP (15 cm lateral and 20 cm vertical) and was found to be increased upto 12 months, i.e. at harvest. The maximum movement of N was observed at harvest (30 to 45 cm lateral and 40 to 60 cm vertical). These results are in conformity with the results reported by Bangar and Chandhari (2000) about movement of nutrients applied through WSF in lnceptisol and Vertisols. The higher levels of fertilizer marginally increased mobility. The N mobility was varied significantly due to schedule of fertilizer also. The schedule A resulted into more N mobility as compared to schedule B. It may be because of more quantity of fertilizer was applied during each split in schedule A as compared to schedule B.

The nitrogen mobility was found to be affected greatly due to source of fertilizers. The WSF (T_1 to T_6) resulted in maximum N movement to a distance of 30 to 45 cm laterally and 40 to 60 cm vertically as compared to 30 cm lateral movement and 40 cm vertical movement in T_8 (drip with CF applied through soil). This may be due to application of fertilizers exactly at the point of water application. Similar trend of results were reviewed by Sathya *et al.* (2008) in fertigation of banana with nitrate and ammonical nitrogen under drip irrigation and observed that the concentration of NO_3-N was highest under drippers and decreased gradually with distance from it in three directions.

Phosphorus mobility

The P mobility was found to be varied considerably with period in all the treatments (Table 3). It was minimum at 90 DAP (15 cm horizontal and 20 cm vertical). The maximum movement of P_2O_5 was observed at 270 DAP (30 cm lateral and 40 cm vertical) in treatment where nutrients were applied in water soluble form in 18 equal splits (T_1). The levels of WSF (100, 80 and 60 per cent) and schedule (A and B) showed slight effect on the mobility of phosphorus in almost all the treatments. The phosphorus mobility was found to be affected to greater extent due to source of fertilizers. The WSF (T_1 to T_6) resulted into increase in mobility and was found to be 15 to 30 cm horizontally and

Table 3 Periodical NPK mobility as influenced by different treatments (Av. of 2 years)

Treatment	N mobility								P mobility								K mobility							
	90 DAP		180 DAP		270 DAP		At harvest		90 DAP		180 DAP		270 DAP		At harvest		90 DAP		180 DAP		270 DAP		At harvest	
	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V
T_1	30	20	30	40	30	60	45	60	15	20	30	40	30	40	15	40	30	40	45	60	45	60	45	60
T_2	15	20	30	40	30	60	45	60	15	20	15	40	15	40	15	20	30	40	30	40	45	60	30	60
T_3	15	20	30	40	30	60	30	60	15	20	15	20	15	20	15	20	15	40	30	40	30	40	30	40
T_4	15	20	45	40	45	60	45	60	15	20	30	40	30	20	15	20	30	40	45	60	45	60	45	60
T_5	15	20	30	40	45	60	30	60	15	20	15	40	15	20	15	20	30	40	45	60	45	60	45	60
T_6	15	20	30	40	30	60	30	60	15	20	15	20	15	20	15	20	15	20	30	40	30	40	30	60
T_7	15	20	30	40	45	60	45	60	15	40	15	40	15	20	15	20	15	20	45	60	45	60	45	60
T_8	15	40	30	40	30	40	15	40	15	40	15	40	15	20	15	20	15	20	45	60	45	60	45	60

Where H- Horizontal distance from emitter, V- Vertical distance from emitter

20 to 40 cm vertically as compared to 15 cm horizontally and 20 cm vertically in T_7 and T_8 (drip irrigation with P applied through soil).

Potassium mobility

The K mobility was also found to be varied considerably with period in all treatments (Table 3). It was minimum at 90 DAP (15 to 30 cm horizontal and 20 to 40 cm vertical) and was found to be increased up to harvest. The maximum movement of potassium was observed at harvest (30 to 45 cm horizontal and 40 to 60 cm vertical). These findings are in close conformity to those reported by Bangar and Choudhari (2000). The higher doses showed marginally increased K mobility. Whereas, less mobility was observed in 60% fertigation treatments, i.e. T_3 and T_6. The schedule A resulted into almost same mobility as that of schedule B. The potassium mobility was found to be unaffected due to fertilizer source (T_4, T_7 and T_8).

Periodical NPK availability in soil

Nitrogen availability

The N availability (pooled mean of 3 years) was increased with period from planting in all the treatments. The minimum availability was found at 90 DAP and was increased up to 270 DAP and afterwards it decreased at harvesting stage (Table 4 and Fig 1). The decreased N availability at harvesting stage may be due to uptake of N by plants without any N addition. The schedule B, where N was applied as per crop growth stages resulted into more N availability in soil at all the stages except 90 DAP as compared to schedule A (equal splits).

The source of fertilizer and fertilizer application method (Fig 1) also resulted into moderate change in 'N' availability in the root zone soil of banana at all the stages. The WSF applied though resulted into more availability of N in soil as compared to conventional fertilizers and irrigation pracrice. As more quantum of water was available just beneath the dripper, there was corresponding increase in available N in the soil. This has inferred a direct association between N availability and presence of *in situ* irrigation water (Sathya *et al.* 2008).

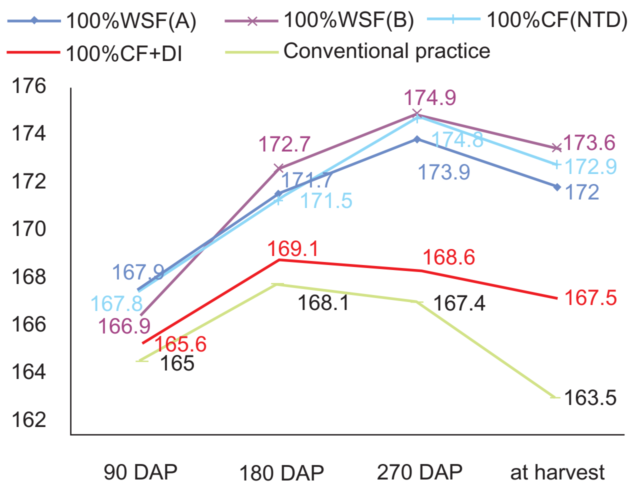

Fig 1 N availability (kg/ha) as per fertilizer application application method

Phosphorus availability

The average phosphorus availability (pooled mean of 3 years) in the root zone was found to be influenced by period and level of fertilizers (Table 4 and Fig 2). The P availability was increased with period from planting in all the treatments except T_7, T_8 and T_9. The minimum availability was found at 90 DAP and was increased up to 270 DAP and afterwards it was decreased at harvesting stage. The decreased P availability at harvesting stage may be due to higher uptake of P by plants during flowering and maturity stage (Fig 5). In treatments T_7, T_8 and T_9, P availability decreased with period may be due to basal application of P fertilizer in these treatments. The schedule B, where P was applied as per growth stages resulted into more P availability in the soil at 90 (DAP) and 180 (DAP) and decreased afterwards due to increased uptake and reduced application dose of P (Fig 5) whereas, schedule A showed increased availability upto 270 DAP and decreased at harvesting stage (Fig 2).

Potassium availability

The K availability increased with period from planting in all the treatments (Table 4 and Fig 3). The minimum

Table 4 Periodical NPK availability (kg/ha) in soil as influenced by various treatments

Treat-	N availability				P availability				K availability			
ment	90 DAP	180 DAP	270 DAP	At harvest	90 DAP	180 DAP	270 DAP	At harvest	90 DAP	180 DAP	270 DAP	At harvest
T_1	167.9	171.7	173.9	172.0	15.86	16.51	16.86	15.61	518.6	531.4	536.3	532.3
T_2	166.8	170.8	173.3	171.0	15.46	15.96	16.42	15.19	514.9	529.6	533.0	529.5
T_3	165.4	168.9	170.9	169.8	15.27	15.74	15.85	15.01	508.7	526.5	531.0	527.2
T_4	166.9	172.7	174.9	173.6	16.12	16.75	16.44	15.43	517.5	533.7	539.8	536.0
T_5	166.2	171.4	173.2	171.5	15.57	16.05	15.95	15.09	515.3	531.3	536.5	532.5
T_6	165.2	169.8	171.3	169.8	15.36	15.90	15.47	14.3389	512.6	527.9	531.5	529.0
T_7	167.8	171.5	174.8	172.9	16.31	15.91	15.55	14.71	503.4	534.5	539.0	540.5
T_8	165.6	169.1	168.6	167.5	16.32	15.82	15.42	14.67	502.5	534.7	539.1	541.5
T_9	165.0	168.1	167.4	163.5	16.1	15.6	14.8	14.0	500.3	532.4	537.2	538.3

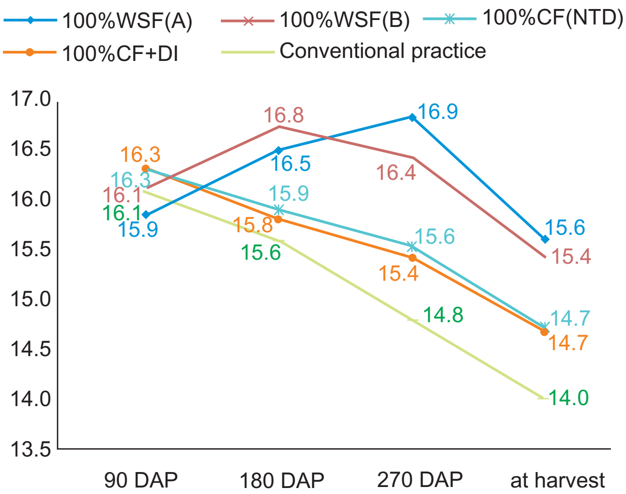

Fig 2 P availability (kg/ha) as per fertilizer application method

availability was found at 90 DAP and was increased upto 270 DAP and decreased afterwards except treatment T_7, T_8 and T_9. The decreased K availability at harvesting may be due to higher uptake of K by plants at maturity stage (Fig 6). In case of T_7, T_8 and T_9 as 25% of K was applied at 300 DAP; it resulted into increased K availabilities till harvesting. The schedule B, where K was applied as per the growth stages resulted into more K availability in the soil at all stages as compared to schedule A. Nalina *et al.* (2009) also reported increased nutrient availability under fertigation of water soluble fertilizers than conventional method.

Nutrient uptake

Banana leaves

The pooled means (2008-2011) of NPK uptake by leaves were significantly varied with different irrigation and fertilizer application methods (Fig 4 to Fig 6). However among different fertigation treatments, T_4 (100% RD through WSF in 18 splits as per growth stages) resulted into significantly maximum total NPK uptake (240.4, 50.2 and

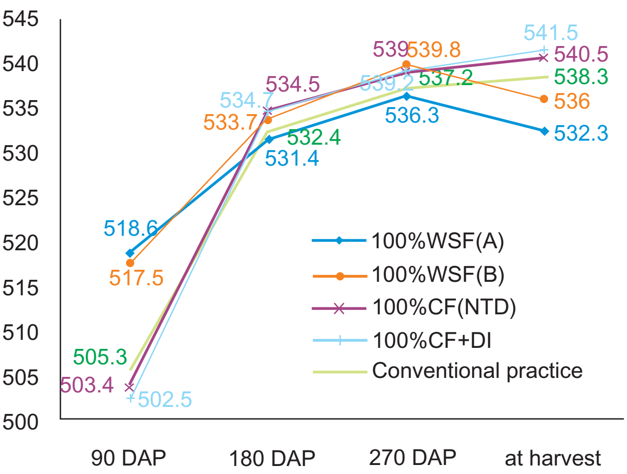

Fig 3 K availability (kg/ha) as per fertilizer application method

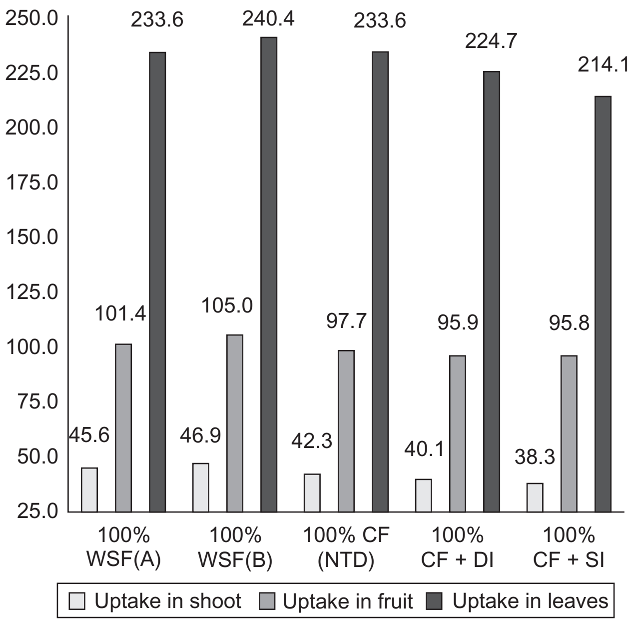

Fig 4 N uptake (kg/ha) as per fertilizer application method

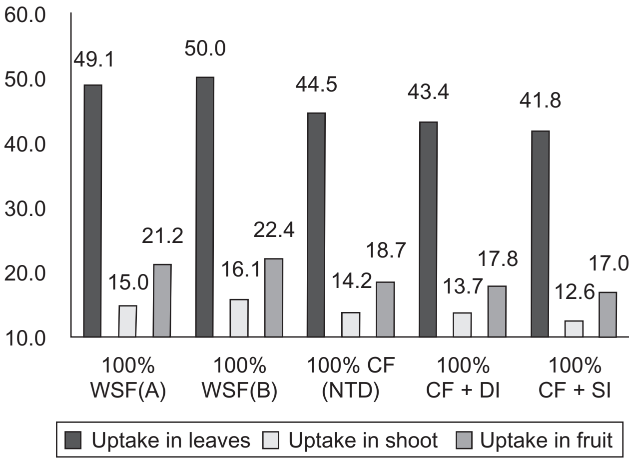

Fig 5 P uptake (kg/ha) as per fertilizer application method

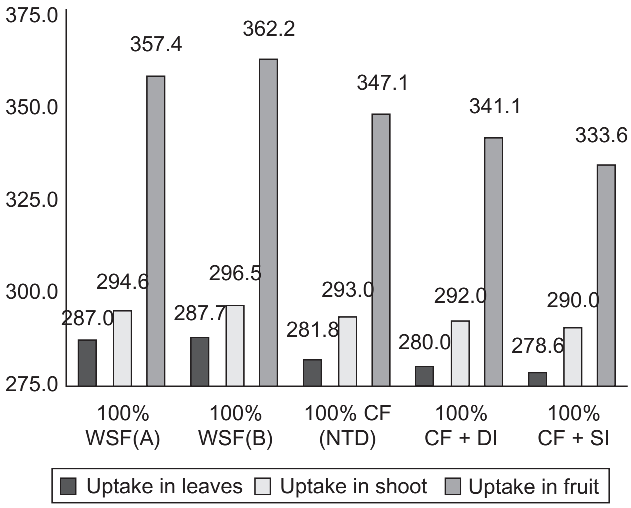

Fig 6 K uptake (kg/ha) as per fertilizer application method

287.7 kg/ha, respectively) over other treatments except T_1. Treatment T_9 (surface irrigation with conventional fertilizer) recorded lowest values of NPK uptake (214.0, 41.83 and 278.6 kg/ha, respectively). The better nutrient uptake in case of WSF through drip over surface irrigation with conventional fertilizer may be due to availability of nutrients in ample quantum in soil solution in the presence of right quantity of water (Srinivas *et al.* 2001).

Banana shoot

The NPK uptake of banana shoot was increased with increasing levels of fertilizers. The treatment T_4 where 100% RD of WSF was applied as per growth stages in 18 splits recorded significantly maximum NPK uptake (46.87, 16.07 and 296.5 kg/ha, respectively) over other treatments except T_1 (45.6, 15.04 and 294.6 kg/ha, respectively). Pan *et al.* (2011) reported greater mobility of water soluble fertilizers resulted into more uptake of phosphate than conventional fertilizers.

Banana fruit

The NPK uptake by banana fruit was significantly higher in drip irrigated plot as compared to conventional irrigation method. However, among different fertigation treatments, 100% RD through WSF in 18 splits as per growth stages (T_4) resulted into maximum value of NPK uptake (105.03, 22.36 and 362.21 kg/ha, respectively) and was significantly superior over other treatment except T_1 (103.4, 21.2 and 359.4 kg/ha, respectively). Drip irrigation had very significant effect over surface irrigation in terms of nutrient uptake may be due to increased water in root zone increased solubility of nutrients and thereby resulted in more uptake of nutrients in drip than surface irrigation (Palwe *et al.* 2007).

Total nutrient uptake of banana

The total nutrient uptake of banana was determined as sum of nutrient uptake by shoot, leaves and fruit. The drip method recorded significantly increased uptake over surface irrigation treatment. Among drip fertigated treatments, T_4 treatment (392.34, 88.65 and 946.98 NPK kg/ha) was significantly superior over other treatments and treatment T_9 recorded lowest nutrient uptake (333.61, 71.44 and 900.68 NPK kg/ha). The drip fertigation gave better nutrient uptake may be due to frequent as well as proper amount of water and nutrients which resulted into maintenance of soil-air ratio at an optimum. The lower water tension and decline in soil temperature in the drip irrigated plots helped in enhanced nutrient uptake (Pan *et al.* 2011).

Cost economics

The pooled data of three years regarding cost of cultivation, net income and benefit: cost ratio of drip fertigation under different treatments is presented in Table 5. The fixed cost of drip system for banana was estimated as ₹ 29 152 considering 12 months crop period. It is revealed from Table 5 that more cost of cultivation was estimated in 100% fertigation treatments (₹ 178 469) because of high market cost of water soluble fertilizers. The lowest cost of cultivation (₹ 130 634) was obtained for conventional method.

Table 5 Cost of cultivation, net income & B:C ratio as influenced by different treatments. (Pooled mean of 3 years)

Treatment	Seasonal cost (₹/ha)	Net seasonal income (₹/ha)	B:C ratio
T_1	178 469	267 527	2.5
T_2	168 537	238 876	2.4
T_3	158 604	223 455	2.4
T_4	178 469	288 757	2.6
T_5	168 534	276 426	2.6
T_6	158 307	239 526	2.5
T_7	158 307	260 324	2.6
T_8	158 307	234 418	2.5
T_9	130 634	192 731	2.5
SE+_		10 566	0.1
CD (P=0.05)		30 040	NS

Selling price of banana (₹/tonne) = 5 633

Net seasonal income and B: C ratio

The maximum net income of ₹ 288 757 ha was obtained in 100% WSF schedule B (T_4) which was on par with T_5 (80% WSF) and T_1 (100% WSF in 18 splits in equal fortnightly splits). The fruit yields increased under application of water soluble fertilizers through drip than straight fertilizers and the additional returns compensated the additional cost of water soluble fertilizers indicating economic feasibility of water soluble fertilizers. The surface method of irrigation recorded lowest net income among all treatments (₹ 192 731). In case of benefit cost ratio treatment T_5 (80% fertigation schedule B) and T_7 (N through drip and P, K through soil) performed higher B: C ratio (2.6) followed by conventional method (2.5). The findings supported the work of Namara *et al.* 2007.

CONCLUSIONS

The significantly higher yield of banana was obtained in T_4 (100% RD apportioned as per growth stages in 18 splits) over all other treatments except T_1 (100% RDF as per schedule A) and T_5 (80% RDF as per growth stages in 18 splits). The N and K moved horizontally up to 45 cm and vertically up to 60 cm and P was moved up to 30 cm horizontally and 40 cm vertically for WSF treatment, which was more than conventional fertilizer. The higher available NPK content in soil after harvest of banana was observed in WSF than conventional fertilizer. Likewise, nutrient uptake by banana leaves, shoot and fruit was also significantly higher under drip fertigation over conventional band placement of fertilizers whereas, among levels 100% fertigation as per growth stages showed higher availability and uptake values.

Hence, from present investigation it is recommended that drip fertigation at 80% of recommended dose of water soluble fertilizers in 18 fortnightly splits as per schedule B (Table 1) is recommended for improved productivity, efficient nutrient use and for higher economical returns from banana cultivated in Vertisols.

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