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Effect of drip *vis-à-vis* surface irrigation on fruit yield, nutrient uptake, water use efficiency and quality of banana in Gangetic plain of West Bengal

Sanjit Pramanik* and S.K. Patra**
Department of Soil and Water Conservation, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur 741 252, West Bengal

ABSTRACT

A field experiment was conducted on a silty clay soil in the Gangetic plain of West Bengal for two consecutive years (2008-09 to 2009-10) to assess the drip *vis-à-vis* surface irrigation under varying levels of NPK fertilizers on fruit yield, nutrient uptake, water use efficiency and quality of banana. The treatments consisted of three drip irrigation levels at 50, 60 and 70% of cumulative pan evaporation (CPE) and three fertigation levels at 50, 60 and 80% of recommended dose of NPK fertilizers including surface irrigation at IW/CPE 1.0 laid out in an augmented factorial complete block design with three replications. The results of the study showed that fruit yield, yield components and quality parameters of banana increased with increasing levels of drip irrigation and fertigation. Maximum fruit yield (46.59 t/ha), yield components and quality attributes was observed in drip irrigation at 60% of CPE with 80% of recommended dose of NPK fertilizers applied through drip system. However, leaf nutrient uptake was relatively higher in drip irrigation at 70% of CPE with 80% of recommended dose of NPK fertilizers. Maximum crop water use efficiency (0.40 t/ha-cm) was registered in drip irrigation at 60% of CPE with water savings of 39.7% over surface irrigation. Thus, application of drip irrigation at 60% of CPE with 80% of recommended dose of NPK fertilizers through drip-fertigation was found to be the best option in obtaining of higher fruit yields, yield components and quality of produce. Alternatively, surface irrigation at IW/CPE 1.0 could also be advocated with almost same efficiency if the initial investment for laying the drip irrigation system is an impediment for the banana growers of the region.

Key words: Banana, drip fertigation, fruit yield, nutrient uptake, fruit quality, water use efficiency.

INTRODUCTION

Banana is an important leading fruit crop in India contributing about 32% of the total fruit production. The crop has high evaporative and nutritional demands and thus requires liberal supply of water and nutrients towards sustainable growth and development (Reddy *et al*., 13). In the Gangetic plain of West Bengal, the resource poor farmers generally follow the conventional surface method of irrigation in banana cultivation which is quite ineffective and renders excessive wastage of water and nutrients in deep percolation below the root zone, besides contributing to waterlogging, poor soil aeration and weed infestation (Raina *et al*., 12).

In the backdrop of water scarcity and nutrient unavailability, drip irrigation is considered the most efficient micro-irrigation technology in India and offers a great promise due to its higher water and nutrient use efficiency against lower amounts of water and nutrient application directly to the crop root zone and escaping moisture stress during critical period (Kumar *et al*., 8). This approach could habitually save as much as 12 to 84% of irrigation water and augment crop productivity by 10 to 55% depending upon the crop, soil and climate variability (Shashidhara *et al*., 14; Pawar and Dingre, 11). In usual method of soil fertilizer application, the nutrient use efficiency by crop is exceedingly low due to many associated factors (Bharambe *et al*., 2). Drip fertigation (application of fertilizer with drip irrigation), on the other hand, has proved its superiority by providing judicious amounts of water and nutrient in the vicinity of root zone matching with the crop requirements, thereby facilitates higher yield and quality of produce (Patel and Rajput, 9). In this perspective, the present study was undertaken to assess the drip irrigation and fertigation levels as compared to the conventional surface irrigation and soil fertilizer application on fruit yield, yield components, leaf nutrient uptake, water use efficiency and quality of banana in the Gangetic plain of West Bengal, India.

MATERIALS AND METHODS

A field experiment was conducted during 2008-09 to 2009-10 at the Mondouri Research Farm of AICRP on Tropical Fruits, Bidhan Chandra Krishi Viswavidyalaya, West Bengal. The site lies at 23.5° N latitude and 80° E longitude with 9.75 m above mean sea level. Soil is of Gangetic alluvium having silty clay in texture (Typic Haplaquepts) with bulk

*Corresponding author's E-mail: sanjit.bckv@gmail.com
**Department of Agricultural Chemistry and Soil Science

density 1.27 Mg/m^3, infiltration rate 11 cm/h, hydraulic conductivity 6.34 cm/h, pH 6.46, EC 0.12 dS/m and organic carbon 4.62 g/kg. Available N, P and K_2O content of surface soil was 156.5, 15.6 and 122.3 kg/ha, respectively. Average monthly maximum and minimum temperature during the cropping seasons varied from 25.4 to 36.8°C and 14.7 to 26.6°C, respectively. The daily pan evaporation ranged between 1.1 to 6.5 mm. and total rainfall was 1,604 mm for plant crop and 1,300 mm for ratoon crop. Planting material of banana cv. Martaman (AAB-Silk) consisted of 2.5-month-old healthy sword suckers weighing around 2.0 kg each were planted at 2.0 m × 2.0 m spacing (2,500 plants/ha) on 25th January, 2008 for plant crop. After harvesting the main planted crop, one sucker per mother clump was allowed as follower for ratoon crop. These suckers were cut back at the height of 20 cm from the ground level to get the uniform cropping and were maintained from 15th March, 2009 up to 24th February, 2010. A buffer strip of 2 m was maintained between the two plots. Every plant received about 10 kilogram of farm yard manure before 7 days of planting. Standard cultural operations and plant protection measures were uniformly followed.

The experiment was arranged in an augmented factorial complete block design (AFCBD) with three replications. There were ten treatments consisted of three drip irrigation schedules at 50 (I_1), 60 (I_2) and 70% (I_3) of cumulative pan evaporation (CPE) and three fertigation schedules at 50 (F_1), 60 (F_2) and 80% (F_3) of recommended N, P and K fertilizers through drip irrigation with one surface irrigation at IW/CPE 1.0 as standard check. A separate lateral line (12 mm) was laid for each treatment. Two drippers per plant were provided on either side of plant at a distance of 30 cm. Discharge rate of emitters was 1.8 lph at a pressure of 1.2 kg/cm^2. The crop water requirement of banana was computed on daily basis using the following equation as suggested by (Shukla *et al.*, 15):

$V = Ep \times Kp \times Kc \times Sc \times Wp$

Where, V = volume of water (litre/day/plant), E_p = open pan evaporation (mm/day), K_p = pan coefficient, K_c = crop coefficient, S_c = crop spacing and W_p = wetted area (1.0). The effective rainfall was calculated by balance sheet method from the actual rainfall received and was used for daily water requirement of crop. The crop coefficient values used for different crop stages were computed based on the existing relative humidity and wind velocity (Doorenbos *et al.*, 4). The pan coefficient value was 0.7 as suggested for USDA class A pan. The irrigation frequency by drip system was once in every 3 days in summer and 5 days in winter based on 50, 60 and 70% of CPE. In surface method of irrigation, water was applied at IW/CPE 1.0 in 38 splits at 7-day interval with 50 mm depth per irrigation in basin.

The recommended dose of N, P and K fertilizers were 250, 50 and 300 g/plant/year and applied through urea (46% N), phosphoric acid (31.7% P) and muriate of potash (60% K_2O), respectively. Solid and liquid fertilizers as per schedules dissolved in an overhead tank connected to a bore well delivering good quality irrigation water controlled through a valve. This fertilizer-water mixture was injected into the drip system through a fertilizer injector at 3-5 day interval starting from 45 days after planting to 210 days. The concentration of nutrient solution passing through irrigation water was around 1.1 to 1.7%. Drip fertigation was scheduled in 30 splits each commencing from 9th to 38th week for main and ratoon crops. In surface method of irrigation, 100% recommended dose of N, P and K fertilizers were applied in soil in 4 splits at 2, 5, 7 and 9 months after planting of main and ratoon crops.

The fruit yield, bunch weight and other bunch traits on maturity (usually 120 days after flowering) were recorded at harvesting stage. Total soluble solids (TSS) were determined using a hand refractometer from 10 randomly selected ripen fruits. The total sugars and reducing sugar contents of fruits were determined by the standard methods (AOAC, 1). The titrable acidity as well as ascorbic acid content of fruits was also estimated by suitable methods (AOAC, 1). The peel: pulp ratio was estimated from the pulp and peel weights of 10 ripe fruits from each treatment. The water use efficiency was computed by dividing fruit yield with total water use by the crop. The N, P and K uptake by banana leaves was calculated from the nutrient concentration and dry matter of leaves. The data were subjected to statistical analysis such as analysis of variance (ANOVA) using software packages of MS Excel and SPSS 12.0 version.

RESULTS AND DISCUSSION

The fruit yield and yield contributing parameters was significantly influenced by varying levels of drip irrigation and fertigation (Table 1). Among three irrigation levels, drip irrigation at 60% of CPE recorded the highest yield of 41.17 t/ha, which was superior to drip irrigation at 50 and 70% of CPE. This improvement in yield was ascribed to the significant increase in bunch length, hands/bunch, finger/bunch and bunch weight. Further increase in evaporation replenishment resulted in a significant decrease in fruit yield. These findings are in agreement with the report of Hegde and Srinivas (5). Similarly, among the fertigation levels, the fruit yield consistently and significantly increased with increase in NPK

Table 1. Yield and yield components of banana as influenced by irrigation methods and drip fertigation levels (pooled data of two years).

Treatment	Bunch length (cm)	Finger length (cm)	Finger girth (cm)	Hand/ bunch	Finger/ bunch	Finger wt. (g)	Bunch wt. (kg)	Fruit yield (t/ha)
Irrigation								
I_1	48.03	12.96	11.50	7.33	111.45	123.68	13.67	34.17
I_2	53.82	14.63	12.75	8.52	125.66	136.25	16.47	41.17
I_3	52.72	14.63	12.80	8.48	128.12	136.73	15.90	39.74
CD at 5%	0.69	0.23	0.17	0.10	2.36	2.13	0.23	0.59
Fertilizer								
F_1	44.79	12.93	11.51	7.10	102.98	118.46	13.00	32.48
F_2	53.33	14.27	12.63	8.45	129.32	136.69	16.12	40.31
F_3	56.44	15.02	12.91	8.79	132.93	141.51	16.91	42.28
CD at 5%	0.69	0.23	0.17	0.10	2.36	2.13	0.23	0.59
Irrigation × Fertilizer								
I_1F_1	42.65	12.30	10.57	6.30	86.69	107.58	11.00	27.50
I_1F_2	49.41	12.78	11.74	7.61	120.23	128.71	14.74	36.84
I_1F_3	52.03	13.81	12.20	8.10	127.44	134.76	15.26	38.16
I_2F_1	45.13	12.70	11.52	7.18	101.96	118.99	13.31	33.24
I_2F_2	56.21	15.21	13.26	9.14	137.47	142.75	17.47	43.68
I_2F_3	60.11	15.97	13.48	9.26	137.55	147.01	18.64	46.59
I_3F_1	46.60	13.80	12.45	7.82	120.29	128.80	14.68	36.71
I_3F_2	54.37	14.83	12.89	8.58	130.26	138.62	16.17	40.41
I_3F_3	57.18	15.27	13.07	9.03	133.81	142.76	16.84	42.09
CD at 5%	1.20	0.40	0.29	0.18	4.08	3.69	0.41	1.02
Mean drip	51.52	14.07	12.35	8.11	121.74	132.21	15.34	38.36
Surface	46.37	13.96	12.38	7.92	118.14	121.41	14.39	35.96
CD at 5%	1.27	NS	NS	0.19	NS	3.89	0.43	1.07

NS = not significant

fertigation up to 80% of recommended dose of fertilizers. This increase in yield was largely due to higher nutrient absorption by crop as consequence of timely application of judicious amounts of nutrients directly to the crop root zone (Kavino *et al*., 6; Dahiwalkar *et al*., 3; Shashidhara *et al*., 14), which subsequently reflected in higher bunch weight, more number of hands/bunch, higher fingers/bunch and higher finger weight (Pawar and Dingre, 11). The interaction between drip irrigation and NPK fertigation on fruit yield showed that maximum yield of 46.59 t/ ha was obtained with drip irrigation at 60% of CPE with 80% of recommended dose of NPK fertilizers and were superior to best of the treatment combinations. This higher yield might be due to optimum supply of irrigation and fertilizers matching with the crop water and nutrient requirements maintained throughout the growing period. The drip irrigation overall registered significantly the higher fruit yield of 38.36 t/ha as compared to surface irrigation (35.96 t/ha). This increase in yield under drip irrigation was mainly due to significant increase in yield enhancing parameters due to maintenance of the soil near field capacity throughout the growth period in the active root zone leading to low soil suction, which thereby facilitated the better water utilization, higher nutrients uptake and excellent maintenance of soil-water-air relationship with higher oxygen concentration in the root zone (Raina *et al*., 12). Surface irrigation, on the other hand, resulted in considerable wastage of water in from of runoff and deep percolation below root zone and invited a chain of undesirable hazards such as leaching loss of available nutrients, waterlogging, poor soil aeration and weed infestation leading to the

declined crop yield. These results are in accordance with the findings of Hegde and Srinivas (5).

Average depth of irrigation water applied during the cropping seasons through drip at 50, 60 and 70% of CPE was 220.4, 264.5 and 308.6 mm, respectively; whereas the corresponding figures for surface irrigation was 950 mm (Table 2). The average effective rainfall and soil moisture contribution were 762.3 and 14.5 mm, respectively. Water use efficiency was calculated as the ratio of fruit yield and total water used including irrigation water applied, effective rainfall and soil moisture contribution. Accordingly, total water used by crop was 997.2, 1041.3, 1085.4 mm through drip irrigation at 50, 60 and 70% of CPE, respectively and 1726.8 mm for surface irrigation. The results showed that maximum water use efficiency of 0.40 t/ha-cm was registered in drip irrigation at 60% of CPE, while minimum of 0.21 t/ha-cm was in surface irrigation. On an average, about 39.85% of water could be saved with drip irrigation over surface irrigation. The higher water use efficiency and water saving in drip irrigation as compared with surface irrigation was the result of precise amount of water delivery directly in the crop root zone at right time and avoidance of water losses in deep percolation and surface runoff (Bharambe *et al*., 2).

The uptake of N, P and K by banana leaf was significantly influenced by irrigation methods and drip fertigation levels at vegetative, shooting and harvest stages of crop (Table 3). There was consistent and significant increase in nutrient uptake with the concomitant increase in the level of drip irrigation up to 70% of CPE or drip fertigation up to 80% of the recommended dose of fertilizer (RDF) at all growth stages. The interaction between drip irrigation and fertigation revealed that drip irrigation at 70% of CPE with 80% of RDF registered significantly the maximum leaf nutrient uptake as compared to the remaining treatment combinations. It is discernible to the fact that relatively the higher nutrient uptake, regardless of the levels of drip irrigation and fertigation, was observed at vegetative and shooting stages than in harvesting stage. Drip irrigation, on an average, resulted in higher uptake of N, P and K in leaves at all growth stages over surface irrigation. These corroborated the findings of Dahiwalkar *et al.* (3) who reported that leaf N concentration increased with the increase in fertilizer and moisture levels through drip irrigation and that too in shooting stage than in vegetative and harvesting stages of crop.

The fruit quality parameters were influenced by the drip irrigation and fertigation levels (Table 4). Relatively higher pulp and peel content, TSS, non-reducing sugar, total sugars, sugar/acid ratio and higher acidity was observed in drip irrigation at 70% of CPE, whereas, higher reducing sugar and ascorbic acid with lower acidity was recorded in drip irrigation at 60% of CPE. Similarly, application of 80% of RDF promoted all these quality parameters as compared with other fertigation levels. Kumar and Pande (7) also found the highest TSS, total sugars and reducing sugar content with 70% of RDF schedule at the vegetative, flowering and fruit development to maturity stage of the crop. The combination of drip irrigation at 60% of CPE with 80% of RDF showed maximum peel content (30.63 g), TSS (23.75°Brix), reducing sugar (6.59) and ascorbic acid, whereas drip irrigation at 70% of CPE with 80% of RDF recorded the maximum non-reducing sugar (9.72%), total sugars (16.10%) and higher acidity (0.43%). This is in conformity with the findings of Kavino *et al.* (6) who observed that the lower level of irrigation water but higher level of fertilizer nutrients was beneficial in increasing the TSS, reducing sugars and total sugars in ripe fruits. The increase in total sugars during banana ripening can be attributed to the hydrolysis of starch to sugar, thus, leading to the higher TSS (Patel *et al.*, 10). All these quality attributes, on an average, were relatively higher in surface irrigation than in drip irrigation with some exceptions. Pawar and Dingre (11) also recorded the

Table 2. Water use and water use efficiency of banana as influenced by irrigation methods at different evaporation replenishment (pooled data of two years).

Evaporation replenishment (%)	Effective rainfall (mm)	Soil moisture contribution (mm)	Irrigation water (mm)	Total water use (mm)	Fruit yield (t/ha)	Water use efficiency (t/ha-cm)	Water saving (%)
Drip 50 CPE	762.3	14.5	220.4	997.2	34.17	0.35	42.2
Drip 60 CPE	762.3	14.5	264.5	1041.3	41.17	0.40	39.7
Drip 70 CPE	762.3	14.5	308.6	1085.4	39.74	0.37	37.1
Drip overall	762.3	14.5	264.5	1041.3	38.36	0.37	39.7
Surface*	762.3	14.5	950.0	1726.8	35.96	0.21	-

*Surface irrigation water applied at IW/CPE 1.0 with 5 cm depth

Table 3. Nutrient uptake by banana leaf as influenced by irrigation methods and drip fertigation levels (pooled data of two years).

Treatment	N (%)			P (%)			K (%)		
	Vegetative	Shooting	Harvest	Vegetative	Shooting	Harvest	Vegetative	Shooting	Harvest
Irrigation									
I_1	2.14	2.31	1.30	0.33	0.40	0.20	2.52	2.73	2.05
I_2	2.29	2.46	1.40	0.37	0.44	0.24	2.58	2.85	2.11
I_3	2.41	2.61	1.48	0.40	0.50	0.27	2.68	2.97	2.16
CD at 5%	0.02	0.03	0.03	0.01	0.03	0.02	0.04	0.07	0.04
Fertilizer									
F_1	1.83	2.01	1.17	0.25	0.32	0.15	2.31	2.48	1.88
F_2	2.35	2.51	1.36	0.35	0.44	0.23	2.61	2.85	2.13
F_3	2.66	2.85	1.66	0.48	0.59	0.33	2.86	3.22	2.31
CD at 5%	0.02	0.03	0.03	0.01	0.03	0.02	0.04	0.07	0.04
Irrigation × Fertilizer									
I_1F_1	1.64	1.85	1.13	0.23	0.25	0.12	2.28	2.42	1.83
I_1F_2	2.23	2.35	1.29	0.33	0.41	0.19	2.53	2.68	2.07
I_1F_3	2.55	2.75	1.50	0.43	0.53	0.30	2.76	3.09	2.25
I_2F_1	1.84	1.98	1.18	0.26	0.34	0.15	2.28	2.44	1.86
I_2F_2	2.36	2.54	1.34	0.35	0.41	0.24	2.59	2.88	2.17
I_2F_3	2.67	2.85	1.67	0.49	0.59	0.32	2.88	3.23	2.31
I_3F_1	2.01	2.20	1.22	0.28	0.37	0.17	2.38	2.59	1.94
I_3F_2	2.45	2.65	1.43	0.38	0.49	0.26	2.72	2.99	2.16
I_3F_3	2.75	2.97	1.80	0.53	0.64	0.37	2.96	3.33	2.37
CD at 5%	0.04	NS	0.05	NS	NS	NS	NS	NS	NS
Mean drip	2.28	2.46	1.40	0.37	0.45	0.24	2.60	2.85	2.11
Surface	2.55	2.63	1.50	0.43	0.49	0.29	2.71	2.90	2.14
CD at 5%	0.04	0.46	0.08	1.33	1.28	0.33	0.06	NS	NS

NS = not significant

higher TSS in the pulp under conventional surface irrigation as compared to drip fertigation.

It can be concluded that drip fertigation with precise amounts of water and fertilizer nutrients application matching with the crop requirements is likely to have enhanced the fruit yield, yield components, leaf nutrient uptake and quality parameters with maximum water use efficiency and water saving of banana crop grown in the Gangetic plain of West Bengal, India. The results showed that application of drip irrigation at 60% of CPE with 80% of recommended NPK dose through fertigation was found to be the best option in promoting maximum fruit yield and quality characteristics of banana. The leaf nutrient uptake appeared to be higher in drip irrigation at 70% of CPE coupled with 80% of recommended NPK through fertigation. Crop water use efficiency was found maximum in drip irrigation at 60% of CPE with 39.7% of water saving. Alternatively, surface irrigation at IW/CPE 1.0 could also be advocated if the initial investment for laying the drip irrigation system is an impediment for the resource poor banana growers of the region.

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Table 4. Fruit quality of banana as influenced by irrigation methods and drip fertigation levels (pooled data of two years).

Treatment	Pulp wt. (g)	Peel wt. (g)	Total soluble solids (°Brix)	Reducing sugar (%)	Non-reducing sugar (%)	Total sugars (%)	Acidity (%)	Sugar: acid ratio	Ascorbic acid (mg/ 100 g pulp)
Irrigation									
I_1	100.16	23.86	21.11	5.73	9.10	14.83	0.36	41.15	5.04
I_2	108.98	27.47	22.54	6.22	9.07	15.29	0.39	39.77	5.55
I_3	108.45	28.22	22.88	6.15	9.35	15.50	0.41	37.74	5.40
CD at 5%	1.39	0.94	0.20	0.06	0.12	0.12	0.01	0.90	0.13
Fertilizer									
F_1	96.52	22.06	20.71	5.60	9.09	14.70	0.35	42.16	4.93
F_2	108.51	28.37	22.56	6.16	9.09	15.25	0.39	38.88	5.45
F_3	112.55	29.12	23.27	6.35	9.33	15.68	0.42	37.61	5.61
CD at 5%	1.39	0.94	0.20	0.06	0.12	0.12	0.01	0.90	0.13
Irrigation × Fertilizer									
I_1F_1	88.80	19.28	19.35	5.33	9.07	14.39	0.32	44.69	4.68
I_1F_2	103.07	26.02	21.30	5.79	9.13	14.92	0.37	40.44	5.13
I_1F_3	108.61	26.28	22.69	6.07	9.09	15.16	0.40	38.31	5.32
I_2F_1	97.69	21.82	20.46	5.64	9.01	14.65	0.34	42.86	5.00
I_2F_2	112.87	29.95	23.42	6.44	9.02	15.46	0.40	39.13	5.66
I_2F_3	116.37	30.63	23.75	6.59	9.18	15.77	0.42	37.31	6.00
I_3F_1	103.06	25.08	22.30	5.84	9.21	15.04	0.39	38.92	5.10
I_3F_2	109.60	29.14	22.96	6.24	9.11	15.36	0.42	37.08	5.56
I_3F_3	112.69	30.45	23.38	6.38	9.72	16.10	0.43	37.21	5.53
CD at 5%	2.41	NS	0.35	0.11	0.20	0.21	NS	NS	NS
Mean drip	105.85	26.52	22.18	6.04	9.17	15.21	0.39	39.55	5.33
Surface	98.64	25.59	22.63	6.04	9.22	15.26	0.43	35.91	5.40
CD at 5%	2.54	NS	0.37	NS	NS	NS	0.02	1.64	NS

NS = not significant

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