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

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ABSTRACT

A field study was conducted during 2008-2009 to 2009-2010 in the Gangetic Plain of West Bengal to assess three drip irrigation schedules at 50, 60 and 70% of cumulative pan evaporation (CPE) and three drip fertigation schedules at 50, 60 and 80% of recommended NPK fertilizers with inclusion of conventional surface irrigation on banana cv. Martaman (AAB, Silk). The experiment was laid out in augmented factorial complete block design with three replications. The coefficient of variation of the emitter discharge used in drip irrigation system was 0.062 and 0.088 in 2008-09 and 2009-10, respectively. The experimental results showed that there was considerable improvement in plant height, pseudostem girth, leaf area, leaf area index and leaf number with drip irrigation at 70% of CPE compared to conventional surface irrigation. Maximum fruit yield and water use efficiency (WUE) in main and ratoon crop was obtained with drip irrigation at 60% CPE with 80% of recommended NPK fertilizers. WUE of crops increased progressively with concomitant increase in the levels of drip fertigation. Drip irrigation, as a whole, registered the higher fruit yield and WUE with savings of 38.3 to 41.5% of water compared to surface irrigation. Seasonal moisture distribution efficiency in soil towards horizontal and vertical directions through drip system was uniform and relatively much higher than the surface irrigation system.

Key words: Banana, drip fertigation, water distribution efficiency, water use efficiency.

INTRODUCTION

Banana is the leading fruit crop in India contributing 32% of total fruit production. The water and nutrient requirements of the crop is relatively higher than any other fruit crops. The curtailment of these two vital resources limit its growth and productivity (Reddy *et al*., 13). Farmers in the Gangetic alluvial plains generally follow the conventional surface method of irrigation in banana cultivation which is quite inefficient and renders excessive losses of water through runoff and deep percolation beyond the crop root zone. Water is going to be a critical input in agriculture in view of competitive demands from domestic and industrial sectors (Hedge and Srinivas, 5). The need of the hour is to maximize production per drop of water. Drip irrigation is undoubtedly the most efficient and offers a great promise due to its higher water and nutrient use efficiency by crops against lower amounts of water and nutrient applied (Kumar *et al*., 6). This system could save about 12-84% of irrigation water and increase crop productivity by 10-55% depending upon the soil and climate (Sharma and Kumar, 14; Pawar and Dingre, 10). Similarly, drip fertigation (application of fertilizers with drip irrigation) also proved its superiority over conventional method of fertilizer application by way of timely application of water and nutrients in small quantities in the vicinity of root zone matching with the crop requirements, thereby leading to higher yield and quality of produce (Patel and Rajput, 9). It also enhances the nutrient use efficiency of crop by reducing leaching losses (Raina *et al*., 11). In this backdrop, the main objective of the study was to assess the drip fertigation at variable soil moisture regimes as compared to surface irrigation on fruit yield, water use and distribution efficiency of banana in the Gangetic plain of West Bengal.

MATERIALS AND METHODS

The field experiments were conducted during the period 2008-2009 to 2009-2010 at the Research Farm of AICRP on Tropical Fruits, Mondouri, BCKV, Mohanpur, West Bengal. The farm is located at an altitude of 9.75 m above mean sea level and is intersected by 23.5°N latitude and 80°E longitude. The mean monthly maximum and minimum temperatures varied from 25.4 to 36.8°C and 14.7 to 26.6°C, respectively. Soil is Gangetic alluvium with silty clay in texture (Typic Haplaquepts). Physical, chemical and hydro-physical properties of the experimental soil are furnished in Table 1. The daily pan evaporation during the crop growing seasons was 1.1 to 6.5 mm. Total

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Table 1. Physical, chemical and hydro-physical properties of the experimental soil site.

Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)	Bulk density (Mgm^{-3})	Hydraulic conductivity (cm hr^{-1})	WHC (%)	p^H (1:2)	EC (dS m^{-1})	Organic carbon (%)	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
0-15	10.1	40.0	49.9	1.27	6.34	50.2	6.46	0.10	0.46	156.5	35.7	147.4
15-30	10.5	41.3	48.2	1.31	4.86	49.1	6.38	0.08	0.40	135.4	28.4	129.1
30-45	12.2	42.1	45.7	1.42	3.49	48.2	6.28	0.09	0.36	117.6	22.4	108.7
45-60	14.3	40.8	44.9	1.46	2.30	46.8	6.30	0.07	0.31	96.3	21.1	102.9

amount of rainfall received was 1,604 mm for main crop and 1,300 mm for ratoon crop. Planting material of banana cv. Martaman (AAB, Silk) of 2.5-month-old healthy sword suckers weighing around 2.0 kg each were planted at 2 m x 2 m spacing (2,500 plants ha^{-1}) on 25th January, 2008 for main crop and its ratoon was maintained from 15th March, 2009 up to 25th February, 2010. A buffer strip of 2 m was maintained between the two plots. Every plant received about 10 kg of FYM 7 days before planting. Standard cultural and adequate plant protection measures were followed uniformly. The data were subjected to statistical analysis such as analysis of variance using software SPSS 12.0 version. Statistical significance between means of individual treatments was assessed using Fisher's least significant difference (LSD) at P <0.05 level.

The experiment was arranged in augmented factorial complete block design 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 NPK fertilizers (RDF) through drip irrigation with one conventional surface irrigation method at IW/CPE 1.0 as standard check. A separate lateral line (12 mm) was laid for each treatment. Two drippers for each plant with a discharge rate of 1.8 lph were provided on either side of plant at a distance of 30 cm. The operating pressure of drip system was 1.2 kg cm^{-2}.

The crop water requirement of banana was computed on daily basis using the equation as suggested by (Shukla *et al.*, 15). 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 factor values used for different crop stages were computed based on the existing relative humidity and wind velocity (Doorenbos *et al.*, 4). The pan factor 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 evaporation replenishment. In surface method, irrigation water was applied at 100% of IW/CPE in 30 splits scheduled at 7-day interval with 50 mm depth per irrigation in basin. The emission uniformity of water application was carried out at the start of the season. The discharge from drippers at selected laterals was measured for a specified period and was computed using the equation given by Nakayama and Bucks (7).

The recommended dose of N, P and K fertilizers was 250, 50 and 300 g $plant^{-1}$ $year^{-1}$ applied through urea (46% N), phosphoric acid (31.68% P) and muriate of potash (60% K_2O), respectively. Solid and liquid fertilizers as per schedule were 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%. Scheduling of drip fertigation was given in 30 splits each from 9th to 38th week for main and ratoon crops. In surface irrigation, 100% recommended dose of N, P and K fertilizers were applied in soil in 4 equal splits at 2, 5, 7 and 9 months after planting of main and ratoon crops.

Soil moisture contents were monitored periodically just before and after 3-5 days of every irrigation event during growth of main and ratoon crop by gravimetric method (oven-dry basis) at 0, 15, 30, 45 cm distances from dripper and 0-15, 15-30, 30-45 and 45-60 cm soil depth. These bulk data from both crops was converted to monthly average, which was then bifurcated into winter (November, 2008 to February, 2009) and summer (March, 2009 to June, 2009) season. The distribution efficiency of soil water along the drip run was estimated using the equation: $Ed = 100 (1-\bar{y}/d)$, where Ed = water distribution efficiency in percent; $\bar{y}$ = average numerical deviation in depth of water stored in root zone soil from the average depth of water stored during irrigation and d = average depth of water stored during irrigation. Water use efficiency of crop was computed by dividing fruit yield with total water used including effective rainfall, profile moisture contribution and irrigation water applied.

RESULTS AND DISCUSSION

The results pertaining to the uniformity of drip irrigation system was found to be 91.3% for the first year and 90.7% for the second year of experimentation (Table 2). The higher values of emission uniformity with lower coefficients of variation (0.062-0.088) indicated the excellent performance of drip system in supplying irrigation water uniformly during the two cropping seasons. These findings are in agreement with the observations of Kumar *et al.* (6) who recorded the emission uniformity coefficients of 90-93% for the drip irrigation system.

Different biometrical parameters such as plant height, pseudostem girth, leaf area, leaf area index (LAI) and leaf number were measured for both main and ratoon crops. Maximum plant height, pseudostem girth, leaf area, LAI and leaf number was observed at shooting stage in both main crop and ratoon crop with irrigation at 70% CPE, which differed significantly from other irrigation levels under consideration (Table 3). Among

Table 2. Emission uniformity of in-line surface drip system and coefficient of variation (CV).

Year	Emission uniformity (%)	Coefficient of variation (CV)
2008-09	91.3	0.062
2009-10	90.7	0.088

Table 3. Effect of different levels of drip fertigation on growth attributes of banana at shooting stage.

Treatment	Plant height (cm)		Pseudostem girth (cm)		Leaf area index (LAI)		Leaf area (m^2)		Leaf number	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop
Irrigation										
I_1 (CPE 50)	285.66	290.24	67.78	69.99	2.75	2.38	11.00	9.51	13.30	12.58
I_2 (CPE 60)	291.90	296.84	69.59	72.05	2.92	2.6	11.68	10.40	13.55	12.99
I_3 (CPE 70)	295.09	300.76	71.42	73.62	3.09	2.79	12.37	11.16	13.80	13.48
$CD_{0.05}$	0.53	0.92	0.35	0.52	0.06	0.08	0.23	0.34	0.13	0.22
Fertilizer										
F_1 (50% RDF)	280.29	284.43	65.31	67.13	2.41	2.15	9.63	8.59	12.82	12.31
F_2 (60% RDF)	291.14	296.01	69.37	71.68	2.93	2.62	11.73	10.47	13.52	13.20
F_3 (80% RDF)	301.20	307.39	74.11	76.84	3.42	3.00	13.69	12.01	14.31	13.53
$CD_{0.05}$	0.53	0.92	0.35	0.52	0.06	0.08	0.23	0.34	0.13	0.22
Irrigation x Fertilizer										
I_1F_1	272.94	276.66	63.03	65.11	2.23	1.96	8.93	7.83	12.54	12.03
I_1F_2	287.74	291.92	67.90	70.00	2.76	2.40	11.03	9.59	13.28	12.55
I_1F_3	296.31	302.14	72.41	74.87	3.26	2.78	13.03	11.11	14.08	13.16
I_2F_1	281.84	286.69	65.72	67.59	2.41	2.16	9.64	8.64	12.84	12.24
I_2F_2	292.06	296.00	69.18	71.59	2.94	2.64	11.78	10.54	13.55	13.23
I_2F_3	301.8	307.84	73.88	76.98	3.41	3.00	13.63	12.01	14.26	13.49
I_3F_1	286.11	289.95	67.19	68.69	2.58	2.32	10.34	9.3	13.08	12.67
I_3F_2	293.64	300.12	71.04	73.47	3.09	2.82	12.37	11.27	13.73	13.82
I_3F_3	305.51	312.2	76.05	78.69	3.60	3.23	14.4	12.91	14.6	13.95
$CD_{0.05}$	0.92	1.60	0.61	NS	NS	NS	NS	NS	NS	NS
Drip overall	290.88	295.95	69.60	71.88	2.92	2.59	11.68	10.36	13.55	13.01
Surface	294.26	300.11	71.35	73.65	3.16	2.78	12.62	11.14	13.85	13.13
$CD_{0.05}$	0.58	1.69	0.65	0.95	0.11	0.15	0.42	0.62	0.23	NS

NS = Non significant

fertilizer levels, 80% of RDF significantly produced the higher growth attributes in main as well as ratoon crop. The interaction between irrigation and fertilizer schedules showed that except the plant height in main and ratoon crop and pseudostem girth in main crop, none of the growth attributes did exhibit any significant difference. However, drip fertigation scheduled at 70% CPE with 80% RDF demonstrated the higher growth attributes for both main and ratoon crop, whereas the lower attributes was noticed under drip fertigation scheduling at 50% CPE with 50% RDF. But overall performance of drip fertigation regardless of irrigation and fertilizer levels in promoting growth and yield characteristics of banana was inferior to conventional surface irrigation with 100% RDF application in soil. However, drip irrigation at higher evaporation replenishment rate in conjunction with higher fertigation level resulted in maximum contribution on growth attributes in comparison with conventional method of irrigation. This improved growth could be attributed to regular and timely supply on required water and nutrients through drip fertigation which might have enhanced the uptake of the nutrients (Srinivas *et al*., 16). The maintenance of favourable soil moisture and readily availability of nutrients in the active root zone and consequent their accumulation leading to increased growth parameters of banana plant with drip fertigation system have also been reported by early workers (Dahiwalkar *et al*., 3; Hegde and Srinivas, 5).

The different levels of drip irrigation and drip-fertigation had pronounced effects on the fruit yield of main and ratoon crops (Table 4). Among

Table 4. Different levels of irrigation and drip fertigation on fruit yield and water use efficiency (WUE) of banana.

Treatment	Fruit yield ($t\ ha^{-1}$)		Total water use (cm)		WUE ($t\ ha^{-1}\ cm^{-1}$)	
	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop
Irrigation						
I_1 (CPE 50)	35.33	33.00	113.51	85.93	0.31	0.38
I_2 (CPE 60)	42.86	39.48	119.04	89.21	0.36	0.44
I_3 (CPE 70)	41.40	38.07	124.59	92.48	0.33	0.41
$CD_{0.05}$	0.85	1.22	-	-	-	-
Fertilizer						
F_1 (50% RDF)	33.75	31.21	119.04	89.21	0.28	0.35
F_2 (60% RDF)	41.71	38.91	119.04	89.21	0.35	0.43
F_3 (80% RDF)	44.13	40.43	119.04	89.21	0.37	0.45
$CD_{0.05}$	0.85	1.22	-	-	-	-
Irrigation x Fertilizer						
$I_1 F_1$	29.25	25.76	113.51	85.93	0.26	0.30
$I_1 F_2$	37.59	36.09	113.51	85.93	0.33	0.42
$I_1 F_3$	39.17	37.15	113.51	85.93	0.34	0.43
$I_2 F_1$	34.07	32.40	119.04	89.21	0.29	0.36
$I_2 F_2$	45.37	41.99	119.04	89.21	0.38	0.47
$I_2 F_3$	49.14	44.04	119.04	89.21	0.41	0.49
$I_3 F_1$	37.94	35.48	124.59	92.48	0.30	0.38
$I_3 F_2$	42.18	38.64	124.59	92.48	0.33	0.42
$I_3 F_3$	44.09	40.10	124.59	92.48	0.35	0.43
$CD_{0.05}$	1.48	2.12	-	-	-	-
Drip overall	39.87	36.85	119.04	89.21	0.33	0.41
Surface	37.09	34.84	192.81	152.55	0.19	0.22
$CD_{0.05}$	1.56	1.82	-	-	-	-

three irrigation levels, drip irrigation at 60% of CPE registered the highest yield of 42.86 t ha^{-1} for main crop and 39.48 t ha^{-1} for ratoon crop and was superior to other two levels of drip irrigation. Further increase in evaporation replenishment resulted in a significant decrease in yield of both crops. This improvement in fruit yield was ascribed to the significant increase in hands $bunch^{-1}$, bunch weight and finger weight (Hegde and Srinivas, 5). Similarly, among three levels of drip-fertigation, the fruit yield consistently and significantly increased up to 80% of recommended NPK fertilizers. This increase in yield was largely due to higher nutrient uptake of crop due to timely application of judicious amounts of nutrients directly to the root zone with simultaneous decrease in N and K losses through leaching and deep percolation (Pawar and Dingre, 13), which in turn influenced the yield and yield contributing parameters. The interaction between drip irrigation and NPK fertigation on fruit yields were significant. Maximum yield of 49.14 t ha^{-1} for main crop and 44.04 t ha^{-1} for ratoon crop was recorded with drip irrigation at 60% of CPE along with 80% of recommended NPK fertilizers and were found significantly superior to the remaining levels of irrigation-fertilizers combinations. This higher yield might be due to optimum supply of irrigation and nutrients through drip system matching with crop water-nutrient requirements maintained throughout the growth period. As a whole, drip irrigation resulted in significantly the higher fruit yield of 39.87 t ha^{-1} for main crop and 36.85 t ha^{-1} for ratoon crop over the conventional method of irrigation which gave fruit yield of 37.09 and 34.84 t ha^{-1} for main and ratoon crops, respectively. This improvement in yields even in deficit irrigation regimes under drip system was due to significant increase in growth and yield contributing parameters caused by better water utilization, higher uptake of plant nutrients and excellent maintenance of soil-water-air continuum with higher oxygen concentration in the root zone (Raina *et al.*, 11, 12). Besides, drip irrigation may also facilitate to maintain the soil moisture at field capacity especially in the crop root zone which might have influenced the root CEC and thereby increased the nutrient uptake leading to higher production (Bangar and Chaudhari, 1). The traditional surface irrigation, on the other hand, resulted in considerable wastage of water in runoff and deep percolation below root zone and might invite a chain of undesirable hazards such as leaching loss of available plant nutrients, water congestion with poor soil aeration and weed infestation leading to the declined fruit yield (Patel and Rajput, 8). Another possible reason of low yield in surface irrigation might be that crop had to undergo water stress between two irrigations (Pawar and Dingre, 13). It is interesting to note that the fruit yield of ratoon crop was relatively lower than that of main crop regardless of different irrigation and fertigation levels. These results are in accordance with the findings of Hegde and Srinivas (5).

During the cropping seasons of 2008-2009 and 2009-2010, the depth of irrigation water applied through drip irrigation at 50, 60 and 70% of CPE was 277.0, 332.3 and 387.8 mm and 163.8, 196.6 and 229.3 mm for main and ratoon crops, respectively, whereas the corresponding figures through surface irrigation was 1070 and 830 mm, respectively (Table 5). The effective rainfall and the soil profile moisture contribution were 842.1 and 16.0 mm and 682.5 and 13.0 mm for main and ratoon crops, respectively. Water use efficiency (WUE) was calculated as the ratio of fruit yield and total water used including irrigation water applied, effective rainfall and soil profile moisture contribution. Accordingly, the total water used by the main and ratoon crops was 1135.1, 1190.4, 1245.9 mm and 859.3, 892.1, 924.8 mm through drip irrigation at 50, 60 and 70% of CPE, respectively and the corresponding figures

Table 5. Water use by main and ratoon crops of banana as affected by irrigation methods and evaporation replenishment.

Evaporation replenishment (%)	Effective rainfall (mm)		Soil profile contribution (mm)		Depth of irrigation water (mm)		Total water use (mm)	
	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop
Drip 50 CPE	842.1	682.5	16.0	13.0	277.0	163.8	1135.1	859.3
Drip 60 CPE	842.1	682.5	16.0	13.0	332.3	196.6	1190.4	892.1
Drip 70 CPE	842.1	682.5	16.0	13.0	387.8	229.3	1245.9	924.8
Drip overall	842.1	682.5	16.0	13.0	332.3	196.6	1190.4	892.1
Surface*	842.1	682.5	16.0	13.0	1070.0	830.0	1928.1	1525.5

*Irrigation water applied at IW/ CPE 1.0 with 5 cm depth for surface irrigation was 1928.1 and 1525.5 mm. It is evident from Table 4 that drip irrigation at 60% of CPE recorded the higher WUE as compared to that of drip irrigation at 50 and 70% of CPE. Similarly, WUE increased progressively with the concomitant increase in drip-fertigation levels and accordingly, the higher value of WUE was registered with 80% of RDF administered through drip irrigation. The interactions between drip irrigation and fertigation revealed that maximum water use efficiency was registered in drip irrigation at 60% of CPE with 80% of RDF (0.41 and 0.49 t ha^{-1} mm^{-1} for main and ratoon crops, respectively) followed by drip irrigation at 60% of CPE with 60% of RDF (0.38 and 0.47 t ha^{-1} mm^{-1} for main and ratoon crops, respectively). The higher water use efficiency in drip irrigation (0.33-0.41 t ha^{-1} cm^{-1}) as compared to surface irrigation (0.19-0.22 t ha^{-1} cm^{-1}) was the result of precise and measured quantity of water delivery directly into the individual plant root zone without wetting the entire area. Averaged over all irrigation levels, there was 38.2 and 41.5% of water savings with drip irrigation over conventional method of irrigation for main and ratoon crops, respectively. The saving of water combined with higher yield under drip irrigation are the reasons for increased WUE. On the contrary, the plants under surface irrigation showed low WUE, because the increased amount of water applied did not result in corresponding increase in yield. These are in agreement with the findings of Bharambe *et al*. (2) that drip system can increase the fruit yield of banana in addition to water savings.

The soil water distribution efficiency in drip irrigation at 50, 60 and 70% of CPE and conventional surface irrigation during winter and summer season of crop growing period is presented in Table 6. The results indicated that the seasonal downward movement of irrigation water was more than its lateral movement and the water distribution efficiency was higher near the dripper, thereafter decreased consistently with the increase in distance both horizontally and vertically. In other words, the vertical and horizontal moisture distribution pattern was considerably higher at surface layer, thereafter it decreased with the increase in soil depth. The values regardless of drip irrigation levels and seasons ranged from 98.2 to 75.9%. The plausible reason for higher flow of water from dripper towards vertical direction than in horizontal direction might be due to predominant role of gravitational force over capillary force. Thus, the drip system of irrigation facilitated to decrease the soil moisture loss by way of evaporation and could save more water in the subsurface soil layers for subsequent plant use. On the contrary, in conventional surface irrigation system, the moisture distribution efficiency in both vertical and horizontal directions, irrespective of seasons was much lower than drip irrigation system and it varied from 85.1 to 63.5%. These findings were in accordance with the observations of Bharambe *et al.* (2), and Patel and Rajput (9).

Thus, drip fertigation is an efficient and effective method of applying precise amounts of irrigation water and also fertilizer nutrients for higher fruit production of banana in the Gangetic plain of West Bengal. Maximum fruit yield and water use efficiency of main and ratoon crops could be obtained with drip irrigation at 60% of CPE with 80% of recommended NPK fertigation through drip system. Drip irrigation, as a whole, registered the higher fruit yields and water use efficiency with savings of 38.3 to 41.5% of water compared to conventional surface irrigation for banana. The seasonal moisture distribution efficiency in drip system was uniform and relatively much higher than surface irrigation and it was higher near the dripper and then decreased consistently with increasing distance in both horizontal and vertical directions.

REFERENCES

1. Bangar, A.R. and Chaudhari, B.C. 2004. Nutrient mobility in soil, uptake, quality and yield of Suru sugarcane as influenced by drip fertigation in medium vertisols. *J. Indian Soc. Soil Sci.* **52**: 164-71.

2. Bharambe, P.R., Mungal, M.S., Shelke, D.K., Oza, S.R., Vaishnava, V.G. and Sondge, V.D. 2001. Effect of soil moisture regimes with drip on spatial distribution of moisture, salts, nutrient availability and water use efficiency of banana. *J. Indian Soc. Soil Sci.* **49**: 658-65.

3. Dahiwalkar, S.D., Divekar, B.K. and Sonawane, D.A. 2004. Relative performance of fertigation on growth, yield and quality of banana. *J. Maharashtra Agric. Univ.* **29**: 235-37.

4. Doorenbos, J., Pruitt, W.O., Aboukhaled, A. and Dastane, A.B. 1984. Guidelines for predicting crop water requirements. *Irrigation and Drainage Paper No.* 24, FAO, Rome.

5. Hedge, D.M. and Srinivas, K. 1990. Growth, productivity and water use of banana under drip and basin irrigation in relation to evaporation replenishment. *Indian J. Agron.* **35**: 106-12.

6. Kumar, S., Sharma, I.P. and Raina, J.N. 2005. Effect of levels and application methods of irrigation and mulch materials on strawberry production in north-west Himalayas. *J. Indian Soc. Soil Sci.* **53**: 60-65.

Table 6. Distribution efficiency of water (%) under drip irrigation system in banana crop in winter and summer season.

Season	Irrigation level	Vertical distance from dripper (cm)	Horizontal distance from dripper (cm)			
			0	15	30	45
Winter (November 2008 to February 2009)	Drip 50% CPE	0-15	91.7	89.5	87.3	84.2
		15-30	91.6	86.6	84.0	78.8
		30-45	90.9	83.4	81.2	76.5
		45-60	87.2	81.3	76.0	75.9
	Drip 60% CPE	0-15	95.6	92.4	88.9	87.5
		15-30	93.1	89.9	86.8	85.6
		30-45	92.3	88.6	85.7	84.4
		45-60	90.5	87.2	84.2	83.6
	Drip 70% CPE	0-15	95.1	94.2	93.8	92.4
		15-30	92.5	90.9	89.1	86.7
		30-45	89.6	88.7	87.2	85.5
		45-60	87.3	85.9	84.6	83.1
	Surface	0-15	85.1	84.2	76.2	73.4
		15-30	82.5	80.9	79.1	77.7
		30-45	79.9	78.7	74.1	69.8
		45-60	75.3	72.3	68.2	67.5
Summer (March-June 2009)	Drip 50% CPE	0-15	93.7	92.3	90.7	86.4
		15-30	91.4	89.7	88.9	86.3
		30-45	88.1	86.8	85.4	79.1
		45-60	83.4	82.3	78.9	77.5
	Drip 60% CPE	0-15	96.8	95.2	94.6	87.4
		15-30	95.5	94.8	89.9	86.3
		30-45	91.3	89.8	87.4	84.4
		45-60	87.4	86.6	85.0	83.2
	Drip 70% CPE	0-15	98.2	95.5	93.7	89.4
		15-30	94.3	93.2	89.6	86.7
		30-45	91.9	90.1	88.5	85.3
		45-60	89.8	87.7	86.6	85.5
	Surface*	0-15	80.7	81.0	73.5	68.3
		15-30	78.2	76.4	75.3	72.6
		30-45	74.6	72.5	67.9	63.5
		45-60	69.2	67.8	76.0	68.3

*Irrigation water applied at IW/CPE 1.0 with 5 cm depth.

7. Nakayama, F.S. and Bucks, D.A. 1986. *Trickle irrigation for Crop Production: Design, Operation and Management*, Elsevier, New York, 383 p.
8. Patel, N. and Rajput, T.B.S. 2004. Fertigation-a technique for efficient use of granular fertilizer through drip irrigation. *IEI J.* **85**: 50-54.
9. Patel, N. and Rajput, T.B.S. 2010. Use of simulation modeling for enhancing potato production using sub-surface drip. *Potato J.* **37**: 21-27.
10. Pawar, D.D. and Dingre, S.K. 2013. Influence of fertigation scheduling through drip on growth and yield of banana in western Maharashtra. *Indian J. Hort*. 70: 200-205.
11. Raina, J.N., Sharma, T. and Suman, S. 2011.

Effect of drip fertigation with different fertilizers on nutrient distribution in soil, leaf nutrient content and yield of apricot (*Prunus aremeniaca* L.). *J. Indian Soc. Soil Sci.* **59**: 268-77.

12. Raina, J.N., Thakur, B.C. and Verma, M.L. 1999. Effect of drip irrigation and polyethylene mulch on yield, quality and water use efficiency of tomato (*Lycopersicon esculentum*). *Indian J. Agric. Sci.* **69**: 430-33.

13. Reddy, B.M.C., Srinivas, K., Padma, P. and Raghupati, H.B. 2002. Response of robusta banana to N and K fertigation. *Indian J. Hort.* **59**: 342-48.

14. Sharma, I.P. and Kumar, S. 2007. Effect of drip irrigation and N and P application on soil moisture distribution and water use efficiency of chrysanthemum (*Dendranthema grandiflorum*) in Inceptisols. *Indian J. Soil Cons.* **35**: 50-53.

15. Shukla, K.N., Singh, P.K. and Singh, K.K. 2001. Crop water requirement under drip irrigation. *In*: Plasticulture Development Centre, GBPUAT, Pantnagar, UP, India.

16. Srinivas, K., Reddy, B.M.C., Kumar, S.S.C., Gowda, S.T., Raghupati, H.B. and Padma, P. 2001. Growth, yield and nutrient uptake of Robusta banana in relation to N and K fertigation. *Indian J. Hort.* **58**: 287-93.

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