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Growth, Yield, Quality and Irrigation Water Use Efficiency of Banana under Drip Irrigation and Fertigation in the Gangetic Plain of West Bengal

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Abstract: A field experiment was carried out during 2008-2010 inthe Gangetic plain of West Bengal, India to study the effect of drip irrigation and fertigation on growth, yield, nutrient uptake, fruit quality and irrigation water use efficiency of banana. The treatments consisted of three levels of drip irrigation (50, 60 and 70% of cumulative pan evaporation) and three levels of drip fertigation (50, 60 and 80% of recommended NPK fertilizers) including surface irrigation and conventional soil fertilization was laid out in an augmented factorial complete block design. The results showed that improvedgrowth, yield, leaf nutrient uptake, fruit quality and irrigation water use efficiency were obtained under drip irrigation compared to surface irrigation. The increasing levels of drip fertigation consistently and significantly increased all these characteristics. However, drip irrigation at 60% CPE with fertigation at 80% RDFproduced maximum growth, yield and fruit quality attributes and higher irrigation water use efficiency, besides water saving of 41.7% for plant and 40.4% for ratoon crop of banana over the surface irrigation and soil fertilization.

Key words: Drip irrigation · Fertigation · Bananayield · Quality · Irrigation water use efficiency

INTRODUCTION

Water and nutrients are the two vitalcomponents for sustaining the production and productivity of agriculture, but their use efficiency is appreciable low because of unscientific management practices. Due to water scarcity, the available water resources should be utilized very effectively through water saving irrigation technologies to maximize the yield. Furrow and basin irrigation methods are commonly adopted to irrigate the crop, which causes adverse effects of water excess and water stress [1, 2]. Drip irrigation is the most efficient and new technology of irrigation in India to supply precise amounts of water directly into the vicinity of root zone at right time, matching with the consumptive water demand of plant for optimum growth, improved yield and quality of produce with substantialwater saving [3, 4, 5]. However, drip irrigation alone without incorporating the fertilizer nutrients could not achieve the desired results. Fertigation is the most efficient andless expensive method of fertilizer application along withirrigation water which satisfies the total and temporal requirementsof water and nutrients during critical periods of plants [6, 7, 8]. This approach could also save considerable amounts of water and nutrients in comparison to surface irrigation and conventional soil fertilization [9, 2]. Banana (*Musa sp)* is a giant perennial herb that requires high amount of water and nutrients for proper growth and development, but very sensitive to moisture stress than other fruit crops [10, 7]. Adoption of drip fertigation system may also helpin increasing yields and quality parameters due to improvedirrigation and nutrients use efficiencies [7, 2]. Keeping all these in view, the present experiment was undertaken to evaluate the different levels of drip irrigation and fertigationcompared with surface irrigation and conventional soil fertilization on growth, yield, quality parameters and irrigation water use efficiency of banana in the Gangetic plain of West Bengal, India.

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MATERIALS AND METHODS

Experimental Site and Soil: The field experiment wascarried out during 2008-2009 and 2009-2010 at the Research Farm of AICRP on Tropical Fruits, BCKVrepresenting the Gangetic plain of West Bengal, India (Latitude 23.5° N, Longitude80° E with altitude of 9.75 m above mean sea level). Mean monthly maximum and minimum temperature and daily pan evaporation during the cropping varied from 25.4 to 36.8°C, 14.7 to 26.6°C and 1.1 to 6.5mm, respectively. Total rainfall during the cropping period was 1604 mm for plant and 1300 mm for ratoon crop.The soil of the experimental site was silty clay having bulk density1.28 Mg/m^3, pH 6.46, EC 0.10 dS/m, 0.46% organic C and medium in available nitrogen (156.5 kg N/ha), available phosphorus (13.7 kg P/ha) and low in available potassium (117.9 kg K/ha). The soil had 0.63 cm/hr saturated hydraulic conductivity and 50.25% water holding capacityand moisture contents at field capacity (-0.033 MPa) and permanent wilting point (-1.50 MPa) were 31% and 16%, respectively.

Planting Materials and Agro-Production Techniques: The banana plant (cv. Martaman, AAB, Silk) consisted of 2.5 month-old healthy sword sucker weighing around 2.0 kg each was used as the test crop. It was planted at a spacing of 2 x 2m (2500 $suckersha^{-1}$) during 3rd week of January 2008 for plant crop and harvested during 2nd week of March 2009. All the suckers were removed from mother plant and 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 2nd week of March 2009 andharvested during 3rd week of April 2010. A buffer strip of 2 m was maintained between the two plots.

Experimental Treatments: The treatments consisted of three drip irrigation levels at 50 (I_1), 60 (I_2) and 70 (I_3) percent of cumulative pan evaporation (CPE) and three fertigation levels at 50 (F_1), 60 (F_2) and 80 (F_3) percent of recommended dose of fertilizers (RDF) including a control treatment which includes surface irrigation at 100 percent CPE with conventional soil fertilization at 100 per cent RDF.

Experimental Design: The experiment was laid out in an augmented factorial completeblock design with ten treatments replicated thrice with 9 plants under each treatment.

Fertigation and Fertilization Schedules: The recommended dose of fertilizers (RDF) for banana is 250:50:300 g NPK per plant. The water soluble fertilizers *viz*., urea (46% N), phosphoric acid (31.7% P) and muriate of potash (49.8% K) were used for drip fertigation. The fertilizers were scheduled in 18 equal splits for N, 2 splits for P and 9 splits for K apportioned in different growth stages of crop as tabulated below.

Week after planting	N (%)	P (%)	K (%)
9 to 16	20(4 splits)	50 (1 split)	20 (2 split)
17 to 28	40(6 splits)	50 (1 split)	40 (3 split)
29 to 40	30(6 splits)	-	30 (3 split)
41 to 42	10(2 splits)	-	10 (1 split)

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 %. In conventional soil fertilization, the RDF was applied in 4 splits at 2, 5, 7 and 9 months after planting of plant and ratoon crop. Every plant received about 10 kilogram of farm yard manure before 7 days of planting.

Drip Irrigation Schedules: The drip irrigation system was installed to meet the crop water requirement and for fertigation of water soluble fertilizers. The water requirement of banana was computed on the basis of CPE, pan factor, crop coefficient, canopy area factor and wetted area factor. The drip was scheduledonce in three days in summer and five days in winter based on evaporation replenishment splitting 80 irrigations in each plant and ratoon crop.

Cultural practices and Plant Protection Measures: Standard agronomic and plant protection measures were adopted as per package of practice as when necessary in the experimental field.

Data Collection and Chemical Analysis: The observations on growthparameters, yield attributes, yield and quality parameters of plant at harvest were recordedfrom five randomly sampled plants from each replication.The relevant soil properties were determined by the method of Jackson [11]. Total soluble solids (TSS) were determined using a hand refractometer from five randomly selected ripen fruit. The total sugar, acidity and

reducing sugar contents of fruits were estimated by the standard methods [12]. The uptake of N, P and K by banana leaves at vegetative, shooting and harvest stages of cropswas calculated from the nutrient concentration and dry matter of leaves.Irrigation water use efficiency of crop was computed by dividing fruit yield with irrigation water applied.

Statistical Analysis: The data obtained for different parameters were subjected to proper statistical investigationfollowing the analysis of variance techniques by using software packages of MS Excel and SPSS 12.0 version. Statistical significance between means of individual treatments was assessed using Fisher's Least Significant Difference (LSD) at 5% level of probability [13].

RESULTS AND DISCUSSION

Biometrical Characteristics: Pooled data onplant height, pseudostem girth, leaf number, leaf length, leaf breadth, leaf area and leaf area index (LAI) at shooting stage of both plant and ratoon crops showed maximum values with drip irrigation at 70% CPE (I_3), which differed significantly from other irrigation levels (Table 1). The increasing rate of drip fertigation consistently and significantly increased the growth parameters, the maximum values being observed with fertigation at 80% RDF (F_3). The interactions between drip irrigation and fertigation on overall growth factors were also significantly influenced exceptingleaf number, leaf breadth, leaf area and LAI of plants. Maximum growth attributes were detected under drip irrigation at 70% CPE with fertigation at 80% RDF (I_3F_3), whereasthe corresponding values were found minimum under drip irrigation at 50% CPE with fertigation at 50% RDF. The overall drip irrigation resulted in significant increase in growth characteristics compared to conventional surface irrigation. The higher availability of inputs due to regular supply ofrequisite amounts of water and nutrients through drip system might have improved the better physiological conditions, which probably resulted in increased nutrients uptake (Table 4) and in effect, increased the growth attributes of plants. These results are in accordance with the findings of [14, 15, 16, 17] who observed higher growth attributes of banana with drip fertigation as compared to surface irrigation and conventional soil fertilization.

Bunch Characteristics: The bunch characteristicsof plant and ratoon crops *viz*., bunch weight, finger weight, hand/bunch and finger/bunch were significantly influenced bydrip irrigation and fertigation levels (Table 2). The bunch weight for plant and ratoon crops and hand/bunch for ratoon crop at drip irrigation with 60% CPE and finger/bunch for plant crop at drip irrigation with 70% CPE recorded the superior values. The rest bunch parameters of both crops at drip irrigation with 60% CPE and 70% CPEwere not significant. Similarly, the increasing application of fertilizers through drip irrigation steadily and significantly increased the bunch characters, the maximum being obtained with drip fertigation at 80% RDF. The interactions between drip irrigation and fertigation revealed that drip irrigation at 60% CPEwith fertigation at 80% RDFgave significantly the higher bunch characters of plant and ratoon crop, therebyindicating the necessity of applying higher levels of water and fertilizer nutrients through drip system for increased plant vigour and physiological parameters resulting in higher bunch weight and related bunch traits. Notably, all the bunch characters values were comparatively lower in ratoon crop than in plant crop. The overall drip irrigation system produced the superior bunch characteristics than in surface irrigation with some exceptions. These findingsare in line with the findings of Hegde and Srinivas [1] who reported that the improvement of bunch weight under drip irrigation compared to basin irrigation was the consequence of significant difference in finger weight, finger lengthand finger/bunch.

Time of Shooting, Bunch Harvesting and Crop Duration: The increasing levels of drip irrigation and fertigation and their interactions on days to shooting, bunch harvest and duration of plant and ratoon crop were significantly affected (Table 3). The early shooting, advanced bunch harvesting and shorter crop durationof both crops were observed at the lowest level of drip irrigation at 50% CPE and fertigation at 50% RDFand their combinations. However, combination of drip irrigation at 60% CPE and fertigation at 80% RDF (I_2F_3) was considered to be promising in view of advancement of these attributesand increased fruit yields. These results are competitive with the findings of Mahalakshmi *et al*. [15]. The decrease in cropping period might be due to the timely supply of low amounts of water and NPK nutrients in synchrony with crop demand, which resulted in the early physiological maturity of crop. Plant crop needed more number of days to shooting, bunch harvest and maturity period than the ratoon crop. This might be attributed to more time taken by plant crop for establishment after planting contrary to the ratoon crop which was benefitted well from the established soil environment. Hegde and Srinivas [1] reported that days to flowering differed significantly both

Table 1: Effect of different levels of drip fertigation on growth attributes of banana at shooting stage(pooled data of 2-year)

Treatments	Plant height (cm)	Pseudostem girth (cm)	Leaf number	Leaf length (cm)	Leaf breadth (cm)	Leaf area (m^2)	Leaf area index (LAI)
Irrigation (I)							
I_1	287.95	68.88	12.94	178.03	55.15	10.26	2.56
I_2	294.37	70.82	13.27	181.09	57.04	11.04	2.76
I_3	297.92	72.52	13.64	183.42	58.40	11.76	2.94
SEm(±)	0.22	0.12	0.04	0.35	0.34	0.09	0.02
CD(0.05)	0.46	0.25	0.08	0.73	0.70	0.18	0.04
Fertilizer (F)							
F_1	282.36	66.22	12.57	172.51	52.42	9.11	2.28
F_2	293.58	70.53	13.36	182.11	56.92	11.1	2.77
F_3	304.30	75.48	13.92	187.92	61.26	12.85	3.21
SEm(±)	0.24	0.12	0.04	0.35	0.34	0.09	0.02
CD(0.05)	0.46	0.25	0.08	0.73	0.70	0.18	0.04
Irrigation x Fertilizer (I x F)							
I_1F_1	274.80	64.07	12.29	167.99	50.69	8.38	2.10
I_1F_2	289.83	68.95	12.92	180.24	55.29	10.31	2.58
I_1F_3	299.22	73.64	13.62	185.86	59.49	12.07	3.02
I_2F_1	284.26	66.65	12.54	172.95	52.66	9.14	2.29
I_2F_2	294.03	70.38	13.39	182.51	57.05	11.16	2.79
I_2F_3	304.82	75.43	13.88	187.80	61.42	12.82	3.20
I_3F_1	288.03	67.94	12.87	176.58	53.93	9.82	2.45
I_3F_2	296.88	72.25	13.77	183.58	58.41	11.82	2.95
I_3F_3	308.86	77.37	14.27	190.10	62.87	13.66	3.41
SEm(±)	0.39	0.21	0.07	0.62	0.59	0.15	0.04
CD(0.05)	0.79	0.43	0.15	1.26	1.22	0.31	0.08
Overall drip irrigation	293.41	70.74	13.28	180.85	56.87	11.02	2.75
Surface irrigation	291.18	69.50	13.09	178.52	55.25	10.48	2.64
SEm(±)	0.29	0.15	0.05	0.46	0.44	0.11	0.03
CD(0.05)	0.59	0.31	0.10	0.94	0.90	0.22	0.06

Table 2: Effect of different levels of drip fertigation on bunch characteristics and yield of banana

	Bunch weight (kg)		Finger weight (gm)		Hand/ bunch		Finger/bunch		Yield (t/ha)	
Treatments	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
Irrigation (I)										
I_1	14.13	13.20	128.21	119.16	7.51	7.16	115.24	107.67	35.33	33.00
I_2	17.15	15.79	141.39	131.11	8.73	8.32	130.20	121.12	42.86	39.48
I_3	16.56	15.23	142.53	130.96	8.73	8.22	133.78	122.45	41.40	38.07
SEm(±)	0.12	0.17	0.99	1.23	0.07	0.05	0.91	1.73	0.29	0.42
CD(0.05)	0.34	0.49	2.87	3.54	0.20	0.06	2.62	5.01	0.85	1.22
Fertilizer (F)										
F_1	13.51	12.49	124.86	112.05	7.32	6.88	108.28	97.68	33.75	31.21
F_2	16.69	15.56	141.46	131.93	8.69	8.20	133.31	125.33	41.71	38.91
F_3	17.65	16.17	145.81	137.21	8.95	8.63	137.64	128.23	44.13	40.43
SEm(±)	0.12	0.17	0.99	1.23	0.07	0.05	0.91	1.73	0.29	0.42
CD(0.05)	0.34	0.49	2.86	3.54	0.20	0.06	2.62	5.01	0.85	1.22
Irrigation x Fertilizer (I x F)										
I_1F_1	11.70	10.31	110.50	104.65	6.45	6.15	89.45	83.93	29.25	25.76
I_1F_2	15.04	14.44	133.75	123.68	7.87	7.35	124.73	115.74	37.59	36.09
I_1F_3	15.67	14.86	140.37	129.15	8.2	8.00	131.55	123.33	39.17	37.15
I_2F_1	13.66	12.96	125.57	112.41	7.38	6.99	107.18	96.75	34.07	32.40
I_2F_2	18.15	16.80	147.23	138.27	9.35	8.93	140.85	134.10	45.37	41.99
I_2F_3	19.66	17.62	151.37	142.64	9.46	9.05	142.58	132.52	49.14	44.04
I_3F_1	15.18	14.19	138.51	119.09	8.15	7.50	128.20	112.38	37.94	35.48
I_3F_2	16.87	15.46	143.40	133.85	8.85	8.31	134.35	126.16	42.18	38.64
I_3F_3	17.64	16.04	145.68	139.84	9.2	8.86	138.80	128.83	44.09	40.10
SEm(±)	0.20	0.29	1.72	2.12	0.12	0.09	1.57	2.98	0.51	0.73
CD(0.05)	0.59	0.85	4.96	6.14	0.35	0.27	4.55	8.67	1.48	2.12
Overall drip irrigation	15.95	14.74	137.37	127.06	8.32	7.90	126.41	117.08	39.87	36.85
Surface irrigation	14.26	13.11	125.83	117.01	8.05	7.78	124.20	113.12	37.09	34.84
SEm(±)	0.24	0.69	1.28	1.58	0.09	0.07	1.17	2.24	0.38	0.55
CD(0.05)	0.49	1.41	5.233	2.61	0.18	NS	NS	NS	0.77	1.12

NS: not significant

Table 3: Effect of different levels of drip fertigation on days to shooting, bunch harvest and crop duration of banana

	Days to shooting		Days to bunch harvest		Crop durationin days	
Treatments	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
Irrigation (I)						
I_1	315.48	276.87	89.03	84.94	404.56	362.52
I_2	321.68	281.78	91.23	86.72	412.95	368.61
I_3	325.51	287.99	94.71	90.11	420.09	379.79
SEm(±)	1.33	1.51	1.08	1.02	1.81	1.91
CD(0.05)	3.85	4.38	3.13	2.94	5.22	5.51
Fertilizer (F)						
F_1	306.98	269.22	84.47	82.07	391.47	352.38
F_2	319.35	282.57	92.46	86.18	411.77	369.35
F_3	336.35	294.85	98.05	93.52	434.37	389.18
SEm(±)	1.33	1.51	1.08	1.02	1.81	1.91
CD(0.05)	3.85	4.38	3.13	2.94	5.22	5.51
Irrigation x Fertilizer (I x F)						
I_1F_1	301.95	264.53	82.68	81.58	384.75	345.28
I_1F_2	314.60	278.43	89.98	83.95	404.58	362.88
I_1F_3	329.90	287.65	94.45	89.30	424.35	379.40
I_2F_1	308.08	267.88	82.70	80.58	390.73	348.58
I_2F_2	320.15	283.45	92.28	85.35	412.43	369.03
I_2F_3	336.83	294.00	98.73	94.23	435.70	388.23
I_3F_1	310.90	275.25	88.03	84.05	398.93	363.30
I_3F_2	323.30	285.83	95.13	89.25	418.30	376.15
I_3F_3	342.33	302.90	100.98	97.03	443.05	399.93
SEm(±)	2.31	2.62	1.88	1.76	3.13	3.31
CD(0.05)	6.67	7.58	5.43	5.09	9.05	9.55
Overall drip irrigation	320.90	282.21	91.66	87.26	412.53	370.31
Surface irrigation	347.13	305.48	102.58	99.93	449.70	404.55
SEm(±)	1.72	1.96	1.40	1.31	2.33	2.46
CD(0.05)	4.97	5.66	4.04	3.78	6.73	7.10

Table 4: Nutrient uptake by banana leaf as influenced by different levels of drip fertigation levels (Pooled data of 2-year)

	N (%)			P (%)			K (%)		
Treatment	Vegetative	Shooting	Harvest	Vegetative	Shooting	Harvest	Vegetative	Shooting	Harvest
Irrigation (I)									
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
SEm (±)	0.01	0.02	0.01	0.01	0.02	0.01	0.02	0.03	0.02
CD (0.05)	0.02	0.03	0.03	0.01	0.03	0.02	0.04	0.07	0.04
Fertilizer (F)									
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
SEm (±)	0.01	0.02	0.01	0.01	0.02	0.01	0.02	0.03	0.02
CD (0.05)	0.02	0.03	0.03	0.01	0.03	0.02	0.04	0.07	0.04
Irrigation x Fertilizer (I x F)									
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
SEm (±)	0.02	0.03	0.03	0.01	0.02	0.01	0.03	0.06	0.04
CD (0.05)	0.04	NS	0.05	NS	NS	NS	NS	NS	NS
Overall drip irrigation	2.28	2.46	1.40	0.37	0.45	0.24	2.60	2.85	2.11
Surface irrigation	2.55	2.63	1.50	0.43	0.49	0.29	2.71	2.90	2.14
SEm (±)	0.01	0.16	0.03	0.46	0.44	0.11	0.02	0.03	0.03
CD (0.05)	0.04	0.46	0.08	1.33	1.28	0.33	0.06	NS	NS

in plant and ratoon crop. Badgujar *et al*. [18] also found significant difference for days to harvest due to varying fertigation levels. Moreover, the overall drip irrigation exhibited less number of days to shooting, early bunch harvest and less crop duration than the surface irrigation.

Fruit Yield: The banana yield was significantly differed due to variations in drip irrigation and fertigation levels (Table 2). Drip irrigation at 60% CPE gave significantly the highest yield of 42.86 t/ha for plant crop and 39.48 t/ha for ratoon crop, followed by 70% CPE (41.4 and 38.07 t/hafor plantand ratoon crop, respectively) and 50% CPE (35.33and33.0 t/hafor plantand ratoon crop, respectively). The increase in yield under drip irrigation at 60% CPE was 15.5% for plant and 13.3% for ratoon crop and the corresponding figures under drip irrigation at 70% CPE was 11.6 and 9.3%, respectivelyover surface irrigation (Table 5). Similarly, drip fertigation at 80% RDF produced the maximum yield (44.13 t/ha for plant crop and 40.43 t/ha for ratoon crop)and were superior to other fertigation levels. The fruit yield in all cases was comparatively lower in ratoon than in plant crop. This corroborated with the findings of Hegde and Srinivas [1] who reported that yield of ratoon crop was lower than plant crop irrespective of different irrigation and fertilizer levels. Among different interaction levels studied, significantly the highestfruit yield was obtained with drip irrigation at 60% CPEwith fertigation at 80% RDF (49.14 t/ha for plant crop and 44.04 t/ha for ratoon crop) and was superior to other combinations of drip irrigation and fertigation. This treatmentcombination contributed about 32.5% increase in yield for plant crop and 26.4% for ratoon crop over surface irrigation and conventional soil fertilization (Table 6). Overall drip irrigation resulted in significantly the highest yield in both plant (39.87 t/ha) and ratoon crop (36.85 t/ha) over conventionalmethod of irrigation. The increase in fruit yield was due to the improvement in bunch weight of banana under drip fertigation, possibly due to enhanced water utilization through drip, better nutrients uptake and excellent soil-water-air environment in the root zone [2, 8]. Almost similar results had been reported by Kavino *et al*. [19] who recorded the maximum yields with higher levels of irrigation and NPK fertilizers application. The reasons of low yields in surface irrigated-soil fertilized plants might be due to water stress during last few days before next irrigation, aeration choking during first few days immediately after irrigation and runoff and deep percolation losses of water and nutrients [20].

Leaf Nutrient Uptake: The uptake of N, P and K by banana leaf was significantly influenced by irrigation methods and fertigation levels at vegetative, shooting and harvest stages of crop (Table 4). There was consistent and significant increase in nutrient uptake with the increase in either 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 conventional method of surface irrigation. These results corroborated with the findings of Saad [21] and Dahiwalkar *et al*. [13] who reported that leaf N concentration increased with the increase in fertilizer and moisture level through drip irrigation and that too in shooting stage than in vegetative and harvesting stages of crop.

Fruit Quality: The fruit quality parameters of banana were significantly affected by drip irrigation and fertigation levels (Table 5). Drip irrigation scheduling at 60 and 70% CPE were almost identical in promoting higher total soluble solids (TSS), reducing sugarand total sugar contentsand less acidity of fruitsin plant and ratoon crop, but were superior to drip irrigation at 50% CPE. The overall drip irrigated plants showed significantly the higher values of quality parameters as compared to surface irrigated plants exhibiting relatively poor quality of fruits. The increasing levels of fertigation concomitantly and significantly increased the quality parameters. However, drip-fertigation at 80% RDF improved fruit quality parameters with higher soluble solids, reducing sugar, total sugar and lowest acidity of both plant and ratoon crops. These results are in agreement with the findings of Kumar and Pande [14] who observed the highest values of TSS, total sugar content and reducing sugar in banana fruit with fertilization at 70% RDF. The interactionsbetween drip irrigation and fertigation showed that drip irrigation at 60% CPE with fertigation at 80% RDF resulted in maximum values of quality attributesof plantand ratoon crop, which were almost competitive with the treatment combination of drip irrigation at 60% CPE with fertigation at 60% RDF.

Table 5: Effect of different levels of dripfertigation on fruit quality of banana

	Total soluble solids(° brix)		Reducing sugar		Total sugar (%)		Acidity (%)	
Treatments	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
Irrigation (I)								
I_1	21.37	20.86	5.89	5.58	15.04	14.61	0.37	0.36
I_2	22.98	22.11	6.34	6.11	15.44	15.15	0.40	0.38
I_3	23.23	22.54	6.28	6.02	15.62	15.39	0.42	0.40
SEm(±)	0.10	0.15	0.01	0.06	0.03	0.11	0.006	0.005
CD(0.05)	0.28	0.45	0.04	0.17	0.09	0.31	0.017	0.016
Fertilizer (F)								
F_1	21.21	20.20	5.77	5.43	14.98	14.41	0.35	0.35
F_2	22.86	22.26	6.22	6.09	15.36	15.15	0.40	0.38
F_3	23.51	23.04	6.51	6.18	15.76	15.6	0.43	0.40
SEm(±)	0.10	0.15	0.01	0.06	0.03	0.11	0.006	0.005
CD(0.05)	0.28	0.45	0.04	0.17	0.09	0.31	0.017	0.016
Irrigation x Fertilizer (I x F)								
I_1F_1	19.83	18.88	5.53	5.13	14.71	14.08	0.33	0.32
I_1F_2	21.66	20.94	5.85	5.74	15.14	14.71	0.38	0.36
I_1F_3	22.63	22.76	6.28	5.86	15.27	15.05	0.40	0.39
I_2F_1	21.07	19.85	5.80	5.48	14.95	14.35	0.34	0.34
I_2F_2	23.72	23.13	6.51	6.37	15.51	15.42	0.41	0.38
I_2F_3	24.16	23.33	6.70	6.47	15.86	15.68	0.45	0.40
I_3F_1	22.75	21.86	6.00	5.68	15.29	14.80	0.4	0.38
I_3F_2	23.20	22.71	6.31	6.17	15.42	15.31	0.42	0.41
I_3F_3	23.73	23.04	6.55	6.21	16.14	16.06	0.45	0.42
SEm(±)	0.17	0.27	0.03	0.10	0.05	0.19	0.01	0.01
CD(0.05)	0.48	0.77	0.08	0.30	1.16	0.55	0.03	0.03
Overall drip irrigation	22.53	21.83	6.17	5.90	15.37	15.05	0.40	0.38
Surface irrigation	22.16	21.10	6.12	5.73	15.26	14.74	0.38	0.36
SEm(±)	0.12	0.20	0.02	0.08	0.04	0.14	0.007	0.007
CD(0.05)	0.25	0.41	0.04	0.16	0.08	0.28	0.014	0.014

Table 6: Comparison of yield and irrigation water use efficiency in banana under different levels drip fertigation and conventional surface irrigation and soil fertilization

	Irrigation water applied (cm)		Yield (kg/ha)		Irrigation water use efficiency (kg/ha-cm)		Increase in yield over surface irrigation (%)	
Treatments	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
Irrigation (I)								
I_1	27.7	16.4	35330	33000	1275.6	2014.0	-4.74	-5.28
I_2	33.3	19.7	42860	39480	1289.7	2007.9	15.55	13.31
I_3	38.8	22.9	41400	38070	1067.5	1659.9	11.62	9.27
Irrigation x Fertilizer (I x F)								
I_1F_1	27.7	16.4	29250	25760	1056.1	1572.2	-21.13	-26.06
I_1F_2	27.7	16.4	37590	36090	1303.0	2202.7	1.34	3.58
I_1F_3	27.7	16.4	39170	37150	1414.3	2267.3	5.60	6.63
I_2F_1	33.3	19.7	34070	32400	1025.2	1647.9	-8.14	-7.00
I_2F_2	33.3	19.7	45370	41990	1365.2	2135.6	22.32	20.52
I_2F_3	33.3	19.7	49140	44040	1478.7	2239.8	32.48	26.40
I_3F_1	38.8	22.9	37940	35480	978.3	1546.9	2.29	1.83
I_3F_2	38.8	22.9	42180	38640	1087.6	1684.8	13.72	10.90
I_3F_3	38.8	22.9	44090	40100	1136.8	1748.4	18.87	15.09
Overall drip irrigation	33.3	19.7	39870	36850	1199.6	1874.4	7.49	5.76
Surface irrigation	57.0	33.0	37090	34840	650.7	1055.8	-	-

Almost similar findings h ad been reported by Kavino *et al*. [19] who observed that the combination with lower levels of water along with higher levels of fertilizers registered the highest TSS, reducing sugars and total sugars besides the lowest values of acidity. It is interesting to note that all these quality parameters were relatively higher in plant crop than in ratoon crop, irrespective of different levels of irrigation and fertilizers.

Irrigation Water Use Efficiency: Higher irrigation wateruse and lower irrigation wateruse efficiency wereobserved under the conventional surface irrigation as compared to varying levels of drip irrigation (Table 6). The irrigation wateruse efficiency at a particular level of water application consistently increased with increasing levels of fertigation through drip system. This might be due to the efficient utilization of water and nutrients coupled with increase in yield. There was considerable water saving to the tune of 41.7% in plant and 40.4% in ratoon under drip irrigation at 60% CPE and fertigation at 80 RDF. The drip system delivers precise amount of water directly into the root zone matching with crop evapotranspiration demand which probably resulted in higher water use efficiency underdrip irrigation as compared to traditionalsurface irrigation [3, 2, 17].

CONCLUSIONS

The study clearly suggests theadvantage of drip fertigation with applying precise amounts of water and fertilizer nutrients over surface irrigation and conventional soil fertilization for banana production. The drip irrigation at 60% CPE with drip fertigation at 80% RDF may be recommended for obtaining maximum growth, yield, fruit quality and irrigation water use efficiency of banana. It could not only save water by 41.7% for plant and 40.4% for ratoon crop but also helped increase the fruit yield by 32.5% for plant and 26.4% for ratoon crop over surface irrigation and soil fertilization.

REFERENCES

1. Hedge, D.M. and K. Srinivas, 1990. Growth, productivity and water use of banana under drip and basin irrigation in relation to evaporation replenishment. Indian J. Agron., 35(1-2): 106-112.
2. Raina, J.N., Sharma Tarika and SumanShashi, 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: 268-277.
3. Kumar, S., I.P. Sharma and J.N. Raina, 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(1): 60-65.
4. Shashidhara, K.K., A. Bheemappa, L.V. Hirevenkanagoudar and K.C. Shashidhar, 2007. Benefits and constraints in adoption of drip irrigation among the plantation crop growers. Karnataka J. Agril. Sci., 20: 82-84.
5. Thangaselvabai, T., S. Suresh, J. Prem Joshua and K.R. Sudha, 2009. Banana nutrition - A review. Agric. Rev., 30: 24-31.
6. Patel, N. and T.B.S. Rajput, 2010. Use of simulation modeling for enhancing potato production using sub-surface drip. Potato J., 37: 21-27.
7. Pawar, D.D. and S.K. Dingre, 2013. Influence of fertigation scheduling through drip on growth and yield of banana in western Maharashtra. Indian J. Hort., 70: 200-205.
8. Singandhupe, R.B., G.G.S.N. Rao, N.G. Patil and P.S. Brahmanand, 2003. Fertigation studies and irrigation scheduling in drip irrigation system in tomato crop (*Lycopersicon esculentum* L.). European J. Agron., 19: 327-340.
9. Mohammad, M.J. and Z. Said, 2003. Enhancement of yield and nitrogen and water use efficiencies by nitrogen drip-fertigation of garlic. J. Plant Nutr., 26: 1749-1766.
10. Gomez, K.A. and A.A. Gomez, 1984. Statistical procedure for agricultural research, 2nd Edition, International Rice Research Institute, John Wiley and Sons, New York, pp: 1-340.
11. Jackson, M.L., 1973. Soil chemical analysis, 2nd Ed. Prentice Hall, India Pvt. Ltd., New Delhi, pp: 111-182.
12. AOAC, 1990. Official methods of analytical chemistry. Washinton, D.C., USA.
13. Dahiwalkar, S.D., B.K. Divekar and D.A. Sonawane, 2004. Relative performance of fertigation on growth, yield and quality of banana. J. Maharashtra Agric. Univ., 29(2): 235-237.
14. Kumar, Dinesh and V. Pandey, 2008. Effect of NPK fertigation on growth, yield and quality of banana 'Rasthali' (AAB-Pathkapoora) in coastal agro-climatic conditions of eastern India. Indian J. Agric. Sci., 78(9): 798-800.

15. Mahalakshmi, M., N. Kumar, P. Jayakumar and K. Soorianathasundaram, 2001. Fertigation studies in banana under high density planting system. In: Proceedings of the National Seminar on Changing Scenario in the Production Systems of Horticultural Crops., Coimbatore, Tamil Nadu, India, 28-30 August 2001. South Indian Hort., 49(Spl.): 86-91.
16. Srinivas, K., 1997. Growth, yield and quality of banana in relation to N fertigation. Trop. Agric., 74: 260.
17. Srinivas, K., B.M.C. Reddy, S.S.C. Kumar, S.T. Gowda, H.B. Raghupati and P. Padma, 2001. Growth, yield and nutrient uptake of Robusta banana in relation to N and K fertigation. Indian J. Hort., 58(4): 287-293.
18. Badgujar, C.D., S.S. Deshmukh, S.M. Dusane and S. S. Shide, 2004. Influence of N and fertigation and different plant densities on yield of banana cv. Grand-Naine. South Indian Hort., 52(1/6): 22-28.
19. Kavino, M., N. Kumar, K. Soorianathasundaram and P. Jeyakumar, 2002. Effect of source of fertilizers for fertigation on yield and quality of banana cv. Robusta (AAA). South Indian Hort., 50(4-6): 301-307.
20. Agrawal, N. and S. Agrawal, 2005. Effect of drip irrigation and mulches on the growth and yield of banana cv. Dwarf Cavendish. South Indian Hort., 62(3): 233-240.
21. Saad, M.M., 1997. Effect of nitrogen fertilization on growth, yield and fruit quality of "Williams" banana in sandy soil under drip irrigation system. Annals Agril. Sci., 35: 2357-2363.