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Economic Evaluation of Drip-fertigation System in Banana cv. Martaman (AAB, Silk) Cultivation in New Alluvium Zone of West Bengal

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Abstract

The study has assessed the economic viability of drip-fertigation system techniques in banana cultivation in West Bengal. The study was carried out in augmented factorial complete block design during 2008-10. The main factor was irrigation at 3 levels (I_1= 50% CPE, I_2= 60% CPE and I_3= 70% CPE) and sub-factor was fertilizer at 3 levels (F_1=50% RDF, F_2=60% RDF and F_3=80% RDF). It has been found that the variations in fertilizer and irrigation levels provide different yields of banana. The highest yield was obtained for both plant (49.2 t/ha) and ratoon (44.1 t/ha) crops of banana with combined application of irrigation at 60 per cent CPE and 80 per cent RDF. The water-use efficiency has been found higher under drip fertigation and was highest under 60 per cent CPE and 80 per cent RDF, resulting in a considerable saving of water (41.7% in plant crop and 40.4% in ratoon crop). The drip fertigation has been found economically-viable because of higher gross returns, net returns and return per rupee investment as compared to conventional method of irrigation. The high initial investment cost for the system is one of the major constraints, but considering the benefits in terms of water-saving, increased crop productivity and higher returns, the study has suggested its wider dissemination.

Key words: Banana, drip irrigation, fertigation, economic viability, yield, West Bengal

JEL Classification: Q15, Q12

Introduction

India has one of the largest irrigated areas in the world, but its per-capita as well per-hectare availability of water is one of the lowest in the world. The efficient and judicious use of both water and fertilizer is the key for improving agricultural production and productivity in the country. Fertigation (application of water-soluble solid or liquid fertilizer through drip irrigation system) is an attractive method of fertilization in intensive agricultural systems. The drip method of irrigation also helps in reducing over-exploitation of groundwater that partly occurs in surface irrigation. Water saving through drip irrigation system is estimated to be in the range of 12-84 per cent in different crops, besides its beneficial impact on crop yields (Narayanamoorthy, 1996; 1997). The drip fertigation method has considerable potential to improve water and fertilizer use efficiency. The other issue related to drip irrigation is its economic viability and the farmers are often reluctant to adopt this method due to their weak resource base. Under this backdrop, this paper has investigated the economic viability of drip fertigation in banana cultivation in the New Alluvial Zone of West Bengal.

Materials and Method

The paper is based on the data from the experiments on banana crop carried out at the Teaching Farm of the

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Bidhan Chandra Krishi Viswavidyalaya in new alluvial zone of West Bengal (23.5° N and 80^0 E with 9.75 msl) during 2008-10. The mean monthly maximum temperature, minimum temperature, and pan evaporation during the crop season varied from 25.4 °C to 36.8 °C, 14.7 °C to 26.6 °C and 1 mm to 6.5 mm, respectively. The soil had the capacity to hold 108 mm available water in the top 60-cm soil profile between -0.01 MPa (Mega Pascal) and -15 MPa of soil matric potential. The water table was below 300 cm during the cropping period and hence groundwater contribution to root zone was considered negligible. The total rainfall in the plant and ratoon crop cycles was 1604 mm and 1300 mm, respectively.

The soil (0-15 cm) at experimental site was silty clay having pH, 6.46; EC, 0.10 ds/m; organic carbon, 0.46 per cent; available N, 156.49 kg/ha, P_2O_5, 31.37 kg/ha; and K_2O, 142.06 kg/ha. The experimental soil had 1.76 $10^{-6}MS^{-1}$ saturated hydraulic conductivity with 50.25 per cent water-holding capacity, bulk density was 1.28 Mgm^{-3} and moisture content was 31 per cent at field capacity and 16 per cent at permanent wilting point.

The experiment was laid out in augmented factorial complete block design with four replications. The main factor was irrigation at 3 levels [I_1= 50% CPE (cumulative pan evaporation), I_2= 60% CPE, and I_3= 70% CPE], sub-factor was fertilizer at 3 levels [F_1=50% RDF (recommended dose of fertilizer), F_2=60% RDF, and F_3=80% RDF] [the recommended dose of N, P and K is 250:50:300 g/plant/year]. The control treatment included irrigation at 100 per cent at CPE and N, P, K at 250: 50: 300 g / plant. The plot size was 6 m × 4 m and the total number of treatments was 3 × 3+1 = 10. The uniform healthy 2 months old sword suckers of cv. Martaman (AAB, silk) of 1.5 kg weight were planted in a pit (1 ft × 1 ft × 1 ft) at a spacing of 2m × 2m (square planting) after treating them with a solution containing 10g carbendazim, 1g streptocycline and 10 mL monocrophos in 10 litres of water for 30 minutes. The farm yard manure (FYM) was applied @ 5 kg/ pit before planting of sucker. Plant protection measures and cultural operations were followed as per the recommendations throughout the study period.

Method of Irrigation

Three levels of irrigation (50%, 60% and 70% CPE) were given at an interval of 3 days during summer and of 5 days during winter. The recorded pan evaporation data at various growth stages were obtained on a regular basis and the amount of irrigation water applied through drippers was calculated before application. The evaporation data were collected from a USWB class A pan located at meteorological observatory near the experimental field. The irrigation was skipped where considerable amount of rainfall was received and thereby keeping the soil profile wet for a few consecutive days. Depending on the amount of effective rainfall (> 2.25 mm), the next date of irrigation was adjusted, as suggested by Dastane (1967). The uniformity coefficient (Uc) of application of water was determined by collecting the discharge of drippers in the buckets for a specified period at selected laterals using formula (1) (Raina *et al.,* 1999):

$$Uc = \frac{1 - \Delta q}{Q} \qquad \ldots(1)$$

where, q is the mean emitter (emitters are used to dissipate pressure and discharge water through drip irrigation system) discharge rate (L/h); and “q is the mean deviation in emitter discharge from mean value.

There were two drippers at the bottom of each plant of standard capacity 2 L/h. The actual discharge of both the drippers was measured to be 3.6 L/h (1.8 × 2 L for each). The discharge of drippers at remote and head ends of flow net in the orchard was taken to adjust the time of operating the drippers according to the volume of water exactly required on the basis of varying irrigation requirement throughout the crop season. Irrigation water was made available from a shallow tube-well adjacent to the experimental field.

The fertilizer solutions were injected into the drip system through a fertilizer injector at weekly intervals starting from 45 days after planting to 210 days, except in the rainy month, when the irrigation was not required as per the cumulative pan evaporation rate. The concentration of nutrient solution passing through irrigation water was around 1.0-1.4 per cent. The nutrients, namely N, P and K, were applied in the form of urea (46% N), phosphoric acid (31.6% P) and muriate of potash (60% K_2O). In cases of drip fertigation, all the nutrient sources were dissolved in a tank along with irrigation water and applied at different times as per the requirement of the banana crop. The irrigation water-use efficiency was derived by formula (2) (Biswas *et al.,* 1999):

$$\text{Irrigation water-use efficiency (kg/ha-cm)} = \frac{\text{Yield (kg/ha)}}{\text{Irrigation water applied (cm)}} \quad ...(2)$$

The yield was recorded when bunches matured (approximately 120 days after flowering), and one sucker was retained per plant for the ratoon crop. Yield was computed by multiplying the average bunch weight with the total number of plants per hectare.

Economic Analysis

The cost of cultivation for each treatment was calculated by the cost of each input used during experimentation and gross return was calculated from the market price of banana during the experiment period. Net return was estimated by deducting total cost of cultivation invested in each treatment from the respective gross returns. The total cost of cultivation was computed by adding the cost of cultivation of the banana crop with fixed cost (installation cost of drip system with fertigation). The return per rupee investment was calculated by dividing the net return of each treatment with cost of cultivation. It provided the economic viability of drip method of irrigation under the non-constraint situation of water source.

Statistical Analysis

The data obtained were analyzed statistically by the augmented factorial ANOVA technique (Federer, 1956), which was repeated discretely for each year of observations. SPSS ver- (7.5) along with MS-Excel software was used to carry out statistical analysis.

Table 1. Effect of different levels of drip fertigation on yield of banana in West Bengal

Treatments	Yield (t/ha)	
	Plant crop	Ratoon crop
Irrigation		
I_1	35.3	33.0
I_2	42.8	39.5
I_3	41.4	38.1
SEm (±)	0.29	0.42
CD (P=0.05)	0.85	1.22
Fertilizer		
F_1	33.8	31.2
F_2	41.7	38.9
F_3	44.2	40.4
SEm (±)	0.29	0.42
CD (P=0.05)	0.85	1.22
Irrigation × Fertilizer		
I_1F_1	29.3	25.8
I_1F_2	37.6	36.1
I_1F_3	39.2	37.2
I_2F_1	34.1	32.4
I_2F_2	45.3	41.1
I_2F_3	49.2	44.1
I_3F_1	37.9	35.5
I_3F_2	42.2	38.7
I_3F_3	44.1	40.1
SEm (±)	0.51	0.73
CD (P=0.05)	1.47	2.12
SEm (±) for treatment	0.51	0.73
CD (P=0.05) for treatment	1.47	2.12
Mean drip irrigation	39.9	36.8
Conventional irrigation	37.1	34.8
SE(d) of contrast	0.54	0.77
CD (P=0.05) of contrast	1.55	2.23

Notes: I_1 = 50% CPE, I_2 =60% CPE, I_3 =70% CPE
F_1 = 50% RDF, F_2 =60% RDF, F_3 80% RDF

Results and Discussion

Yield of Banana

The levels of drip irrigation and drip-fertigation had a pronounced effect on fruit yields of both plant and ratoon crops. The banana yield differed significantly due to variations in fertilizer and irrigation levels (Table 1). The irrigation at 60 per cent CPE gave highest yield for both plant (42.9 t/ha) and ratoon (39.5 t/ha) crop, followed by 70 per cent CPE (41.4 t/ha and 38.1 t/ha, respectively), and 50 per cent CPE (35.4 t/ha and 33.0 t/ha, respectively). The application of 80 per cent RDF produced a higher yield (44.2 t/ha for plant and 40.5 t/ha for ratoon crop) than the other fertilizer application levels. In both the cases, ratoon crop produced a lower yield than plant crop. Bharambe *et al.* (2001) have also reported that yield of ratoon crop was lower than of plant crop irrespective of irrigation and fertilizer levels.

Among different interaction levels, the combined application of 60 per cent CPE irrigation and 80 per cent RDF provided higher yields (49.2 t/ha for plant crop and 44.1 t/ha for ratoon crop), followed closely by 60 per cent CPE irrigation and 60 per cent RDF (45.4 t/ha for plant crop and 42.0 t/ha for ratoon crop). The drip fertigation method provided a higher yield both in plant (39.9 t/ha) and ratoon crop (36.8 t/ha) as compared to by the conventional method of irrigation (37.1 t/ha and 34.8 t/ha for plant and ratoon crop, respectively), which might be the resultant effect of significant increase in bunch weight. The increase in bunch weight under drip irrigation was the consequence of significant difference in hand bunch and finger weight. These results support the earlier findings of Kumar and Pandey (2008).

The yield improvement under drip irrigation was mainly due to the maintenance of soil near field capacity throughout the growth period in the active root zone, leading to low soil suction, which thereby facilitated better water utilization, higher nutrients uptake and excellent maintenance of soil-water-air relationship with a higher oxygen concentration in the root zone (Kumar *et al*., 2007; Raina *et al*., 1999, 2011). In the traditional surface method of irrigation in banana cultivation, there is a considerable wastage of water due to runoff and deep percolation below the root zone and might invite several undesirable hazards such as leaching loss of available plant nutrients, water congestion with poor soil aeration and weed infestation leading to a declined fruit yield (Patel and Rajput, 2004). Kavino *et al.* (2002) have also stated that higher yield in a banana crop could be attributed to higher levels of N, P and K application in balanced proportions along with different irrigation levels at different crop stages. Similar results were obtained with the first crop of banana by other workers (Dahiwalkar *et al.,* 2004; Badgujar *et al.,* 2004).

Irrigation Water Requirement and Water-use Efficiency

The irrigation water-use was found to be highest under the conventional method of irrigation (57.0 cm for plant crop and 33.0 cm for ratoon crop) for the life-cycle of the crop (Table 2). The irrigation requirement of the crop was found to be lower in plants under drip fertigation. Considerable saving in water (41.7% in plant and 40.4% in ratoon crop) was observed in drip fertigation under 60 per cent CPE and 80 per cent RDF. Under this drip fertigation treatment, the yield of both plant and ratoon crop was also higher (32.5% and 26.4% for plant and ratoon crop, respectively) as compared to in the conventional method of irrigation.

The water-use efficiency (WUE) was found to be higher in plants under drip fertigation than under the conventional methods of irrigation (Table 2). The highest WUE was recorded in plants under 60 per cent CPE and 80 per cent RDF application and the lowest in conventional irrigated plants.

To sum-up, the drip fertigation economizes the water use and improves the crop yields.

Economic Analysis

The economics of different treatments in banana cultivation under both drip fertigation and conventional method of irrigation were worked out and are presented in Table 3 for plant crop and in Table 4 for ratoon crop. For plant crop, the drip fertigation system has been found more profitable than surface irrigation due to higher yield of banana plant. The gross as well as net returns were also higher when the crop was given irrigation at 60 per cent CPE + 80 per cent RDF; these were closely followed by the treatment with irrigation at 60 per cent CPE plus 60 per cent RDF. Both these treatment combinations yielded a higher return per rupee investment (₹ 2.41 and ₹ 2.36, respectively), indicating that investment on drip fertigation is economically viable for banana crop.

The water-saving due to drip fertigation over the conventional method was about 41.7 per cent in plant and 40.4 per cent in ratoon crop of banana. Considering the rapid decline in irrigation water availability and low WUE under the conventional method, appropriate steps should be taken to increase the area under drip fertigation in under to avoid demand-supply gap in water-use in near future. Drip fertigation treatments performed well with respect to net returns and return per rupee investment, but use of liquid fertilizer provided a considerable saving in solid fertilizers. But the high cost of liquid fertilizers vis-à-vis solid fertilizers increased the total cost on fertilization. Nevertheless, drip fertigation system reduced the labour costs by 15-20 per cent and allowed mechanized and easy cultivation. More *et al.* (2005) have revealed that a major portion of human labour was used for irrigating

Table 2. A comparison of yield and water use in banana crop under different levels of drip fertigation and conventional method of irrigation in West Bengal

Treatment	Irrigation water applied (cm)		Yield (kg/ha)		Irrigation water-use efficiency (kg/ha-cm)		Per cent increase in yield over conventional method	
	Plant crop	Ratoon crop	Plant crop	Ratoon crop	Plant crop	Ratoon crop	Plant crop	Ratoon crop
Irrigation								
I_1	27.7	16.4	35,330	33,000	1,276	2,014	-4.74	-5.28
I_2	33.3	19.7	42,860	39,480	1,289	2,007	15.55	13.31
I_3	38.8	22.9	41,400	38,070	1,068	1,659	11.62	9.27
Irrigation × Fertilizer								
I_1F_1	27.7	16.4	29,250	25,760	1,056	1,572	-21.13	-26.06
I_1F_2	27.7	16.4	37,590	36,090	1,303	2,203	1.34	3.58
I_1F_3	27.7	16.4	39,170	37,150	1,414	2,267	5.60	6.63
I_2F_1	33.3	19.7	34,070	32,400	1,025	1,648	-8.14	-7.00
I_2F_2	33.3	19.7	45,370	41,990	1,365	2,136	22.32	20.52
I_2F_3	33.3	19.7	49,140	44,040	1,479	2,239	32.48	26.40
I_3F_1	38.8	22.9	37,940	35,480	978	1,547	2.29	1.83
I_3F_2	38.8	22.9	42,180	38,640	1,088	1,685	13.72	10.90
I_3F_3	38.8	22.9	44,090	40,100	1,137	1,748	18.87	15.09
Mean drip irrigation	33.3	19.7	39,870	36,850	1,199	1,874	7.49	5.76
Conventional irrigation	57.0	33.0	37,090	34,840	650	1,056	—	—

the banana crop. Hence, farmers should be encouraged to adopt drip irrigation method which though somewhat costly, is labour-saving. Narayanamoorthy (2003) has concluded that investment on drip is economically-viable even without subsidy.

The drip fertigation system was found more profitable compared to surface irrigation (conventional method) in ratoon crop also due to increase in banana yield (Table 4). Similar to plant crop, gross and net returns were higher when the crop was given irrigation at 60 per cent CPE + 80 per cent RDF; these were closely followed by the treatment having irrigation at 60 per cent CPE plus 60 per cent RDF. These treatments also yielded higher returns per rupee investment. This indicates that investment on drip fertigation is economically viable for the ratoon crop also.

Narayanamoorthy (2006) has mentioned that water saving and the water-use efficiency of different crops are significantly higher under drip irrigation than under flood irrigation. The water-saving was about 29 per cent in banana due to adoption of drip irrigation over flood irrigation (Narayanamoorthy, 2003). They have further added that water required to produce one quintal of banana under drip method is only 1.33 horse power (HP) hours of water against the requirement of 3.17 HP hours of water under flood irrigation.

The drip fertigation system reduces labour cost by 15-20 per cent and favours mechanized and easy cultivation. Therefore, it can be inferred that though initial investment is higher on drip fertigation system than conventional method, the long-term benefits can be achieved in terms of water-saving, increased productivity and higher returns from banana cultivation.

Conclusions

Under drip method of irrigation, the water-use efficiency increases up to 90 per cent against the

Table 3. Economic analysis of plant crop of banana under drip fertigation and conventional method (per ha per year basis)

Treatment combinations (irrigation× fertilizer)	Cost of cultivation, without cost of irrigation & fertilization (₹/ ha)	Treatment cost or cost of irrigation & fertilizer (₹/ ha)	Total cost of cultivation (₹/ha)	Yield of banana (t/ha)	Gross return (₹/ ha)	Net return (₹/ ha)	Return per rupee investment (₹)
I_1F_1	79,800	34,822	1,14,622	29.3	1,90,125	75,503	1.65
I_1F_2	79,800	41,435	1,21,235	37.6	2,44,335	1,23,100	2.01
I_1F_3	79,800	54,318	1,34,118	39.2	2,54,605	1,20,487	1.89
I_2F_1	79,800	35,496	1,15,296	34.1	2,21,455	1,06,159	1.92
I_2F_2	79,800	42,109	1,21,909	45.4	2,94,905	1,72,996	2.41
I_2F_3	79,800	54,992	1,34,792	49.2	3,19,410	1,84,618	2.36
I_3F_1	79,800	35,986	1,15,786	37.9	2,46,961	1,31,175	2.13
I_3F_2	79,800	42,599	1,22,399	42.2	2,74,170	1,51,771	2.23
I_3F_3	79,800	55,482	1,35,282	44.1	2,86,585	1,51,303	2.11
Conventional method	74,800	69,725	1,44,525	37.1	2,41,085	96,560	1.67

Assumed market price of banana: ₹ 6.50 /kg (average)

Table 4. Economic analysis of ratoon crop of banana under drip fertigation and conventional method (per ha per year basis)

Treatment combinations (irrigation× fertilizer)	Cost of cultivation, without cost of irrigation & fertilization (₹/ ha)	Treatment cost or cost of irrigation & fertilizer (₹/ ha)	Total cost of cultivation (₹/ha)	Yield of banana (t/ha)	Gross return (₹/ ha)	Net return (₹/ ha)	Return per rupee investment (₹)
I_1F_1	62,050	34,822	96,872	25.8	1,80,320	83,448	1.86
I_1F_2	62,050	41,435	1,03,485	36.1	2,52,630	1,49,145	2.44
I_1F_3	62,050	54,318	1,16,368	37.2	2,60,050	1,43,682	2.23
I_2F_1	62,050	35,496	97,546	32.4	2,26,800	1,29,260	2.32
I_2F_2	62,050	42,109	1,04,159	41.9	2,93,930	1,89,771	2.82
I_2F_3	62,050	54,992	1,17,042	44.0	3,08,280	1,91,238	2.63
I_3F_1	62,050	35,986	98,036	35.5	2,48,360	1,50,324	2.53
I_3F_2	62,050	42,599	1,04,649	38.6	2,70,480	1,65,831	2.58
I_3F_3	62,050	55,482	1,17,532	40.1	2,80,700	1,63,168	2.38
Conventional method	57,050	69,725	1,26,775	34.9	2,43,880	1,17,105	1.93

Assumed market price of banana: ₹ 7.00 /kg (average) efficiency of 30-40 per cent under the conventional flood method. Besides saving of water, it also increases productivity of crops, reduces cost of cultivation and energy-use. The study has show that water-saving due to drip fertigation over the conventional method is about 41.7 per cent in plant and 40.4 per cent ratoon crop of banana. Under the same drip fertigation, the yield has been higher of both plant crop (32.5%) and ratoon crop (26.4%) over the conventional method. Considering the rapid decline in irrigation-water availability and low water-use efficiency under the conventional method, appropriate initiatives should be taken to increase the area under drip fertigation to avoid demand-supply gap in water-use in the near future. The private benefit-cost ratio, estimated using discounted cash flow technique, has clearly indicated that drip investment is economically viable even without subsidy.

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