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Techno-economic feasibility of microirrigation in pineapple under the Gangetic alluvial plain of West Bengal

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ABSTRACT

A field investigation was conducted in the Gangetic alluvial plain of West Bengal for consecutive three years (2005-07, 2007-09, 2009-11) to assess the techno-economic feasibilities of micro-irrigation systems on yield, water use efficiency and economics of pineapple. The experiment consisted of eight irrigation treatments replicated thrice was laid out in a randomized block design. The results showed that maximum fruit yield of 56.86 t ha^{-1} was obtained with higher level of drip irrigation at 1.0 Eo (evaporation replenishment) and was superior to drip, micro-sprinkler and sub-surface irrigation at all levels. Surface irrigation was quite inferior in promoting yield, economics and water use efficiency. Drip irrigation at 0.6 Eo recorded the higher yield, maximum water use efficiency, water saving and benefit-cost ratio. Alternatively, micro-sprinkler irrigation at 0.6 Eo or, subsurface irrigation at 1.0 Eo could also be advantageous for obtaining higher fruit yield, water utilization and saving and economic benefit.

Key words: Gangetic alluvial plain, economics, pineapple, microirrigation, water use efficiency.

INTRODUCTION

Pineapple (*Ananas comosus* Merr.) is an important and popular fruit crop in India due to its wide adaptability to varying soil and climatic conditions. It has immense potential in increasing the productivity and yield sustainability with assured supply of irrigation water. The farmers generally follow the surface method of irrigation, which is inefficient and leads to excessive water and nutrients losses through runoff and deep percolation (Hedge and Srinivas, 5; Hebbar *et al.*, 4). There is an urgent need to produce maximum per drop of water (Singh and Saha, 18; Raina *et al.*, 13). Microirrigation system provides an opportunity of judicious use of water and other agricultural inputs involving less energy for irrigation (Kumar *et al.*, 7). However, drip irrigation is undoubtedly the most advanced irrigation technology in India which offers a great promise due to higher water and nutrient use efficiency of crop against lower amounts of water and nutrient applied (Raina *et al.*, 14; Kumar *et al.*, 6). It proved its superiority over surface irrigation by applying precise quantity of water in the vicinity of root zone matching with the crop water requirement (Prasad *et al.*, 12; Veeraputhiram *et al.*, 20), besides saving 12-84% of irrigation water and increasing crop productivity by 10-55% (Berad *et al.*, 2; Sharma and Kumar, 15). Sub-surface irrigation is more advantageous than surface drip irrigation due to more reduction in evaporation and deep percolation losses and elimination of surface runoff (Narda and Lubana, 9; Matouk *et al.*, 8; Patel and Rajput, 11). Microsprinkler irrigation system also helps to maintain favourable soil water balance in the root zone by way of limited wetted zone and augmenting water and nutrient uptake, although there is considerable evaporation and runoff loss of water (Kumar *et al.*, 7).

The information relating to the efficacy of microirrigation technique on pineapple is rather limited. The present study was, therefore, undertaken to assess the feasibilities of different microirrigation and sub-surface irrigation systems compared to conventional surface irrigation on yield, water use efficiency and economics of pineapple production in the Gangetic alluvial plain of West Bengal.

MATERIALS AND METHODS

A field experiment was conducted on pineapple for consecutive 3 years (2005-07, 2007-09 to 2009-11) at the Central Research Farm, Bidhan Chandra Krishi Viswavidyalaya, Nadia (23°N latitude, 89°E longitude) representing the Gangetic alluvial plain of West Bengal. The soil is sandy loam with available N 182.4 kg ha^{-1}, P 18.9 kg ha^{-1} and K 135.6 kg ha^{-1}. Mean monthly maximum and minimum temperature and daily pan evaporation during the crop seasons varied from 33.8-20.5°C and 27.4-8.1°C and 0.8-5.5 mm, respectively. Average annual rainfall was 1,650 mm. In microirrigation system, water was applied based on

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the evaporation replenishment (Eo). The experiment consisted of eight irrigation treatments (T_1 = drip at 1.0 Eo, T_2 = drip at 0.8 Eo, T_3 = drip at 0.6 Eo, T_4 = microsprinkler at 1.0 Eo, T_5 = microsprinkler at 0.8 Eo, T_6 = microsprinkler at 0.6 Eo, T_7 = subsurface irrigation at 1.0 Eo and T_8 = conventional surface irrigation) was arranged in a randomized block design (RBD) with three replications.

Thirty-day-old healthy suckers of pineapple cv. Kew were planted at a spacing of 30 cm × 50 cm × 70 cm in paired row system for a density of 44,440 plants ha^{-1}. Crop was planted on 19th November of 2005, 2007 and 2009 and harvested in several pickings between June to July of 2007, 2009 and 2011, respectively. The recommended fertilizers for pineapple were 600-400-600 kg ha^{-1} of N, P_2O_5 and K_2O applied through urea, single superphosphate and muriate of potash, respectively. FYM @ 10 t ha^{-1} with full P and K and one-fourth of N were given at planting and the remaining N was top-dressed in 3 equal splits at 15, 50 and 65 weeks after planting. Standard cultural operations and adequate plant protection measures were adopted uniformly.

The crop water requirement was computed on daily basis following the equation as suggested by Shukla *et al*. (16).

V = Ep × Kp × Kc × Sc × Wp

Where, V = volume of water (L day^{-1} $plant^{-1}$), E_p = pan evaporation (mm day^{-1}), K_p = pan factor, K_c = crop factor, S_c = crop spacing and W_p = wetted area. The crop factor values used for different crop stages were computed based on the existing relative humidity and wind velocity (Doorenbos *et al*., 3). The pan factor value was 0.7 as suggested for USDA class A pan. A separate lateral line (12 mm dia) was laid for each drip and microsprinkler treatment. There were two drippers for each plant placed at a distance of 30 cm on either side of plants with discharge rate of 4 lph. There was one overhead micro-microsprinkler for every four plants with a discharge rate of 38 lph. In the subsurface irrigation system, laterals (16 mm diameter) were buried at 25 cm depth in the soil along the crop rows with one porous pipe (15 mm dia) between two plants (Narda and Lubana, 9) having a discharge of 9.6 lph per metre of pipe length. Water use efficiency of crop was computed by dividing fruit yield with total water use.

RESULTS AND DISCUSSION

A perusal of data showed that different levels of drip, microsprinkler and sub-surface irrigation registered significantly the higher fruit yield over surface irrigation in all the years and their average values (Table 1). It is conspicuous that pineapple, although a shallow rooted crop, appeared to be sensitive to the curtailment of water supply either through drip or microsprinkler irrigation system, which was reflected in the concomitant decrease in fruit yield over the years. Among three irrigation levels, the highest fruit yield (56.86 t ha^{-1}) was obtained with drip irrigation schedule at 1.0 Eo (evaporation replenishment) and was superior to the remaining irrigation levels under drip, microsprinkler and subsurface irrigation systems. The average increase in yield was 8.6, 10.9 and 15.4% in drip irrigation schedule at 0.6, 0.8 and 1.0 of Eo, respectively over surface irrigation. The improvement in yield under drip irrigation might be ascribed to the better water utilization, higher nutrients uptake and excellent maintenance of soil-water-air relationship with higher oxygen concentration in the root zone by way of timely and precise application of water directly to the crop root zone with concomitant reduction of nutrients losses through runoff, leaching and deep percolation (Raina *et al*., 14, 13; Singandhupe

Table 1. Effects of drip, microsprinkler, subsurface and surface irrigation at various level on fruit yields of pineapple during the period of three cropping seasons.

Irrigation level	Fruit yield (t ha^{-1})			Mean (t ha^{-1})
	2005-2007	2007-2009	2009-2011	
Drip at 1.0 E_0	56.67	58.54	55.37	56.86
Drip at 0.8 E_0	54.36	56.40	53.15	54.64
Drip at 0.6 E_0	53.20	54.63	52.70	53.51
Microsprinkler at 1.0 E_0	52.34	50.22	49.20	50.58
Microsprinkler at 0.8 E_0	48.17	48.40	47.15	47.90
Microsprinkler at 0.6 E_0	46.10	46.82	45.78	46.23
Subsurface at 1.0 E_0	47.55	55.68	52.67	51.97
Surface	45.10	52.82	49.86	49.26
CD at 5%	2.19	1.87	1.92	1.98

et al., 17; Tiwari *et al.*, 19). In addition, drip irrigation might facilitate to maintain the soil moisture near field capacity throughout the growth period in the active root zone, thereby influenced the root CEC and increased water and nutrients uptake leading to higher fruit production (Bangar *et al.*, 1). Drip irrigation also provided optimal water supply matching with the crop water requirement around the root rhizosphere compared to conventional surface irrigation which might have resulted in larger and heavier fruits (Paoli *et al.*, 10; Patel and Rajput, 11). In the present study, individual weight of the fruit without crown under drip system regardless of irrigation levels varied from 1.4 to 1.6 kg.

In microsprinkler system, the irrigation schedule at 1.0 E_0 recorded maximum fruit yield over irrigation schedules of 0.8 and 0.6 E_0 in all the years. The average increase in yield at the highest irrigation level was only 2.7% in comparison to surface irrigation. This indicated that microsprinkler irrigation in promotion of fruit yield was not as effective as in drip irrigation. The effect was almost comparable with surface irrigation, mainly due to unbalanced soil moisture distribution pattern around the root zone caused by the extended wetted front and considerable evaporation loss of applied water. The subsurface irrigation also showed significantly the higher fruit yield as compared to surface irrigation in each year and the overall increase in yield was only 5.5%. The performance of subsurface irrigation in enhancing the fruit yield, on an average, was 2.75% higher than that of the microsprinkler irrigation. The results are in agreement with the findings of Matouk *et al*. (8) who observed the highest fruit yield of grape under subsurface irrigation as compared to surface irrigation system. The conventional surface irrigation, on the other hand, might have resulted in water stress during critical period, aeration hazard immediately after irrigation, considerable water and nutrients losses in runoff and deep percolation and soil-water-nutrient imbalance due to heavy load of water application, which led to the declined yield (Hegde and Srinivas, 5).

During the cropping season, average depth of irrigation water applied through drip and microsprinkler irrigation at 1.0, 0.8 and 0.6 of E_0 was 495, 396, 297 mm and 525, 420, 315 mm, respectively; whereas, the corresponding figures for subsurface and surface irrigation was 536 and 703 mm, respectively. The effective rainfall was 420 mm and soil profile moisture contribution irrespective of irrigation levels ranged from 38.6 to 45.0 mm. Accordingly, the total water used by the plant was 953.6, 858.7 and 762.0 mm for drip irrigation at 1.0, 0.8 and 0.6 of E_0, respectively and the corresponding values for microsprinkler irrigation was 987.0, 883.3 and 777.4 mm. This figure was 997 mm for sub-surface irrigation and 1163.5 mm for surface irrigation (Table 2). Water use efficiency (WUE) by plant was calculated as the ratio of fruit yield and total water use including irrigation water applied, effective rainfall and soil profile moisture contribution. The overall results indicated that WUE was variable in different microirrigation systems. However, the higher WUE (59.6-70.2 kg $ha^{-1}mm^{-1}$) by plant was recorded in drip irrigation immediately followed by microsprinkler (51.2-59.5 kg $ha^{-1}mm^{-1}$) and subsurface irrigation (52.1 kg $ha^{-1}mm^{-1}$) and the least (42.3 kg $ha^{-1}mm^{-1}$) in surface irrigation. There was a general trend of increasing WUE with decrease in irrigation levels, the more so in drip irrigation than in microsprinkler irrigation. The higher water use efficiency in drip irrigation in comparison to microsprinkler, subsurface and surface irrigation system was the result of better water utilization as precise amounts was delivered directly into crop root zone at right time, thus inhibiting water losses in evaporation, run-off, seepage and deep percolation as was conspicuously detected in

Table 2. Effects of drip, microsprinkler, sub-surface and surface irrigation at various level on water use, water use efficiency and water saving of pineapple (pooled over 3 years).

Irrigation level	Effective rainfall (mm)	Profile moisture contribution (mm)	Irrigation water (mm)	Water use (mm)	Water use efficiency (kg $ha^{-1}mm^{-1}$)	Water saving (%)
Drip at 1.0 E_0	420	38.6	495	953.6	59.63	18.0
Drip at 0.8 E_0	420	42.7	396	858.7	63.63	26.2
Drip at 0.6 E_0	420	45.0	297	762.0	70.22	34.5
Microsprinkler at 1.0 E_0	420	42.0	525	987.0	51.25	15.1
Microsprinkler at 0.8 E_0	420	43.3	420	883.3	54.23	24.1
Microsprinkler at 0.6 E_0	420	42.4	315	777.4	59.47	33.2
Subsurface at 1.0 E_0	420	41.0	536	997.0	52.13	14.3
Surface	420	40.5	703	1163.5	42.34	-

Table 3. Economics of pineapple cultivation under drip, microsprinkler, subsurface and surface irrigation methods.

Irrigation level	Mean yield ($t\ ha^{-1}$)	No. of fruits	Gross return (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Benefit: cost ratio
Drip at 1.0 E_0	56.86	37,906	1,51,624	48,050	1,03,574	3.15
Drip at 0.8 E_0	54.64	36,426	1,45,704	45,490	1,00,214	3.20
Drip at 0.6 E_0	53.50	35,666	1,42,664	42,930	99,734	3.32
Microsprinkler at 1.0 E_0	49.20	32,800	1,31,200	47,150	84,050	2.78
Microsprinkler at 0.8 E_0	47.14	31,426	1,25,704	44,770	80,934	2.81
Microsprinkler at 0.6 E_0	46.98	31,320	1,25,280	42,390	82,890	2.95
Subsurface at 1.0 E_0	51.97	34,646	1,38,584	48,750	89,834	2.84
Surface	49.89	33,260	1,33,040	51,450	81,590	2.58

Cost of cultivation- Rs. 35,250 ha^{-1}; cost on drip irrigation per ha = Rs. 12,800 at 1.0 E_0, Rs. 10,240 at 0.8 E_0, Rs. 7,680 at 0.6 E_0; cost on microsprinkler irrigation per ha = Rs. 11,900 at 1.0 E_0, Rs. 9,520 at 0.8 E_0, Rs. 7,140 at 0.6 E_0; cost on subsurface irrigation per ha = Rs. 13,500 and surface irrigation per ha = Rs. 16,200; cost of fruit per piece = Rs. 4; average weight of fruits = 1.5 kg.

surface irrigation (Raina *et al*., 13). The water savings under overall microirrigation system was found to vary from 14.3 to 34.5% as compared to surface irrigation method. Maximum water saving of 34.5% followed by to 33.2% was obtained in drip and microsprinkler irrigation at 0.6 of E_0, respectively. The water saving for subsurface irrigation system at 1.0 E_0 was only 14.3%.

The economic analysis (Table 3) of different microirrigation systems on pineapple production showed that relatively higher benefit-cost ratio (3.15-3.32) was obtained from drip irrigation, followed by that of microsprinkler (2.78-2.95) and sub-surface irrigation (2.81). Application of higher level of irrigation to plant using drip or microsprinkler system usually resulted in higher monetary returns, but lesser benefit-cost ratio. This was particularly due to the higher cost involvement on irrigation water. The performance of sub-surface irrigation in terms of gross and net monetary returns was comparatively higher than in microsprinkler irrigation at all levels. However, the benefit-cost ratio was considerably lower at lower level of irrigation, but was competitive at moderate to higher level of irrigation. On the contrary, the lower net return and benefit-cost ratio (2.58) was obtained from the conventional surface irrigation.

Microirrigation is an efficient method of irrigation for pineapple production in the Gangetic alluvial plain of West Bengal. The beneficial effect in increasing fruit yield, water utilization and saving was more pronounced in drip irrigation than in microsprinkler and subsurface irrigation. Maximum fruit yield can be obtained with drip irrigation at 1.0 E_0 (evaporation replenishment) and was superior to the remaining methods of irrigation at all levels. Drip irrigation at 0.6 E_0 registered maximum WUE, water savings and benefit-cost ratio. Alternatively, microsprinkler irrigation at 0.6 E_0 or, subsurface irrigation at 1.0 E_0 could also be used advantageously for achieving higher yield, WUE, water savings and economic returns, which likely to be benevolent to the pineapple growers in the region.

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