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Research Paper

Effect of planting methods and irrigation schedules on cane yield, quality, economics and water productivity of spring sugarcane (*Saccharum officinarum*) in South Western Punjab

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ABSTRACT

The present experiment was conducted during 2009–10 to 2011–12 at Faridkot, Punjab, to study the influence of planting methods and irrigation schedules on cane and sugar yields and water productivity of sugarcane (*Saccharum officinarum*). The experiment was laid out in randomized complete-block design with combinations of 3 planting methods [conventional flat planting at 75-cm-row spacing, paired-row trench planting at 30 : 120-cm-row spacing and furrow irrigated raised bed (FIRB) method at 75-cm-row spacing methods] and 3 irrigation schedules [irrigation at 0.5, 0.75 and 1.0 irrigation water: cumulative pan evaporation (IW: CPE)]. The paired-row trench and FIRB planting systems while being statistically at par with each other resulted in significantly higher cane and sugar yields than conventional flat planted sugarcane. The paired-row trench and FIRB planting systems provided 16.1 and 13.7, and 16.9 and 14.1% higher cane and sugar yield than conventional planting, respectively. The net returns and benefit: cost also followed the similar trends. The sugarcane and sugar yields increased significantly with successive increase in frequency of irrigation from 0.5 to 1.0 IW: CPE, while reverse trend was observed for water productivity. The highest cane and sugar yields were recorded in paired-row trench-planted crop irrigated at 1.0 IW: CPE, which was statistically at par with paired-row trench-planted cane irrigated at 0.75 and FIRB irrigated at 1.0 IW: CPE but significantly better than other combinations of irrigation schedules and methods of planting. Paired-row trench-planted sugarcane resulted in statistically at par cane yield with FIRB and significantly better than conventional planting with 25% less water.

Key words : Cane yield, Economics analysis, Irrigation scheduling, Sugarcane planting methods, Sugar yield, Water productivity

Sugarcane is one of the important tropical crops and requires warm humid climate for efficient solar-energy harvest and to produce 1 tonne sugarcane, the crop needs 125 tonnes water (Jamuna *et al.,* 1994). There is a linear relationship between the growth rate and optimum soil moisture because only vegetative growth is of economic importance (Singh and Mohan, 1994). Sugarcane being one year crop has high water requirement than other crops because of long tillering phase during summer months when there is higher evaporative demand. Formative phase of the crop, in which the crop remains young and tender, coincides with hot and desiccating summer and hence, optimum soil moisture is of paramount important to get good yields. Lal and Shukla (2000) reported that only 35% of the total area under sugarcane receives optimum irrigation and remaining 65% area is under sub-optimum irrigation or un-irrigated. In tropical India, the number of irrigations range from 30 to 36; while in the subtropics 5 to 10 irrigations are required with a depth of 80 mm. The water requirement of sugarcane in India varies widely from 1,143 to 3,048 mm (Hapase *et al*., 1990). Scientists have worked to enhance irrigation water-use efficiency 1.5–2.5 times through devising advance irrigation methods or modifying existing surface-irrigation methods. It is generally accepted that adoption of irrigation in a scientific manner by farmers is far below the expectations and farmers need more comprehensive technological support that is simpler to use and can be integrated into farm management. Non-optimum yields of sugarcane are obtained by maintaining very high moisture in entire rhizosphere during the entire growing season, until about 1 month before harvesting. Thus, irrigation scheduling based on climato-

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logical approach is need of the hour for increasing water-use efficiency in sugarcane. Irrigation scheduling based on pan evaporation reduces the irrigation requirement without any adverse effect on the yields. The major advantage of this approach is that farmers need not change the amount of water applied from one irrigation to another and the event of rain also taking care off. Irrigation based on this approach permits the computation of a timetable for the irrigation, provided the pattern of pan evaporation does not show much yearly variation during the growing period (Singh *et al*., 2007). Over the period, different planting methods have been developed for improving cane productivity. These methods vary in bed configuration and therefore, in evapo-transpiration (ET) losses (Singh, 2012). Conventional flat method is less-time consuming but has low germination of sugarcane (30–35%), due to fast depletion of soil moisture, lesser plant population that lowers cane yield. Over-shading and mutual competition among plants are other reasons for lower productivity of sugarcane grown through flat method. Paired-row trench planting and furrow-irrigated raised bed (FIRB) method of sugarcane helps in generation of greater proportion of mother shoots and primary tillers that are responsible for higher yield and better quality. Various studies indicated yield advantage owing to changing the micro-environment with planting methods like pit planting and paired-row trench planting over conventional method (Yadav and Kumar, 2005). Consequently, the interval between irrigations may differ under these planting methods. Keeping these in view, the present field experiment was conducted to optimize irrigation schedule in sugarcane under different planting methods.

MATERIALS AND METHODS

A field experiment was conducted at Punjab Agricultural University, Regional Station, Faridkot, Punjab, during 2009–10 to 2011–12 (30º67' N, 74º 74' E, 201 m from mean sea-level). The meteorological data recorded at the meteorological observatory of Regional Station, Faridkot, during the crop-growing season is presented in Fig. 1. The soil of the experimental field was sandy loam, slightly alkaline (pH 8.1), with normal electrical conductivity (EC) (0.34 dS/cm), medium in organic carbon (0.40%), low in available N (270.5 kg/ha), low in available P (9.8 kg/ha) but high in available K (521 Kg/ha). The experiment was laid out in randomized complete-block design with combinations of 3 planting methods (flat planting at 75-cm-row spacing, paired-row trench-planting at 30: 120-cm-row spacing and furrow-irrigated raised bed (FIRB) method at 75-cm-row spacing) and 3 irrigation schedules (irrigation at 0.5, 0.75 and 1.0 irrigation water: cumulative pan evaporation (IW: CPE) with 3 replications. Sugarcane

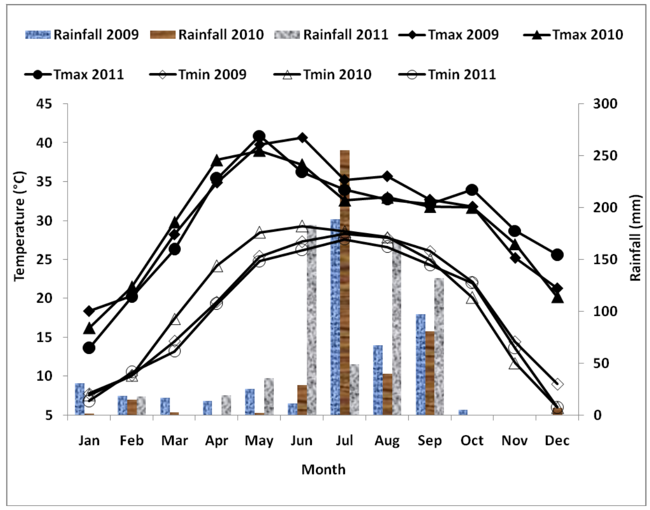

Fig. 1. Meteorological data recorded at meteorological observatory during 2009–2011

cultivar 'CoJ 88' was planted on 16, 18 and 4 February during 2009, 2010 and 2011, respectively, using 150,000 buds/ha. The cane setts were treated with Emisan 6 before planting and Chlorpyriphos 20% EC was sprayed over cane setts before covering them with soil to protect from termite and early shoot-borer. Nitrogen @ 150 kg/ha was applied in two equal splits–half at first irrigation and half in May through urea. To compute irrigation water applied, water head was measured on parshall flume installed at start of water channel and time was noted to fill the experimental units to the pre-marked levels. Total water applied during whole crop growing season was calculated by cumulating the irrigation-wise depth of water delivered and number of irrigation applied. Profile water use was worked by subtracting the water left in soil profile at harvest from the water content at time of planting. Cane yield was recorded after topping and trash stripping given as t/ha. Five millable canes were taken at random from each plot for determining cane length and cane thickness. Juice-quality analysis was done after weighing and crushing through 3 roller miller. A sub sample of crushed cane juice was analyzed for <ºbrix (total solids) by a brix hygrometer. Commercial cane sugar % (CCS) and sugar yield (CCS t/ha) was calculated as per Sastry and Chari (1960).

Commercial cane sugar (%) = [S – (B – S) 0.4] × 0.73
where S = sucrose per cent juice (pol %) and B = Brix

Commercial cane sugar yield: (t/ha) =

$$\frac{\text{CCS}}{100} \% \times \text{Sugarcane yield (t/ha)}$$

The apparent crop water productivity (ACWP) and total crop water productivity (TCWP) were estimated as a function of sugar yield as per Brar *et al.* (2012).

ACWP (kg/m^3) = Sugar yield/irrigation water applied

TCWP (kg/m^3) = Sugar yield/total water expense

RESULTS AND DISCUSSION

Planting methods

Pooled analysis of 3 years data (Table 1) revealed that the number of shoots per unit area was significantly higher in FIRB planting than conventional and paired-row planting. Better sprouting of buds in FIRB system resulted from thin layer of moist soil cover over cane sets in furrows which provided congenial rhizospheric environment around the setts. However, number of millable canes was significantly higher with paired-row planting than FIRB and conventional methods because of better tillering in paired-row planting nullified the effect of better emergence with FIRB methods. Cane length, cane diameter, single cane weight were statistically at par in FIRB and paired-row planting methods which resulted at par cane and sugar yields under both the methods. Bhullar *et al.* (2008) conducted an experiment on flat, paired-row trench-and pit planting methods in sugarcane and reported that trench planting recorded the highest number of shoots and millable canes, whereas pit planting the highest single-cane weight. Singh (2012) also observed significantly higher tiller count in paired-row planting over FIRB in the month of June (at 105 days after planting). The quality traits of juice, viz. sucrose content and CCS, remained statistically at par among all the 3 methods of planting. Irrigation water applied and total water expense remained same in all the three methods of planting because irrigations were applied at same IW: CPE schedules to all the methods of planting (Table 2). However, apparent and total crop water productivity was the highest in paired-row planting which was at par with FIRB but significantly higher than conventional planting because of significantly higher cane yield. Idnani and Kumar (2012) also reported the lowest consumptive use of water and higher water-use efficiency in FIRB method than other sowing methods in wheat. Net returns and benefit: cost ratio were also statistically at par between paired-row trench and FIRB planting but significantly higher than conventional planting. The paired-row trench planting and FIRB planting gave 34.0 and 30.1% higher net returns than conventional planting of sugarcane (Table 3).

Irrigation schedules

Yield parameters of sugarcane improved significantly with the increase in frequency of irrigation (Table 1). The number of millable canes was significantly higher in crop irrigated at IW: CPE of 1.0 than irrigated at 0.75 and 0.50 IW: CPE schedule. This was because of better sprouting and tillering of crop under frequent watering, which improved the microclimatic condition in the crop during summer months. Similarly, single cane weight was also significantly higher in frequent irrigation applied at an IW: CPE schedule of 1.0 than 0.75 and 0.50 IW: CPE schedules, because of improved physiological processes. These all yield-attributing characters resulted in significantly higher cane and sugar yields in crop irrigated at an IW: CPE of 1 than IW: CPE schedules of 0.5 and 0.75. Kumar and Srivastava (1991) also reported significant increase in cane yield with frequent irrigation at IW CPE of 0.8 over IW CPE of 0.5 owing to improved uptake of water with dissolved nutrients in frequently irrigated crop. Juice-quality traits like sucrose content and CCS remained statistically at par among all the 3 irrigation schedules. Irrigation

Table 1. Yield and quality parameters of spring sugarcane as influenced by planting methods and irrigation schedules (pooled data of 3 years)

Treatment	Number of shoots (000/ha)	NMC (000/ha)	Cane length (cm)	Cane diameter (cm)	Single cane weight (g)	Cane yield (t/ha)	Sugar yield (t/ha)	Sucrose (%)	CCS (%)
Planting method									
Conventional flat	178.6	97.0	190.3	2.55	852	65.8	8.68	18.67	13.20
Paired-row trench -planting	187.1	105.7	202.6	2.60	886	76.4	10.15	18.80	13.29
*FIRB	202.4	100.6	203.2	2.55	877	74.8	9.90	18.77	13.32
SEm±	3.45	1.27	3.24	0.033	14.2	1.01	0.14	0.121	0.104
CD (P=0.05)	9.8	3.6	9.2	NS	NS	2.9	0.39	NS	NS
Irrigation schedule									
0.50 IW: CPE	181.9	90.6	188.8	2.56	818	64.5	8.45	18.63	13.16
0.75 IW: CPE	192.2	103.6	202.5	2.58	892	73.7	9.82	18.80	13.33
1.0 IW: CPE	193.9	109.0	204.8	2.55	905	78.7	10.46	18.81	13.31
SEm±	3.45	1.27	3.24	0.033	14.2	1.01	0.14	0.121	0.104
CD (P=0.05)	9.8	3.6	9.2	NS	40	2.9	0.39	NS	NS

FIRB, Furrow-irrigated raised bed method; CCS, commercial cane sugar: IW: CPE, irrigation water, cumulative pan evaporation water applied and water expense were 35 and 69.3, and 29.6 and 65.5 cm higher in crop irrigated at an IW CPE of 1 over that irrigated IW: CPE schedules at of 0.75 and 0.50 (Table 2), which resulted in 30.8 and 59.7, and 11.9 and 25.3% less apparent and total crop-water productivity respectively. The gross returns, net returns and benefit: cost were also significantly higher in crop irrigated at an IW: CPE of than IW: CPE of 0.75 and 0.5 (Table 3).

Interaction

Interaction between sugarcane-planting methods and irrigation schedules was significant (Table 4) for cane yield, sugar yield, water productivity and net returns. The data revealed that maximum cane yield, sugar yield and net returns were recorded in paired-row trench-planted crop irrigated at an IW: CPE of 1, which was at par with FIRB irrigated at same schedule and paired-row planted at IW: CPE schedule of 0.75 but significantly better than all other combinations of methods of planting and irrigation schedules. The data further manifested that paired-row trench and FIRB-planted crop gave statistically at par cane yield, sugar yield and net returns when irrigated either at 1.0 or 0.75 IW: CPE schedule. However, there was significant increase in cane as well sugar yields with the increase in IW: CPE level from 0.75 to 1.0 in conventional planted crop. Thus, conventional planted crop must be irrigated at 1.0 IW: CPE, while paired-row and FIRB-planted crop can be irrigated at 0.75 IW: CPE to get similar yield. The FIRB

Table 2. Effect of methods of planting and irrigation schedules on total water expense (cm) and water productivity of spring sugarcane (pooled data of 3 years)

Treatment	Irrigation water applied (cm)	Effective rainfall (cm)	Profile water use (cm)	Total water expense (cm)	Apparent water productivity (kg/m^3)	Total water productivity (kg/m^3)
Planting method						
Conventional flat	107.5	36.3	8.5	152.3	0.853	0.576
Paired-row trench-planting	107.5	36.3	8.5	152.3	1.006	0.678
*FIRB	107.5	36.3	8.5	152.3	0.993	0.665
SEm±	-	-	-	-	0.016	0.010
CD (P=0.05)	-	-	-	-	0.045	0.029
Irrigation schedule						
0.50 IW: CPE	72.0	37.4	9.2	118.6	1.193	0.713
0.75 IW: CPE	109.3	36.7	8.5	154.5	0.912	0.637
1.0 IW: CPE	141.3	34.9	7.7	183.9	0.747	0.569
SEm±	-	-	-		0.016	0.010
CD (P=0.05)	-	-	-	-	0.045	0.029

FIRB, Furrow-irrigated raised bed method; CCS, commercial cane sugar: IW: CPE, irrigation water, cumulative pan evaporation

Table 3. Economics analysis of spring sugarcane as influenced by planting methods and irrigation schedules (pooled data of 3 years)

Treatment	Input cost (×10^3 ₹/ha)	Gross returns (×10^3 ₹/ha)	Net returns (×10^3 ₹/ha)	Benefit: cost ratio
Planting method				
Conventional flat	78.9	135.1	56.2	0.71
Paired-row trench-planting	81.0	156.3	75.3	0.93
*FIRB	80.7	153.8	73.1	0.90
SEm±	-	2.1	1.9	0.02
CD (P=0.05)	-	6.0	5.4	0.06
Irrigation schedule				
0.50 IW: CPE	78.3	132.6	54.3	0.69
0.75 IW: CPE	80.5	151.1	70.6	0.88
1.0 IW: CPE	81.8	161.4	79.6	0.97
SEm±	-	2.1	1.9	0.02
CD (P=0.05)	-	6.0	5.4	0.06

FIRB, Furrow-irrigated raised bed method; CCS, commercial cane sugar: IW: CPE, irrigation water, cumulative pan evaporation

Table 4. Interactive effect of methods of panting and irrigation schedules on cane yield, sugar yield, apparent water productivity total water productivity and net returns of spring sugarcane (pooled data of 3 years)

Irrigation schedule	Planting method		
	Conventional	Paired-row	FIRB
	Cane yield (t/ha)		
0.50 IW: CPE	56.3	67.2	69.9
0.75 IW: CPE	65.0	80.1	76.0
1.0 IW: CPE	76.0	81.7	78.5
CD (P=0.05)	5.0 (1.75)*		
	Sugar yield (t/ha)		
0.50 IW: CPE	7.29	8.90	9.15
0.75 IW: CPE	8.69	10.66	10.13
1.0 IW: CPE	10.07	10.90	10.41
CD (P=0.05)	0.69 (0.25)		
	Apparent water productivity (kg/m³)		
0.50 IW: CPE	1.031	1.254	1.294
0.75 IW: CPE	0.808	0.986	0.943
1.0 IW: CPE	0.72	0.779	0.743
CD (P=0.05)	0.078 (0.028)		
	Total water productivity (kg/m³)		
0.50 IW: CPE	0.615	0.750	0.772
0.75 IW: CPE	0.563	0.691	0.657
1.0 IW: CPE	0.548	0.594	0.566
CD (P=0.05)	0.50	(0.018)	
	Net returns (×10³ ₹/ha)		
0.50 IW: CPE	39.2	59.0	64.7
0.75 IW: CPE	54.8	82.1	75.2
1.0 IW: CPE	74.6	84.9	79.2
CD (P=0.05)	9.4 (3.3)		

The value mentioned in the parenthesis is SEm±
IW: CPE, Irrigation water: cumulative pan evaporation

and paired-row trench-planted crop gave the maximum and statistically at par water productivity at 0.50 IW: CPE, which was significantly higher than all other combinations of methods of planting and irrigation schedules. The apparent and total crop-water productivity decreased significantly in all the methods of planting with the increase in IW: CPE because of increase in volume of irrigation water applied.

The paired-row trench and FIRB-planted sugarcane resulted in statistically at par but significantly higher cane yield, sugar yield and net returns than conventional method. The cane yield, sugar yield and net returns increased significantly and successively with increase in frequency of irrigation from 0.5 to 1.0 IW: CPE ratio, while reverse trend was seen for water productivity. Paired-row trench-planted sugarcane provided statistically at par cane yield and net returns with FIRB, but significantly better than conventional planting with 25% less water. Thus, conventional planted crop should be irrigated at 1.0 IW: CPE, while paired-row and FIRB-planted crop can be irrigated at 0.75 IW: CPE to get similar yield.

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