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Optimizing irrigation schedule in sugarcane (*Saccharum spp.* hybrid complex) under different planting methods in sub-tropical India

ISHWAR SINGH

Indian Institute of Sugarcane Research, Lucknow, Uttar Pradesh 226002

ABSTRACT

A field experiment was conducted at the Research Farm of Indian Institute of Sugarcane Research, Lucknow for two consecutive crop seasons of 2009-10 and 2010-11 to optimize irrigation schedule in sugarcane under different planting methods. Nine treatment combinations comprising three planting methods viz., conventional planting (at 75 cm row spacing), paired row planting (at 30:120 cm) and FIRB method (75 cm row spacing), and three irrigation schedules viz., irrigation at IW/CPE ratio of 0.50, 0.75 and 1.00 were evaluated in randomized block design (factorial) with three replications. The data revealed that the germination (%) was significantly higher under FIRB method (44.9 %) compared to conventional (39.2%) and paired row planting methods (38.0%). There was practically no difference in cane yields due to variation in planting techniques. Irrigation at IW/CPE ratio of 0.75 significantly improved yield attributes and cane yield (63.9 t/ha) over irrigation at IW/CPE ratio of 0.50 (57.7 t/ha). The response of sugarcane to different irrigation schedule was similar under all the planting methods. The irrigation water use efficiency was, however, higher (1.26 t/ha-cm) with irrigation at IW/CPE ratio of 0.50 as compared to irrigation at IW/CPE ratio of 0.75 and 1.00

Key words: Cane yield, Irrigation water use efficiency, FIRB methods, IW/CPE ratio, Paired row planting, Sugarcane.

Every plant requires water to complete its life cycle. Water is one of the most important inputs essential for the production of crops. Water differs from other plant nutrients in at least three respect firstly it is required in huge quantity, secondly it cannot be applied in a single dose, it needs to be applied at a definite interval and thirdly it governs the response to remaining inputs. Moreover, less than 1% of the water taken by the plants is retained in its body and more than 99% passes as evapotranspiration (ET). Accordingly, the water requirement of any crop is determined as evapotranspiration from the cropped field + water utilized in bio-chemical processes of plant + unavoidable losses during irrigation.

Sugarcane is a high water demanding crop and its requirement ranges from 1400-1800 mm in the sub- tropics (Srivastava and Johari 1979).The water requirement of sugarcane is higher as compared to other crops because it is a long duration crop producing huge amount of biomass and its long span of tillering phase coincides with high evaporative demand period of summer season. Since vegetative growth including stalk elongation is directly proportional to the water transpired, adequate soil moisture throughout the crop growing season is important for obtaining maximum yields. Cane yield has been found to increase directly to a water application rate of 1.46 times the rate of pan evaporation. Sugarcane requires 150-180 kg water to produce 1 kg of cane. Translated into practice, it means that in sub-tropical India, the crop of sugarcane requires 8-10 irrigations to produce a good tonnage.

Although sugarcane occupies only 2.8 per cent of countries net sown area, it uses approximately 6% of the total irrigation potential. It has been reported that only 35 % of the total area under sugarcane receives optimum irrigation while remaining 65 % area is under sub-optimum irrigation and unirrigated conditions (Lal and Shukla 2000). Therefore, there is a need to develop efficient irrigation schedule to cover more sugarcane area under irrigation as well as cane yield.

Over the period, different planting methods have been developed for improving cane productivity. These methods vary in bed configuration and therefore, in ET losses. 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 for two consecutive crop seasons of 2009-10 and 2010-11 at the Research Farm of Indian Institute of Sugarcane Research, Lucknow. The experiment comprising nine treatment combinations (three planting methods viz., conventional planting at 75 cm row spacing, paired row planting at 30:120 cm and Furrow Irrigated Raised Bed (FIRB) method at 75 cm row spacing, and three irrigation schedules viz., irrigation at Irrigation Water/ Cumulative Pan Evaporation (IW/CPE) ratio of 0.50, 0.75 and 1.00, were evaluated in randomized block design

(factorial) with three replications. The depth of irrigation water at each scheduling was 8.0 cm in all the treatments. The irrigation water was measured by water meter. The soil of the experimental field was sandy loam in texture with infiltration rate of 12 and 10 mm/hr and bulk density of 1.43 and 1.45 Mg/m^3. The infiltration rate was measured at the time of planting using double ring infiltrometer. The bulk density of surface 0-15 cm soils was determined from intact soil core sampler of 8.0 cm diameter after first irrigation. For estimation of soil moisture constants and chemical properties of soil, five soil samples were collected randomly from the experimental field at 0-15 cm soil depth, the samples were thoroughly mixed and bulked. The soil samples were analyzed for organic carbon content using the method given by Walkley and Black (1934), for available nitrogen using 2 M KCl, for extractable P using 0.5 m $NAHCO_3$ following Page *et al.* (1982) and for extractable K using Flame Photometer (Jackson 1973).The soil moisture constants viz., field capacity and wilting point were measured at 1/3 and 15 bar, respectively using Pressure Plate Apparatus. The values of field capacity were 17.2 and 16.9 per cent and that of wilting point 6.49 and 6.44 per cent during 2009-10 and 2010-11, respectively. The soil was low in organic carbon (0.39 and 0.32 per cent), available nitrogen (208 and 198 kg/ha), medium in available phosphorus (25.4 P_2O_5 kg/ha in 2009-10) and low (18.1 P_2O_5 kg/ha in 2010-11), medium in extractable potassium (228 and 237 kg/ha) and slightly alkaline in reaction (pH = 7.9 and 8.1) in 2009-10 and 2010-11, respectively.

Sugarcane variety 'CoS 94257' was planted on February 26, 2009 and March 8, 2010 and harvested on February 17, 2010 and February 4, 2011, respectively. Three budded setts were used for planting keeping four setts per meter row length. Thus, the seed rate works out to be 160 thousand buds (53.33 thousand three budded setts) per hectare. The initial plant population was counted at 45 days after planting (DAP) and germination per cent was worked out. The number of tillers including the mother plants were recorded at monthly interval upto165 DAP i.e. in the month of August and the number of millable canes were counted at harvest. Other parameters like cane length, cane diameter, single cane weight, cane yield and juice quality parameters were recorded at harvest of the crop. Irrigation water use efficiency was worked out by dividing cane yield (t/ha) with the total amount of irrigation water applied in hectare centimeter.

During pre-monsoon period 4, 6 and 8 irrigations in 2009-10 and 5, 7 and 10 irrigations in 2010-11 were applied in IW/CPE ratio of 0.50, 0.75 and 1.00, respectively (Table 4). In addition to these, one irrigation in 2009-10 and two irrigations in 2010-11 were applied during the post monsoon period in all the treatments. A total of 1005.8 and 681.8 mm of rainfall was received during 2009-10 and 2010-11, respectively. The weekly distribution of rainfall and evaporation is given in Fig.1.

RESULTS AND DISCUSSION

Planting methods

The experimental findings (Table 1) reveal that the per cent germination was significantly higher in sugarcane planted under FIRB method (47.9 %) compared to conventional (38.4%) and paired row planting (36.7%) methods consequently the tiller count in the month of May i.e. 75 DAP was also significantly higher under FIRB method (97.9 thousand /ha) over paired row planting (83.1 thousand/ha) and conventional planting (82.8 thousand/ha) during 2009-10. Better germination under FIRB system might be due to thin layer of moist soil cover over the cane setts in the furrow that provides congenial rhizospheric environment around the cane setts resulting into physiological processes conducive to bud sprouting. Tiller population (in 2009-10) at 105 DAP i.e. in the month of June was significantly higher in conventional and paired row planting method over FIRB method due to better tillering in conventional and paired row planting methods that nullified the effect of better germination under FIRB

Table 1 Germination and tiller dynamics in sugarcane as affected by different planting methods and irrigation schedule

Treatment	Germination (%)			Tiller population (000'/ha)														
				45 DAP			75 DAP			105 DAP			135 DAP			165 DAP		
	2009-10	2010-11	Pooled mean	2009-10	2010-11	Pooled mean	2009-10	2010-11	Pooled mean	2009-10	2010-11	Pooled mean	2009-10	2010-11	Pooled mean	2009-10	2010-11	Pooled mean
Planting methods																		
Conventional planting	38.4	39.9	39.2	61.5	63.8	62.7	82.8	95.0	88.9	178	141	159.2	193	151	171.9	163	124	143.8
Paired row planting	36.7	39.2	38.0	58.7	62.7	60.8	83.1	103.6	93.4	180	150	164.9	185	158	171.4	150	125	137.7
FIRB method	47.9	41.8	44.9	76.6	66.9	71.8	97.9	96.0	97.0	148	133	140.5	152	137	144.8	132	122	127.0
SEm±	**1.5**	**1.4**	**1.5**	**2.4**	**2.2**	**2.4**	**3.1**	**3.4**	**2.7**	**5.1**	**3.86**	**4.2**	**4.8**	**4.09**	**4.5**	**4.2**	**3.9**	**3.9**
CD (P=0.05)	**4.6**	**NS**	**4.6**	**7.3**	**NS**	**7.2**	**9.4**	**NS**	**8.2**	**15.4**	**11.7**	**12.8**	**14.3**	**12.4**	**13.7**	**12.6**	**NS**	**11.8**
Irrigation Schedule (IW/CPE ratio)																		
0.50	41.6	41.1	41.4	66.5	65.8	66.2	85.8	104.4	95.1	162	146	154.0	163	150	156.9	138	127	132.7
0.75	40.4	38.5	39.5	64.6	61.5	63.2	86.4	96.4	91.4	166	146	155.6	180	149	164.8	153	124	138.7
1.00	41.0	41.2	41.1	65.6	66.0	65.8	91.7	93.7	92.7	179	131	155.0	187	146	166.5	154	120	136.9
SEm±	**1.5**	**1.4**	**1.5**	**2.4**	**2.2**	**2.4**	**3.1**	**3.4**	**2.7**	**5.1**	**4.9**	**4.2**	**4.8**	**4.09**	**4.5**	**4.2**	**3.9**	**3.9**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**15.4**	**NS**	**NS**	**14.3**	**NS**	**NS**	**12.6**	**NS**	**NS**

method. Less tillering in FIRB system might be due to weed flux in moist furrows causing competition with emerging tillers. The tiller count at 135 DAP (in July) in both the crop seasons and at 165 DAP (in August) in 2009-10 was significantly higher in paired row planting and conventional methods due to better tillering over FIRB planting. However, the higher tiller numbers under paired row planting and conventional method could not reflect in NMC because of tiller mortality in latter months. The germination and tiller population during 2010-11 were not affected by planting methods at different stages of crop growth except at 105 and 135 DAP where tiller population was significantly higher under paired row planting method due to higher tillering over FIRB method. The statistical analysis on the basis of pooled mean of both the seasons indicates that germination was significantly higher under FIRB method of sugarcane planting as compared to paired row planting and conventional method and tiller population at 75 DAP was also significantly higher in FIRB method over conventional planting. However, at later stages i.e. 105, 135 and 165 DAP, the tiller population was significantly higher in paired row planting and conventional method of planting over FIRB method due to better tillering (Table 1).

In general, the tiller population (averaged over planting methods) increased upto135 days after planting i.e. in the month of July when it reached 176.7 and 148.7 thousands per hectare in 2009-10 and 2010-11, respectively, and decreased thereafter due to tiller mortality. The tiller mortality was higher in conventional and paired row planting method, consequently the number of millable canes paralleled in all the planting methods.

The yield attributes viz., number of millable canes, cane length, cane diameter and cane weight were not differed significantly due to different planting techniques as a result the cane yield as well as irrigation water use efficiency remained almost same. The cane yield was higher during 2009-10 as compared to 2010-11 (Table 2) due to more and evenly distributed rainfall in 2009-10 (Fig 1) that created better micro-environment for better crop growth. The irrigation water use efficiency was also higher during 2009-10 over 2010-11 firstly because of the higher cane yield and secondly less irrigation water requirement. The juice quality parameters viz., brix, sucrose and purity were not affected significantly by planting techniques (Table 3).

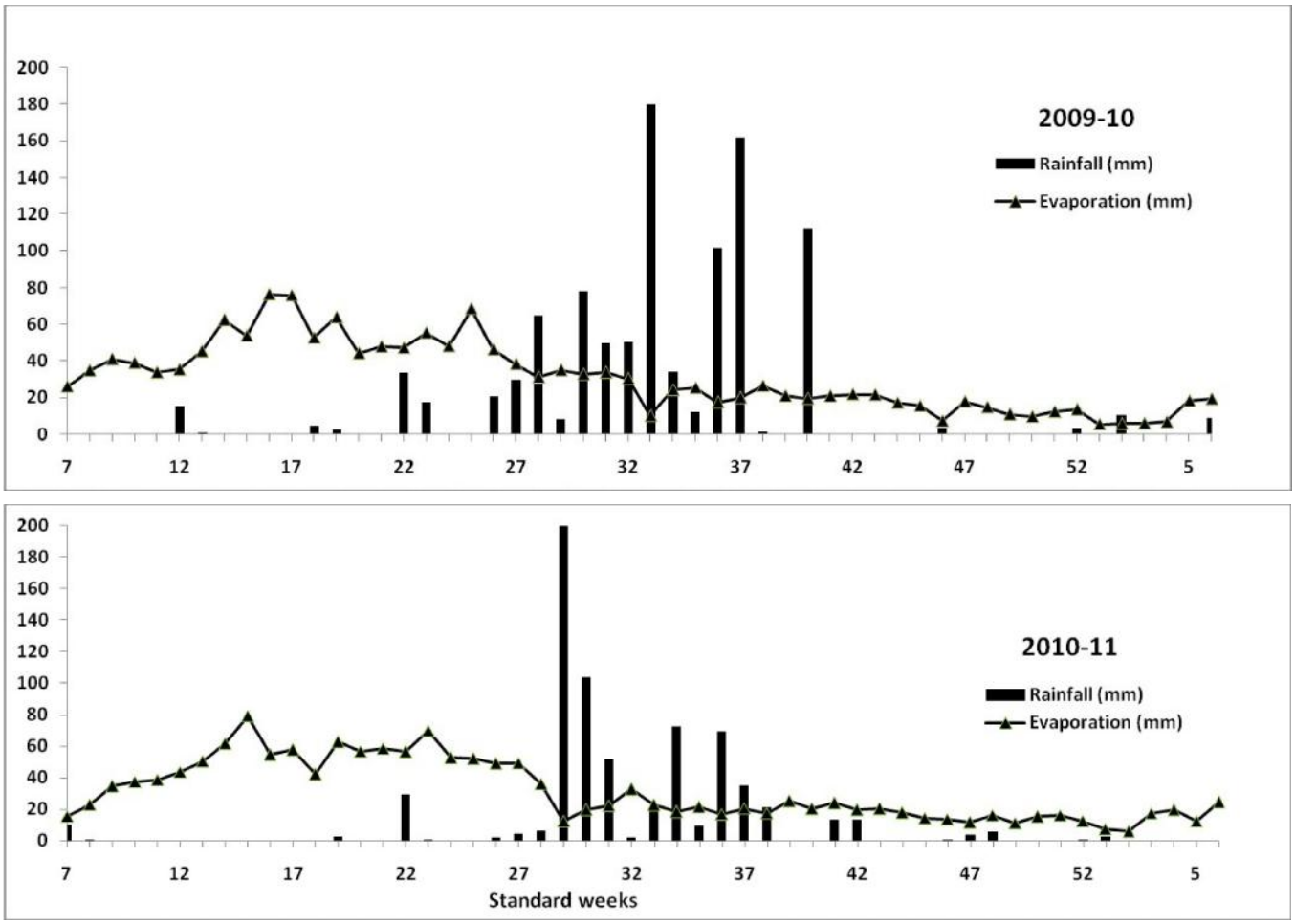

Fig 1 Weekly rainfall and evaporation distribution during the crop seasons

Table 2 Yield attributes and yield of sugarcane as affected by different planting methods and irrigation schedule.

Treatment	Yield attributes in sugarcane												Cane yield (t/ha)			Irrigation water use efficiency (t/ha-cm)	
	NMC (000'/ha)			Cane length (cm)			Cane diameter (cm)			Cane weight(g)							
	2009-10	2010-11	Pooled mean	2009-10	2010-11	Pooled mean	2009-10	2010-11	Pooled mean	2009-10	2010-11	Pooled mean	2009-10	2010-11	Pooled mean	2009-10	2010-11
Planting methods																	
Conventional planting	88.9	82.2	85.5	205	180	192.3	2.31	2.27	2.29	842	743	793	69.4	55.3	62.4	1.29	0.77
Paired row planting	84.9	84.4	84.7	200	175	187.6	2.29	2.28	2.29	837	760	799	67.8	57.8	62.8	1.26	0.80
FIRB method	84.2	79.4	81.8	202	175	188.5	2.32	2.27	2.30	852	736	794	68.3	54.5	61.4	1.28	0.76
SEm±	**2.8**	**2.3**	**2.4**	**3.1**	**2.6**	**3.1**	**0.04**	**0.03**	**0.04**	**8.7**	**103**	**5.8**	**1.7**	**1.5**	**1.6**		
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**		
Irrigation Schedule (IW/CPE ratio)																	
0.50	78.7	78.3	78.5	195	172	183.6	2.30	2.27	2.29	819	719	769	62.6	52.7	57.7	1.57	0.94
0.75	88.4	85.7	87.0	206	181	193.3	2.30	2.28	2.29	852	760	806	70.4	57.4	63.9	1.26	0.80
1.00	90.9	82.1	86.5	206	177	191.6	2.32	2.28	2.30	860	759	810	72.5	57.6	65.1	1.01	0.60
SEm±	**2.8**	**2.3**	**2.4**	**3.1**	**2.6**	**3.1**	**0.04**	**0.03**	**0.04**	**8.7**	**10.3**	**5.8**	**1.7**	**1.5**	**1.6**		
CD (P=0.05)	**8.4**	**7.1**	**7.2**	**9.7**	**7.8**	**7.8**	**NS**	**NS**	**NS**	**26.3**	**31.3**	**17.6**	**5.0**	**4.4**	**4.9**		

Table 3 Juice quality parameters as affected by different planting treatments

Treatment	Juice quality parameters					
	Brix (%)		Sucrose (%)		Purity (%)	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Planting methods						
Conventional planting	18.9	20.7	16.7	18.7	88.1	90.4
Paired row planting	18.8	20.6	16.6	18.7	88.1	90.5
FIRB method	19.1	20.7	17.0	18.8	88.8	90.7
SEm±	**0.2**	**0.3**	**0.2**	**0.2**	**0.5**	**0.5**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Irrigation Schedule (IW/CPE ratio)						
0.50	18.9	20.6	16.8	18.7	88.4	90.7
0.75	19.2	20.9	17.0	18.9	88.6	90.7
1.00	18.7	20.6	16.5	18.6	88.1	90.3
SEm±	**0.2**	**0.3**	**0.2**	**0.2**	**0.5**	**0.5**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Irrigation schedule

Germination and tiller population at 75 days after planting were not affected by irrigation scheduling at different IW/CPE ratio during both the crop seasons. However, during 2009-10, the tiller population at later stages of growth i.e. 105, 135 and 165 days after planting significantly increased with increase in irrigation levels. Irrigation at IW/CPE ratio of 0.75 significantly enhanced tiller populations in sugarcane over irrigation at IW/CPE ratio of 0.50 during 2009-10 (Table 1) might be due to congenial soil conditions for sprouting of sub-surface buds to produce tillers. During 2010-11, tiller population in sugarcane was not affected significantly by irrigation levels. However, the pooled mean of two seasons indicated that tiller population in sugarcane at different growth stages was not affected significantly due to various irrigation levels. The yield attributing characters i.e. cane length, cane weight and millable canes were significantly higher with irrigation at IW/CPE ratio of 0.75 over that at IW/CPE ratio of 0.50 might be due to better crop growth at IW/CPE ratio of 0.75 that helped the crop to uptake more water along with dissolved nutrients for biomass production and translocation in sugarcane. These in turn produced significantly higher cane yield to the tune of 65.1 t/ha with irrigation at IW/CPE ratio of 0.75 compared to 57.7 t/ha with irrigation at IW/CPE ratio of 0.50 (Table 2). However, irrigation at IW/CPE ratio of 1.00 could not enhance yield attributing characters and cane yield significantly over irrigation at IW/CPE ratio of 0.75 indicates that response of sugarcane to irrigation at different levels was not linear as the law of diminishing return seems to operate. Singh *et al.* (2007) also reported that application of irrigation at IW/CPE ratio of 0.75 significantly enhanced cane yield over irrigation at IW/CPE ratio of 0.50. Kumar and Srivastava (1991) reported a significant increase in cane yield with irrigation at IW/CPE ratio 0.80 over IW/CPE ratio of 0.50.

Table 4 Irrigation water use efficiency in sugarcane as affected by irrigation schedule under different planting methods

Planting methods/ irrigation schedule	2009-10												
	Total number of irrigation applied (dates of irrigation)			Total volume of irrigation water applied (ha-cm)			Cane yield (t/ha)				Irrigation WUE (t/ha-cm)		
	IW/CPE ratio			IW/CPE ratio			IW/CPE ratio				IW/CPE ratio		
	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00	Mean	0.50	0.75	1.00
Conventional planting	4 (8 & 24th April, 12th May and 12th June) + one post monsoon	6 (8 & 20th April, 2 & 19th May and 12 & 26th June) + one post monsoon	8 (8, 17 & 24th April, 2, 12 & 25th May and 12 & 21st June) + one post monsoon	40	56	72	62.6	71.6	74.1	69.4	1.57	1.28	1.03
Paired row planting							61.9	68.9	73.5	67.8	1.53	1.23	1.02
FIRB method							64.1	70.8	69.9	68.3	1.60	1.27	0.97
Mean							**62.6**	**70.4**	**72.5**				
CD (P=0.05) for mean values of cane yield = 5.0													
2010-11													
Conventional planting	5 (1& 18th April, 10th May and 1& 20th June) + two post monsoon	7 (1, 14 & 28th April, 14th May, 1& 14th June and 1st July) + two post monsoon	10 (1, 10, 18 & 28th April, 10 & 18th May, 1, 9 & 20th June and 1st July) + two post monsoon	56	72	96	50.8	57.0	58.2	55.3	0.91	0.79	0.61
Paired row planting							54.4	58.8	60.2	57.8	0.97	0.82	0.63
FIRB method							52.9	56.3	54.4	54.5	0.94	0.78	0.57
Mean							**52.7**	**57.4**	**57.6**				
CD (P=0.05) for mean values of cane yield = 4.4													

The cane quality parameters viz. brix%, sucrose% and purity% were not affected significantly by irrigation levels. The irrigation water use efficiency was higher (1.57 and 0.94 t/ha-cm in 2009-10 and 2010-11, respectively) with irrigation at IW/CPE ratio of 0.50 and it reduced to 1.26 and 0.80 t/ha-cm with irrigation at IW/CPE ratio of 0.75 and 1.01 and 0.60 t/ha cm with irrigation at IW/CPE ratio of 1.00 in 2009-10 and 2010-11, respectively (Table 2).

The interaction between planting methods and irrigation schedule was non significant. The findings presented in Table 4 indicate that the response of sugarcane to different irrigation schedule was similar under all the planting methods. The cane yield increased with increase in irrigation level upto IW/CPE ration of 0.75 under all the planting methods during both the crop seasons. Irrigation WUE was also almost similar because the number and volume of irrigation water applied in all the planting methods were same at different irrigation schedule (Table 4).Irrigation WUE was higher with irrigation at IW/CPE ratio of 0.5 over irrigation at IW/CPE ratio of 0.75 and 1.00 under all the planting methods due to saving in irrigation water. The highest Irrigation WUE was recorded in FIRB method (1.60 t/ha-cm) with irrigation at IW/CPE ratio of 0.50 in 2009-10 and in paired row planting (0.97 t/ha-cm) with irrigation at IW/CPE ratio of 0.50 in 2010-11 due to enhanced cane yield.

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