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Research Paper

Productivity and water-use efficiency of spring-planted sugarcane (*Saccharum* sp. hybrid complex) under various planting methods and irrigation regimes

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ABSTRACT

A field experiment was conducted during the spring seasons of 2010–12 at Sugarcane Research Institute, Bihar, Pusa (Samastipur), to investigate the effect of planting methods (conventional, paired row and furrow-irrigated raised bed system) and irrigation regimes [Irrigation water : cumulative pan evaporation (IW: CPE) ratios of 0.50, 0.75 and 1.00] on productivity and water-use efficiency of sugarcane (*Saccharum* sp. hybrid complex). Number of millable canes increased by 12.4% in conventional method, followed by 7.2% in paired row over furrow-irrigated raised bed system (FIRBS) respectively. Cane yield obtained under conventional method of planting was higher over paired row and FIRBS by 5.7 and 12.9% respectively. The water requirement, water-use efficiency and water productivity were higher under conventional method followed by paired row and FIRBS planting. Conventional method of planting fetched significantly higher net returns (₹142.4 × 10^3/ha) followed by paired row (₹136.4 × 10^3/ha) and FIRBS (₹112.5 × 10^3/ha). Significantly higher benefit : cost ratio was recorded in paired row planting (3.21) than FIRBS planting (2.68) whereas it remained at par with conventional method (3.13) of planting. Among the irrigation regimes, irrigation at an IW: CPE ratio 1.00 significantly enhanced all the growth and yield-attributing characters. Though the differences between IW: CPE ratios of 1.00 and 0.75 and 0.75 and 0.50 were not significant. However, crop irrigated at an IW: CPE ratio of 1.00 gave significantly higher number of millable canes (110 × 10^3/ha) and cane yield (98.0 t/ha) being at par with an IW: CPE ratio of 0.75 and both the treatments showed superiority over that of an IW: CPE ratio of 0.50. Sucrose content in juice was not influenced significantly due to different irrigation regimes. Crop irrigated with an IW: CPE ratio 1.00 showed the maximum values of water requirement, water-use efficiency and water productivity. Net return increased markedly with increase in irrigation regimes from an IW: CPE ratio of 0.50 to 1.00. Irrigation at 0.75 and 1.00 IW: CPE ratio increased the net returns by 29.0 and 39.5% over that with the 0.50 respectively. However, an IW: CPE ratio of 1.00 (3.24) being at par with that of 0.75 (3.11) gave significantly higher benefit: cost ratio than that of 0.50.

Key words : Crop productivity, Irrigation regimes, Planting methods, Sugarcane, Water-use efficiency

Sugarcane crop with its high potential to exploit solar energy is one of the important sources of food, fodder, fibre and fuel. Of the many agronomic practices, cane yield is greatly influenced by planting methods and irrigation regime. The prime objective of finding suitable planting method for sugarcane is to provide optimum number of millable canes per unit area which has a positive relationship with cane yield. At sub-optimal plant population, cane yield is limited by the less number of millable canes at harvest, while at over plant population, the same is limited by higher tiller mortality during grand growth phase of the crop. Evaluation of efficient planting methods to achieve optimum plant population for secured millabe canes at harvest is required as conventional planting at 75 cm row spacing has little scope for altering the initial crop stand as well as to ensure uniform growth and development of the crop. Paired row planting has proved beneficial over conventional method of planting for obtaining higher tonnage in north India (Gupta *et al.,* 2004) as it exhibited comparatively higher water use efficiency (Singh *et al.,* 2012). Planting of sugarcane in narrow rows could result in canopy closure and more efficient capture of solar energy. As irrigation water is one of the costliest inputs used in crop production, its economic and efficient utilization becomes quite imperative to quantify 'when and how much' irrigation should be given to harness optimum production potential. Improper management of irrigation water has contributed extensively to the current water scarcity in

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many parts of country, and is also a serious challenge to food scarcity and environmental sustainability. Optimum irrigation regimes vary with agro-climatic conditions, soil types, planting season and cultivation practices of the region. Efficient use of irrigation water requires that water be applied to growing crops at appropriate times and in adequate amounts. Where sufficient water is available to fully meet the crop water requirements, irrigation must be applied before yield or quality reducing stress occurs (Rajput, 2010). At present, most of the work on scheduling irrigation for sugarcane are based on either soil or plant parameters as guide for irrigation. These 2 approaches do not incorporate the climatic components in better way. Thus there is need to quantify the irrigation requirement of sugarcane on the basis of irrigation water: cumulative pan evaporation (IW: CPE). Hence an attempt was made to study the effect of various planting methods and irrigation regimes on yield and economics of sugarcane cultivation under calcareous soil of north Bihar conditions.

MATERIALS AND METHODS

A field experiment was conducted at Sugarcane Research Institute, Rajendra Agricultural University, Pusa, Bihar, during 2010–12 to evaluate different planting methods and irrigation regimes in spring planted sugarcane. The treatments comprised of 3 planting methods, viz. conventional planting at 75 cm row spacing, paired row planting at 30 : 120 cm row spacing and furrow irrigated raised bed system (FIRBS) with 75 cm row spacing and 3 irrigation regimes at irrigation water to cumulative pan evaporation (IW : CPE) ratios of 0.50, 0.75 and 1.00 with 8 cm depth of irrigation water. These ratios were observed when cumulative pan evaporation reached 160, 106.7 and 80 mm at IW: CPE ratios of 0.50, 0.75 and 1.00 respectively. The experiment was laid out in randomized block design (factorial) with 3 replications. Sugarcane 'BO 141' was planted on 31 March 2010 and 27 February 2011. The crop was uniformly fertilized with 150 kg N + 37.1 kg P + 49.8 kg K/ha through urea, diammonium phosphate and muriate of potash respectively. The soil of experimental field was sandy loam, calcareous having 8.3 pH, 0.28 dS/m electrical conductivity, 0.47 % organic carbon, 25.9 % free $CaCO_3$ and 222, 11.8 and 110 kg/ha available N, P and K respectively. Average values of field capacity, permanent wilting point and bulk density were 23.8%, 8.1% and 1.46 g/cc respectively. The mean minimum temperature ranged from 8.1° C to 26.8°C and the mean maximum from 20.0 to 36.8° C. The mean relative humidity varied from 76 to 91% in the morning (7.00 AM) and 35 to 72% in the afternoon (2.00 PM) during the growing period of the crop. On an average, crop received a total of 120.5 cm rain in 63.5 rainy days and lost 115.9 cm moisture through evaporation during its total mean duration of 313 days. Crop was irrigated as per treatment with measured amount of water using 7.5 cm throat Parshall flume, installed at the head of experimental plot. Water productivity in terms of ₹/m^3 was obtained by dividing net return with water requirement. Observations on growth, yield attributes and cane yield was recorded. Juice analysis were done 300 days after planting. Sucrose per cent of juice was worked out as per the method given by Spencer and Meade (1955). Economic analysis of the treatment was done based on the prevailing cost of inputs and price of the produce during the last year. The data collected from the experiment were subjected to statistical analysis by following 'Analysis of variance technique' as suggested by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Growth and yield attributes

The results indicated that except for millable canes all the planting methods remained at par for growth and yield attributes, viz. plant population, cane height, leaf-area index, cane diameter and single cane weight (Table 1). However, conventional method of planting showed higher values of these parameters, followed by paired row planting. The number of millable canes varied significantly due to different planting methods and conventional method of planting being at par with paired row proved significantly superior to FIRBS. Singh *et al.* (2012) also reported the positive effect of planting methods on number of millable canes.

Irrigation regimes had significant impact on growth and yield attributes (Table 1). Significantly higher plant population, cane height, leaf-area index and cane diameter were recorded at an IW: CPE ratio of 1.00, though it was statistically similar to that at 0.75 IW: CPE ratio. The minimum plant population was noticed at an IW: CPE ratio of 0.50. Improvement in plant population at an IW: CPE ratio of 1.00 was due to sufficient moisture availability during the critical period, i.e. at formative stage, which is only critical stage for irrigation in sugarcane deciding the optimum plant population. Higher number of millable canes was obtained at 1.00 IW: CPE ratio, which was significantly higher than that of 0.5 IW: CPE ratio but was at par with that of 0.75 and accounted 5.5 and 18.3% increase over that to 0.75 and 0.50 IW: CPE ratios respectively. However, heavier cane was recorded at 1.00 IW: CPE ratio, though it was on par at an IW: CPE ratio 0.75. Later was also statistically similar to that of 0.50 IW: CPE ratio. Singh (2012) explained that the yield attributing characters, i.e cane length, cane weight and millable canes were significantly higher with irrigation at an IW: CPE ratio of

0.75 over that at an IW: CPE ratio of 0.50. Optimum soil moisture in the root zone depth of crop due to comparatively frequent irrigation at an IW: CPE ratio of 1.00 might have improved the nutrient availability, thereby increasing metabolic activities in plant which in turn increased the growth and yield attributes. A marked variation in growth and yield attributes due to irrigation regimes was also obtained by Singh (2002).

Cane yield and sucrose content

There was significant difference in cane yield due to planting methods (Table 1). The significantly higher cane yield was recorded due to conventional method of planting and was on a par with that of paired row planting. This may be attributed to significantly higher number of millable canes, resulting from better nutrient availability from the soil and the increased rate of light interception, as evident from comparatively greater values of leaf-area index, plant population and cane diameter under the treatment. The effect of planting methods on sucrose content in juice was not significant. Similar values were also expressed by Kumar *et al*. (2012).

Cane yield increased significantly owing to applying irrigation at an increased IW: CPE ratio (Table 1). The higher cane yield was recorded at 1.00 IW: CPE ratio and it declined by 8.5 and 23.1% when the crop was irrigated at 0.75 and 0.50 IW: CPE ratio respectively. Since cane yield is the result of additive and complementary effect of plant growth and yield-attributing characters and the growth and yield attributes had better expression at optimum irrigation owing to adequate quantity and balanced proportion of water supply during the crop growth stages, there was significant increase in cane yield. Gulati and Nayak (2002) also reported similar results. Irrigation regimes did not bring significant improvement in sucrose content juice. Similar trend of results was also obtained by Bhullar *et al.* (2008) and Gupta *et al.* (2004).

Water use

The water requirement was higher under conventional method of planting followed by paired row and FIRBS method of planting. The conventional method of planting recorded higher water requirement which might be due to comparatively higher leaf-area index and plant population under this method causing higher evapo-transpirational loss of water. This was clearly reflected in the FIRBS planting, where comparatively lower leaf-area index and plant population resulted in the lower water requirement. Significantly, the highest water-use efficiency and water productivity (₹12.84/m^3) were recorded under conventional method of planting that was at par with paired row method. The lowest water-use efficiency and water productivity were recorded under FIRBS planting. This was mainly due to higher soil moisture contribution and water requirement leads to higher tonnage in conventional method and reverse in FIRBS planting. The irrigation regimes had significant impact on water-use efficiency (Table 2). Maximum water-use efficiency and water productivity were recorded at an IW: CPE 1.00, which was statistically on a par with that at an IW: CPE 0.75. Water use efficiency is the function of cane yield to water used by the crop during its growing period. Moreover, increase in cane yield under 0.75 IW: CPE was proportionally more than the increase in water requirement.

Economics

The cost of cultivation was ₹ 66.7, 61.3 and 66.7 × 10^3/ha respectively, under conventional, paired rows and

Table 1. Growth, yield attributes, yield and sucrose content of sugarcane as influenced by planting methods and irrigation regimes (pooled data of 2 years)

Treatment	Plant population (×10^3/ha)	Cane height (cm)	Leaf-area index	Cane diameter (cm)	Millable cane (×10^3/ha)	Single cane weight (g)	Cane yield (t/ha)	Sucrose in juice (%)
Planting method								
Conventional	151.9	264	4.02	2.16	108.1	865	92.9	16.72
Paired row	143.9	259	3.94	2.11	103.1	858	87.9	16.65
FIRBS	134.3	252	3.88	2.02	96.2	857	82.3	16.72
SEm±	6.73	6.7	0.067	0.048	3.48	22.4	2.96	0.179
CD (P=0.05)	NS	NS	NS	NS	10.5	NS	8.9	NS
Irrigation regime (IW:CPE)								
0.50	125.5	247	3.83	1.98	93.0	818	75.4	16.74
0.75	145.0	260	3.96	2.11	104.3	865	89.7	16.65
1.00	159.5	268	4.05	2.20	110.0	897	98.0	16.70
SEm±	6.73	6.7	0.067	0.048	3.48	22.4	2.96	0.179
CD (P=0.05)	20.3	20	0.20	0.15	10.5	67	8.9	NS

Table 2. Irrigation requirement, soil moisture contribution, water requirement, water-use efficiency and water productivity of sugarcane as influenced by planting methods and irrigation regimes (pooled data of 2 years)

Treatment	Irrigation requirement		Effective rainfall (cm)	Soil profile moisture contribution (cm)	Water requirement (cm)	Water-use efficiency (kg/ha-cm)	Water productivity (₹/m^3)
	Number	Depth (cm)					
Planting method							
Conventional	3	24	84.35	1.98	110.33	839.7	12.84
Paired row	3	24	84.35	1.90	110.25	795.1	12.31
FIRBS	3	24	84.35	1.84	110.19	745.1	10.18
SEm±	-	-		-	-	20.58	0.298
CD (P=0.05)	-	-		-	-	61.7	0.89
Irrigation regime (IW: CPE)							
0.50	2	16	84.35	2.13	102.48	736.1	10.36
0.75	3	24	84.35	1.87	110.22	813.8	12.42
1.00	4	32	84.35	1.72	118.07	830.0	12.55
SEm±	-	-		-	-	20.5	0.29
CD (P=0.05)						61.7	0.89

Table 3. Economics of sugarcane as influenced by planting methods and irrigation regimes (pooled data of 2 years)

Treatment	Cost of cultivation (×10^3₹/ha)	Net returns (×10^3₹/ha)	Benefit: cost ratio
Planting method			
Conventional	66.7	142.4	3.13
Paired row	61.3	136.4	3.21
FIRBS	66.7	112.5	2.68
SEm±	-	3.34	0.082
CD (P=0.05)	-	5.8	0.25
Irrigation regime (IW: CPE)			
0.50	63.6	106.2	2.67
0.75	64.9	137.0	3.11
1.00	66.2	148.2	3.24
SEm±	-	3.3	0.08
CD (P=0.05)	-	5.8	0.25

Irrigation cost: ₹1,280/ha/ irrigation

FIRBS method. Thus, the cost of cultivation was lower in paired row by ₹ 5.4 × 10^3/ha each than conventional and FIRBS method of planting. Lower cost of cultivation with paired row planting was mainly due to 33% lower seed rate. Conventional method of planting recorded significantly higher net return than paired row and FIRBS planting (Table 3). This was primarily owing to higher cane yield under conventional method of planting. Significantly higher benefit: cost ratio was obtained under paired row planting. However, it was on par with conventional method of planting.

The net returns and benefit: cost ratios were significantly influenced by irrigation regimes (Table 3). Net return increased significantly with each successive increase in irrigation regimes from 0.50 to 1.00 IW: CPE ratios. The magnitude of reduction in net return with application of irrigation water at 0.75 and 0.50 IW: CPE ratios over the IW: CPE ratio of 1.00 was 7.6 and 28.3% respectively. The crop irrigated at an IW: CPE ratio of 1.00 recorded the highest benefit: cost ratio was at par with IW: CPE ratio of 0.75 and both of them were significantly superior to IW: CPE ratio of 0.50.

Based on the 2 years of study, it can be concluded that conventional method of sugarcane planting was better with respect to millable canes, cane yield, water-use efficiency, water productivity, resulted in significantly higher net return over paired row and FIRBS planting. However, irrigation water at an IW: CPE ratio of 1.00 was found economical in sugarcane when compared with 0.75 and 0.50 IW: CPE ratios under calcareous soil of north Bihar condition.

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