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Response of Spring Sugarcane to Irrigation Scheduling and Planting Methods in Sub- tropical India

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A field experiment was conducted during spring 2010 and 2011 on silty clay loam soil to assess the impact of irrigation schedules (IW: CPE 0.40, 0.60, 0.80 and stages based) and planting methods (flat, pit and trench) on yield attributes, cane and water productivity and economics of sugarcane in plant-ratoon system. The cane yield increased with the increasing number of irrigations but the response was not significant beyond 7 and 3 irrigations, applied at IW: CPE 0.60 in plant and ratoon crop, respectively. Though, irrigation scheduled at IW: CPE 0.80 produced the maximum cane yield of 116.7 and 71.6 tha^{-1} in plant and ratoon crop, respectively resulting in maximum water productivity and returns, but was not superior to IW:CPE 0.60 ratio. Among the planting methods, both pit and trench were comparable and produced significantly higher cane yield and water productivity than flat planting in both plant and ratoon crops. Trench planting was economically sound as it gave Rs. 43271 and Rs.10748 ha^{-1} higher net income in plant and Rs. 2092 and Rs. 20447 ha^{-1} in ratoon crop, respectively than pit and flat planting. The irrigation water use efficiency in pit and trench was higher by 51.2 and 48.8 per cent over flat planting, respectively in plant crop.

Key words: Spring sugarcane*,* economics, IW: CPE ratio, planting method, yield, water productivity

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Plateauing yield levels, declining factor productivity and increasing cost of raising sugarcane in recent years have posed alarming concerns for the researchers as well as policy makers. Sugarcane can be planted by various methods. Appropriate planting technique coupled with precise water application is important for improving the cane and water productivity. Selection of suitable planting method not only ensures a uniform and adequate plant population but also results in more conversion of shoots to millable canes. Varying planting methods owing to variation in planting technique modifies microclimate in immediate vicinity of crop plants, thereby affecting cane growth and development. Presently, in North India, flat planting is the most common method, which is though less time consuming but accounts for lower germination (30-35%) and poor plant population (Singh *et al*., 2009). Studies have shown an yield advantage with alternate planting methods like pit and trench over flat planting (Yadav and Kumar, 2005). Further, trench planting is also a convenient and efficient planting system in saving irrigation water and reducing crop lodging due to easiness in inter-culture and earthing-up operations (Malik *et al* ., 1996). Pit planting, developed by Singh *et al.* (1984) encourages the number of mother shoots and suppressed the secondary and tertiary tillers, thus has the potential of almost doubling the cane yield. Pit planting, which requires a high seed rate to compensate for reduced tillering, produced about 20 t/ha^{-1} additional cane yield than the conventional flat method (Yadav *et al.,* 1991). Still these concepts are in fancy state as the results are not consistent, but needs to be explored owing to their high productivity.

Sugarcane, being a high water demanding crop, often receives great setback due to unpredictable behaviour of monsoon in sub-tropical India. In North India, water need of the sugarcane during germination and formative phases (pre-monsoon season) is met through irrigation. As pre-monsoon is a high ET period, adequate soil moisture is essential through proper monitoring and scheduling of irrigation for achieving higher cane and water productivity. The scheduling of irrigation on the basis of climatological approach (IW: CPE ratio) is considered to be more scientific and practical as it takes care of both rainfall and evaporation. Therefore,varied ratios of IW: CPE were compared with conventional stages based irrigation in the present study in relation to planting methods to find out appropriate planting technique and irrigation schedule for spring planted sugarcane in plant-ratoon system.

Materials and Methods

A field experiment was conducted at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (29°N latitude, 79.5°E longitude and 243.8m MSL) during spring 2010 - 2011. The climate of the experimental site is humid sub-tropical with average rainfall of 1400 mm. The soil was silty clay loam with pH 7.24, 1.06 % organic carbon and bulk density of 1.34 Mg/ m^3. The soil had moisture content at field capacity and permanent wilting point 23.04 and 7.70 %, respectively, with infiltration rate of 1.12cmhr-1. The experiment consisting of four irrigation schedules (irrigation at 0.40, 0.60, 0.80 IW: CPE ratio and at critical growth stages) and three planting methods (flat, trench and pit) was conducted in factorial RBD, replicated thrice. Sugarcane Variety Co. Pant 90223 was used for the study. The crop was planted on 03rd March, 2010 following the recommended practices and harvested on 7th Feb, 2011. The ratoon crop was harvested on 25th Dec, 2011. For flat and trench planting, 15 cm deep furrows were opened at 75 cm apart with the tractor mounted furrow opener. The depth of furrows in flat planting was 15cm whereas for trench planting, soil from the first furrow was dug out with the help of a small spade to increase its depth. Then cane setts were placed and covered by the soil removed from next furrow and so on. Pits were prepared manually and the distance between centres of one to another pit was 105 cm having actual pit diameter of 70 cm. Pits were connected to each other by shallow furrow to facilitate irrigation. After fertilizer application, 3 budded 10 setts were placed in a circular fashion. In flat and trench methods, three budded, 4 setts per metre furrow length were placed in bud to bud fashion. The recommended dose of fertilizers i.e. 150 kg N+60 kg P_2O_5 + 40kg K_2O was applied to the crop through urea, single Super Phosphate and muriate of potash. Full dose of phosphorus and potassium and 50 % of nitrogen was applied as basal, while remaining nitrogen was applied in two equal splits before the commencement of monsoon in the month of May and June. In flat method, the furrows were completely filled with soil while in trench and pit plantings, initially the furrows and pits were half filled. At the time of last intercultural operation in end of June, the trenches and pits were completely filled with soil making the surface flat. Various irrigation treatments in plant crop were imposed only during pre-monsoon period after applying a common light irrigation on 07th April. The irrigation depth of 6 cm was maintained for flat planting and as per requirement for trench and pit plantings through parshall flume. Same treatments were also tested in ratoon crop with flat surface in all the planting methods. The number of irrigations applied in plant crop under IW: CPE 0.40, 0.60, 0.80 and growth stages based treatments were 4, 7, 8 and 5, respectively, while in ratoon crop were 3, 4, 4 and 3, respectively. All the irrigations were applied before the commencement of monsoon and in stages based treatment, it were applied at germination, I, II,III and IV order of tillering stages. The total rainfall during plant crop was 2054 mm of which 93.3 per cent (1917.2 mm) was received during the monsoon season (June to September) and only 182 mm during pre-monsoon season. During the ratoon crop growing period, total 2140 mm rainfall was received in 60 rainy days and the monsoon receded by mid of September. The economics was worked out as per prevailing market prices of input and output.

Results and Discussion

Yield attributes

Yield attributes of both plant and ratoon crops *viz.,* individual cane weight, cane length and cane girth did not vary significantly by irrigation levels. However, these values increased with increasing number of irrigations, being the maximum at IW: CPE 0.80 and the minimum at IW: CPE 0.40. But number of millable canes as an exception, was significantly influenced by irrigation levels in the ratoon crop as IW: CPE 0.80 ratio recorded significantly higher number of millable canes (113.6 thousand ha-1) than IW: CPE 0.40 (97.7 thousand ha-1), however, it was statistically at par with rest of the irrigation treatments.

With regard to planting methods, only number of millable canes and cane length were significantly influenced in plant crop. Pit method of planting produced the maximum number of millable canes (128.9 thousand ha-1) significantly higher than trench (115.5 thousand ha-1) and flat planting (109.8 thousand ha-1), while, in terms of cane length, both pit (279 cm) and trench (272 cm) methods were comparable but recorded significantly higher cane length than flat planting (213 cm). Higher number of millable canes in pit planting might be attributed to more conversion of shoots in millable canes owing to planting of higher number of buds per unit area. Individual cane weight and cane girth did not differ significantly due to planting methods.

Table 1. Yield attributes of spring sugarcane plant and ratoon crop as influenced by irrigation levels and planting methods (2010 - 11)

Treatment	Cane weight (g)		Number of millable canes(000 ha-1)		Cane length (cm)		Cane girth (cm)	
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
Irrigation level								
IW:CPE 0.40	1170	778	112.8	97.7	253	190	7.9	7.6
0.60	1213	818	117.7	112.0	253	192	8.2	7.9
0.80	1256	828	117.8	113.6	258	203	8.4	7.8
Stages based	1188	773	116.5	103.0	253	185	8.1	7.8
CD 5%	NS	NS	NS	13.5	NS	NS	NS	NS
Planting method								
Flat	1166	772	109.8	106.3	213	191	7.9	7.8
Trench	1220	813	115.5	114.3	272	195	8.2	7.7
Pit	1260	841	128.9	111.1	279	196	8.6	8.1
CD 5%	NS	NS	6.7	NS	18.8	NS	NS	NS

Table 2. Cane yield and water use parameters of spring sugarcane plant crop as influenced by irrigation levels and planting methods (2010 - 11)

Treatment	Cane yield ($t\ ha^{-1}$)	Irrigation depth (cm)	Irrigation WUE ($t\ ha^{-1}$-cm)	Water applied (cm)	Water productivity ($t\ ha^{-1}$- cm)
Irrigation level					
IW:CPE 0.40	107.2	19.3	5.54	224.6	0.476
0.60	114.2	33.7	3.38	239.1	0.476
0.80	116.7	38.5	3.02	243.9	0.477
Stages based	108.5	24.1	4.49	229.5	0.471
CD 5%	5.4	-	-	-	-
Planting method					
Flat	107.6	36.0	2.99	241.4	0.446
Trench	113.0	25.4	4.45	230.8	0.489
Pit	114.4	25.3	4.52	230.7	0.496
CD 5%	4.6	-	-	-	-

Cane yield

The cane yield of plant crop was higher than ratoon due to better yield components. Almost, 40 per cent reduction in cane yield was noticed in ratoon crop due to lowered cane weight and length. The cane yield of plant and ratoon crop was affected significantly due to both planting methods and irrigation levels. The cane yield increased with high frequency of irrigations but response was not significant beyond 7 and 3 irrigations applied at IW: CPE 0.60 in plant and ratoon crops, respectively. In plant crop, the highest cane yield (116.7 $t\ ha^{-1}$) produced by IW: CPE 0.80 treatment remained on par with IW: CPE 0.60, but was 8.9 and 7.6 per cent higher over IW: CPE 0.40 and critical growth stages based treatments, respectively (Table 2). Similar trend was also observed in ratoon crop but per cent increase in cane yield over IW: CPE 0.40 and critical growth stages were higher by 14.3 and 15.2 per cent, respectively. However, the cane yield did not differ significantly between IW: CPE 0.40 level and irrigation applied at critical growth stages during both the crops. The reduction in cane yield of IW: CPE 0.40 was associated with less number of millable canes and low cane weight. Regular irrigation in IW: CPE 0.80 might have maintained cell turgor pressure and consequently proliferation of tillers and better nutrient uptake which reflected towards better growth and yield (Gulati *et al.,* 1998).

Table 3. Cane yield and water use parameters of spring sugarcane ratoon crop as influenced by irrigation levels and planting methods (2010 -11)

Treatm -ent	Cane yield ($t\ ha^{-1}$)	Irrigation depth (cm)	Irrigation WUE ($t\ ha^{-1}$ - cm)	Water applied Irrig.+Rainfall) (cm)	Water productivity ($t\ ha^{-1}$- cm)
Irrigation level					
IW:CPE 0.40	62.7	18.0	3.48	232.0	0.270
0.60	65.9	24.0	2.75	238.0	0.277
0.80	71.6	24.0	2.98	238.0	0.301
Stages based	62.1	18.0	3.45	232.0	0.268
CD 5%	6.7	-	-	-	-
Planting method					
Flat	61.3	21.0	2.91	235.0	0.260
Trench	70.3	21.0	3.35	235.0	0.299
Pit	69.3	21.0	3.30	235.0	0.295
CD 5%	5.2	-	-	-	-

Table 4. Economics of spring sugarcane plant and ratoon crops as influenced by irrigation levels and planting methods (2010 - 11)

Treatment	Gross Return (Rs. ha^{-1})		Cost of Cultivation (Rs. ha^{-1})		Net Return (Rs. ha^{-1})		B:C ratio	
	plant	ratoon	plant	ratoon	plant	ratoon	plant	ratoon
Irrigation level								
IW:CPE 0.40	268106	158064	105598	43421	162508	114643	1.64	2.64
0.60	285695	168664	108298	44321	177397	124343	1.73	2.81
0.80	291947	182581	109198	44321	182749	138260	1.77	3.11
Stages based	271440	158558	106498	43421	164942	115137	1.64	2.65
CD 5%	13405	18977	-	-	13405	18977	NS	NS
Planting method								
Flat	269169	151969	90012	41807	179157	110162	1.99	2.64
Trench	282611	175692	92706	45083	189905	130609	2.05	2.89
Pit	286111	173240	139477	44723	146634	128517	1.05	2.87
CD 5%	11609	16435	-	-	11609	16435	0.12	NS

For plant crop, pit planting recorded the maximum cane yield (114.4 $t\ ha^{-1}$), which was on par with trench planting but 6.3 per cent higher than flat planting. It was due to more number of millable canes and cane weight. Singh (2002) also noticed direct contribution of yield attributing characters to yield of sugarcane crop. The results are in the conformity of the findings of Yadav *et al.* (1991) who also noted higher yield in pit planting. The localized placement of fertilizers in pit method might have helped to increased nutrient use efficiency and thus produced heavier canes (Yadav, 2004).

The cane yield of ratoon crop recorded with trench method (70.3 $t\ ha^{-1}$) was on par with pit (69.3 $t\ ha^{-1}$), yet both out yielded flat planting (61.2 $t\ ha^{-1}$). Higher cane yield in trench planting was largely due to increased yield attributing components, which is evident from 5.3 and 7.8 per cent higher cane weight and number of millable canes than flat planting, respectively. Bhullar *et al.* (2008) also obtained similar results.

Water use parameters

In plant crop, IW: CPE 0.40 exhibited the maximum irrigation WUE (5.54 t ha-cm$_{-1}$) as it produced relatively higher cane yield (107.2 t ha$_{-1}$) by consuming less number of irrigations. The per cent increase in irrigation WUE with IW: CPE 0.40 over IW: CPE 0.60 and 0.80 irrigation treatment was to the tune of 26.5 and 16.8 per cent, respectively. The water productivity was comparatively more in IW: CPE 0.80 (0.477t ha-cm$_{-1}$) due to more cane yield per unit of total water use while it was the lowest (0.471t ha-cm$_{-1}$) in stages based irrigation treatment. The total depth of irrigation water was the highest in flat planting (36.0 cm) against 25.4 cm in trench and 25.3 cm in pit method of plating. This indicates that trench and pit methods required 10.6 and 10.7 cm less irrigation water, respectively in comparision with flat planting. Among the planting methods, pit and trench recorded 51.2 and 48.8 per cent higher irrigation WUE than that of flat planting, respectively. Gupta *et al.* (2004) also observed 92 per cent higher irrigation WUE in pit than flat planting. As far as water productivity is concerned, it also followed the similar trend. The higher water productivity in pit planting was due to higher cane yield from same quantity of water applied to other planting methods.

Similarly, in ratoon crop, IW: CPE 0.40 showed maximum irrigation WUE (3.48t ha-cm$_{-1}$), however it was comparable with growth stages based irrigation treatments. Water productivity as like plant crop, was also maximum (0.301t ha-cm$_{-1}$) with IW: CPE 0.80 ratio. Among different planting methods, trench planting exhibited maximum irrigation WUE (3.35t ha-cm$_{-1}$) and water productivity (2.99 t/ha$_{-1}$-cm), though, it was almost similar to pit planting but recorded 34.4 and 15 per cent higher irrigation WUE and water productivity than flat planting, respectively due to its higher yield by using same amount of water.

Economics

The data on economics revealed that both gross and net returns of plant and ratoon crops were influenced significantly by treatments (Table 4). Among the irrigation levels, economically, IW: CPE 0.80 treatment was found to be more remunerative in both plant and ratoon crops as it recorded maximum gross and net returns that was significantly higher to IW:CPE 0.40 and stages based irrigation treatments but at par with IW:CPE 0.60.The variation in economic parameters was due to differential irrigation cost and cane yield. The lowest net income obtained from IW: CPE 0.40 treatment in both the crops was due to lower cane yield. However, benefit cost ratio did not vary due to use of any irrigation level in both plant and ratoon crops. Among the planting methods, pit planting method gave the maximum gross return in plant (Rs.286111ha$_{-1}$) and ratoon (Rs. 173240 ha$_{-1}$) crops but had the lowest net returns. The higher cost incurred on pit preparation and higher sett requirement in pit method reduced its net return. The results are in the lines of findings of Bhullar *et al. (*2008). In both plant and ratoon crops, trench planting fetched the maximum net return due to relatively higher cane yield. Trench planting in plant crop gave Rs.43271 and Rs.10746 ha$_{-1}$ additional net income than pit and flat planting, respectively however, in ratoon crop, the values were Rs.2092 and Rs.20447 ha$_{-1}$, respectively. Benefit cost ratio also followed the similar trend. In plant crop, trench (2.05) and flat (1.99) methods recorded significantly higher benefit cost ratio than pit planting (1.05). However, in ratoon crop, differences were not significant, though, B:C ratio value was maximum with trench planting (2.89).

The results of present study suggest IW: CPE 0.60 as the optimum irrigation level for plant and ratoon crop. Trench method of planting may be adopted for both higher cane productivity and irrigation water saving in sub-tropical part of India.

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