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Productivity, profitability and quality of sugarcane (*Saccharum* spp.) plant–ratoon system in relation to planting methods and seeding rate

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ABSTRACT

Field studies were conducted at Ladhowal, on sugarcane (*Saccharum* spp.) plant (2004-05 and 2005-06) and ratoon (2005-06 and 2006-07) crops to work out suitable combination of planting method and seed rate for sugarcane plant-ratoon system. Three planting methods, viz. flat (conventional planting in 15 cm deep furrows spaced 75 cm apart), trench (planting in paired rows on both sides of trench 30 cm wide, 30 cm deep, spaced 120 cm apart), pit (60 cm dia meter, 45 cm deep, spaced 120 cm apart) along with three seeding rates, viz. 4.0 t/ha (transplanted), 8.0 t/ha (sett planting, recommended) and 16.0 t/ha (sett planting), were evaluated in split-plot design. Trench planting recorded the highest number of shoots and millable canes, whereas pit planting the highest single-cane weight. The planting method did not influence the cane and sugar yields in plant crop, but the ratoon-crop yield in trench was significantly higher than by conventional method, but was on a par with that of pit method. Use of 16.0 t/ha seed significantly increased the cane and sugar yields of plant crop than both the lower seed rates, whereas the ratoon-crop yield did not vary among seed rates. The transplanted crop gave crop yield on a par with that of recommended seed. Trench planting showed significantly higher pol reading than pit method, in plant crop and, in ratoon crop 16 t/ha seed gave significantly higher pol, brix and commercial cane sugar content than transplanted crop. Trench planting using 8.0 t/ha seed recorded the highest total net returns (Rs 73,800/ha) as well as benefit: cost ratio (0.920) from sugarcane plant-ratoon system. Trench transplanting also gave higher economic returns than conventional planting with recommended seed.

Key words: Pit, Planting, Ratoon, Seed, Sugarcane, System, Trench

Sugarcane (*Saccharum* spp.) crop occupies an important position in Indian agriculture, as it is the second largest organized agro-industry in the country, next only to textiles. Recently the plateauing yield levels and increasing cost of producing sugarcane has posed serious concerns on the sustainability of this crop. Determination of precise planting technique to improve uniformity in plant population and crop stand is an important issue for improving the sugarcane-system productivity. Planting method plays a crucial role in sustaining higher number of millable canes and sugarcane yield in both plant and ratoon crops. The variation in planting techniques in different regions aims to improve the growth, increase the plant density and reduce the tiller mortality to obtain higher number of heavier millable canes per unit area. In North India, spring sugarcane is generally planted on flat beds in single rows spaced 75 cm apart. However, planting of sugarcane in paired rows compared with that in planting in single rows has proved beneficial in India (Yadav *et al.*, 1997) and in Pakistan (Bajelan and Nazir, 1993). In south India sugarcane is planted in wide, deep trenches. The high degree of anchorage in trenches prevents lodging and gives higher yield than flat or shallow planting. In another system of planting, called pit or ring system, cane setts are placed horizontally in circular pits. This method prevents crop lodging in sandy soils, improves the nutrient-use efficiency through localized placement, and helps maintain multiple ratoons. The crop under pit system primarily consists of mother shoots that are thicker and heavier. The yield advantage of pit method over conventional flat method has been documented by Yadav *et al.* (1990), Yadav (2004) and Yadav and Kumar (2005). Apart from planting method, establishment of sugarcane crop through transplants may be another alternative in achieving the desired plant population. The scientific information on effect of these planting techniques on sugarcane crop for subtropical region of Punjab is lacking. Keeping this in view, the present study was planned to work out a suitable

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combination of planting method and seed rate for achieving higher productivity and profitability in sugarcane plant - ratoon system.

MATERIALS AND METHODS

Field studies were conducted on sugarcane plant (2004-05, 2005-06) - ratoon (2005-06 and 2006-07) system at Sugarcane Research Farm of Punjab Agricultural University at Ladhowal, Ludhiana. Ladhowal (latitude 30° 56 'N, longitude 75° 52 'E, altitude 247 m above mean sea level) represents a subtropical and semi-arid climate with very hot and dry summer from April to June, hot and humid conditions from July to September, cold winters from November to January and mild climate during February and March. In summer, the maximum temperature rises above 42°C and frequent frosty spells are experienced in winter, especially during December and January. The mean annual rainfall is 704 mm, and nearly 80% of the total rainfall received is through south-west monsoon (July-September). The total rainfall during the growing season was 432.8, 671.0 and 586.3 mm during 2004-05, 2005-06 and 2006-07 respectively. Soil was loam, with high content of organic C (0.78%) and available N (410 kg/ha), medium P (19.0 kg/ha) and high K (510 kg/ha), having EC 0.30 dS/m and pH 8.6.

Three planting methods were followed, viz. flat (conventional planting in 15 cm deep furrows spaced at 75 cm), trench (planting in paired rows on both sides of trench 30 cm wide, 30 cm deep, from centre to centre of two trenches 120 cm), and pit (60 cm dia meter, 45 cm deep and centre-to-centre distance of two pits 120 cm) in main plots; and three seeding rates were adopted, viz. 4.0 t/ha (transplanted), 8.0 t/ha (sett planting, recommended), 16.0 t/ha (sett planting) in subplots. These were evaluated in split- plot design. In flat method, the furrows were made with tractor-drawn ridger, cane setts were placed end to end and light planking was done after planting; whereas in transplanting method the furrows were filled manually. Trenches were dug with a tractor-drawn trench-maker, cane setts were placed in paired rows, one row on either side of the trench, and the setts were covered with 5 cm soil layer and irrigated immediately. Mechanical pit-digger was used to dig the pits. Pits were joined from end to end for irrigation. Basal one-third of the pits were filled with a mixture of farmyard manure and upper soil, and cane setts were planted in a circular manner, covered with 5 cm soil layer and irrigated immediately. Three budded setts (conventional planting) were used for planting with two seed rates, viz. recommended and double seed rate. For transplanting, one-budded cane setts were planted in a nursery during October and the seedlings were transplanted in February. In one pit 11 seedlings were transplanted, whereas 7 and 14 three-budded setts were planted under the seed rates of 8.0 and 16 t/ha respectively. A mid-maturing high-sugar variety 'CoJ 88' of sugarcane was used in the trial. The crop was planted on 27 February 2004 and 16 February 2005, and harvested on 28 January 2005 and 30 January 2006 during the first and second years of experimentation respectively. The plant crop was raised as per recommended package and practices. The trenches and pits were filled twice, once after complete germination and then 90 days after planting. The treatments were not applied to the ratoon crop rather carryover effects of the treatments were studied in the ratoon crops harvested on 25 November 2006 and 28 November 2007.

The data on germination percentage were recorded at 45 days after planting, whereas in transplanted crop the survival percentage was recorded. Shoot population was recorded at maximum tillering stage (120 days after planting). Five canes were randomly selected from each plot to estimate the yield attributes, viz. millable canes, cane length, cane weight and juice-quality parameters (pol % juice, brix % and purity %) before harvesting. The perecentage of commercial cane sugar (CCS) was calculated by using the formula {CCS (%) = [S–(B–S) 0.4] × 0.73}, where S = Pol % juice and B = Brix. The data on cane yield were recorded at the time of crop harvest. CCS (%) was multiplied with cane yield to get sugar yield (commercial cane sugar yield). The prevailing market prices of inputs and outputs were taken into account for economic analysis of different treatments. Human labour and tractor hours were the two major components that accounted for differences in the cost of cultivation among planting methods. Human labour accounted for Rs 27,500, Rs 30,000 and Rs 32,500/ha and, tractor hours for Rs 4,230, Rs 4,230 and Rs 11,730/ha under flat, trench and pit planting methods respectively. The cost of sugarcane seed was Rs 1,000/t during both the years. Market price of sugarcane was Rs 1,000/t during 2004-05 and Rs 1,150/t during 2005-06 and 2006-07, and of cane tops which accounted for 23% of cane yield was Rs 300/t during all the three years.

RESULTS AND DISCUSSION

Plant crop

The planting methods did not influence the percentage of germination of sugarcane (Table 1). Trench planting recorded significantly higher number of shoots than the other two planting methods. Millable canes in trench and conventional methods were at par and both were statistically better than pit method. However, single-cane weight and cane length were significantly higher with pit compared with other two methods. Single-cane weight under trench planting was also significantly higher than under conventional method. Higher population of shoots and millable canes in paired row trench planting could be assigned to the border effect that the rows received in the form of higher light interception and proper aeration due to wider spacing between the trenches. Yadav *et al.* (1990) explained that in pit planting method the proportion of primary shoots, which are thicker and heavier, in the final cane population was more than in the conventional flat planting method, where secondary and tertiary tillers (which are shorter, thinner and lighter than the primary shoots) contribute most to the final cane population. The localized placement of fertilizers in pit method results in increased nutrient use-efficiency (Yadav, 2004), which also helps produce healthy canes. The sugarcane crop has the capacity to compensate for lower plant density by increasing the weight of individual canes after stabilization of cane population (Bell and Garside, 2005). The differences in cane yield among planting methods were statistically non-significant. The differential effects of planting methods on yield attributes like number, length and weight of millable canes were responsible for non-significant differences in cane yield. Bell and Garside (2005) examined the relative contribution of millable cane population and individual cane weight to variation in cane yield. They found that in some experiments individual cane weight accounted for more than 70% of the variation in yield whereas in other experiments millable cane population was the more important yield component and, together these two components accounted for more than 98% of the variation in cane yield. Trench planting showed significantly higher pol reading than pit method. As the cane setts are planted deeper in pit than other planting methods, higher moisture availability at the base of the pits probably have increased stalk moisture during ripening, and the sucrose diverted towards growth which would otherwise be used for storage in the stem, which lowered pol reading. Planting methods, however, did not influence brix, purity and commercial cane sugar content. The differences in commercial cane sugar yield among planting methods were also non-significant. Cane sugar yield is a product of cane yield and commercial cane sugar percent. Planting methods did not influence both these parameters, which was also reflected in sugar yield.

The seeding rate did not influence the percentage of germination of sugarcane (Table 1). The seedling survival was 74.1%. The crop raised with 16.0 t/ha seed recorded significantly higher number of shoots and millable canes compared with both the lower seed rates, whether raised by setts or transplanted. As the percentage of germination did not vary among seed rates, more number of buds planted at the highest seed rate revealed significantly higher population of shoots than both the lower seed rates. The shoot mortality also did not show much variation (42.9 to 44.9%) across seed rates, hence 16.0 t/ha seed retained 16.6 and 16.9% higher number of millable canes than 8.0 t/ha and 4.0 t/ha seed respectively. Individual cane weight under 16.0 t/ha seed was on a par with that under standard seed and both were statistically superior to transplanted crop. Garside *et al.* (2002) opined that under assured water supply, as in the present case, higher population density and greater final cane numbers were likely to have received greater radiation interception, and the resultant higher growth rates. Negative impact of increased cane-population density on individual cane weight would therefore have been reduced due to the counter-effect of an increased supply of available assimilate. The cane yield was the highest (79.1 t/ha) with 16.0 t/ha seed, which was significant and 15.0 and 17.7% higher than with 8.0 t/ha

Table 1. Growth attributes, yield and quality of plant crop of sugarcane under different planting methods and seed rates (mean data of 2004-05 and 2005-06)

Treatment	Germination (%)	Shoots (x 10^3/ha)	Millable canes (x 10^3/ha)	Millable cane length (cm)	Single-cane weight (kg)	Cane yield (t/ha)	Pol % juice	Brix (%)	CCS (%)	Sugar yield (t/ha)
Planting method										
Conventional	28.7	180	108.8	178	0.59	71.3	18.94	21.70	13.06	9.29
Trench	34.9	205	108.0	191	0.63	74.9	19.19	21.49	13.27	9.89
Pit	32.4	140	78.9	208	0.83	68.9	18.81	21.85	12.99	8.90
SEm±	1.9	5	4.1	6	0.01	2.79	0.18	0.10	0.10	0.41
CD (P=0.05)	NS	18	8.2	15	0.03	NS	0.27	NS	NS	NS
Seed rate (t/ha)										
4.0 (transplanting)	74.1*	164	93.7	195	0.61	67.2	18.96	21.63	13.10	8.79
8.0 (sett planting)	32.3	164	93.5	192	0.72	68.8	19.01	21.73	13.12	9.00
16.0 (sett planting)	31.8	198	109.0	192	0.71	79.1	18.98	21.68	13.10	10.36
SEm±	1.3	4	3.9	5	0.02	3.62	0.11	0.15	0.12	0.44
CD (P=0.05)	NS	12	8.1	NS	0.05	7.35	NS	NS	NS	0.91

*Survival (%); CCS = commercial cane sugar and 4.0 t/ha seed respectively. Higher number of millable canes increased the cane yield at higher seed rate. The transplanted crop recorded cane yield on a par with that of recommended seed crop. Cane-quality parameters including pol, brix, purity and commercial cane-sugar content did not vary among seed rates. Cane sugar yield with 16.0 t/ha seed was significantly higher than at both the lower seed rates. The higher cane yield at 16.0 t/ha seed increased its sugar yield.

The interaction effects revealed that the variation in seed rate did not influence the population of millable canes statistically both in trench and pit methods; but in conventional method 16.0 t/ha seed was significantly better than both the lower seed rates. Trench planting was statistically superior to pit planting at all the seed rates (data not shown).

Ratoon crop

Trench planting recorded significantly higher population of shoots and millable canes than the other two planting methods in the following ratoon crop (Table 2). However, conventional method was on a par with the pit method. Though the shoot mortality in trench planting was the highest (27.4%) compared with only 16.0 % in conventional, the higher shoot populations as explained under plant crop helped it retain more number of millable canes at harvest. Pit planting revealed significantly higher individual cane weight than the other two planting methods. Trench planting recorded the highest ratoon-cane yield (55.5 t/ha), which was on a par with that pit of method (52.8 t/ha) and both were significantly better than flat method (47.8 t/ha). Trench planting retained 25.7% higher number of millable canes than conventional planting, which increased the cane yield. Higher individual cane weight, as explained under plant crop, was responsible for higher yield of ratoon crop in the pit method. Planting methods did not influence the ratoon-cane quality. However, cane sugar yield was the highest under trench method, which was on a par with the pit method, and both were significantly better than flat planting. The differences in ratoon-cane yield among the planting methods were also reflected in sugar yield.

The variable seed rates used in plant crop were on a par with respect to population of shoots and millbale canes, cane length and individual cane weight in the following ratoon crop (Table 2). The ratoon-cane yield also did not vary statistically with the seed rates. Non-significant differences in population of millable canes and cane weight, major contributors to cane yield, were reflected in cane yield also. Singles *et al.* (2005) opined that response to higher planting density diminishes with each subsequent ratoon, because stools in the lower planting density widens and thus captures more radiation. Besides, even the advantage of increased interception at higher densities diminishes with crop age and not all of the additional radiation intercepted benefits cane yield. The cane-quality parameters, viz. pol, brix and commercial cane sugar content, were significantly higher under 16.0 t/ha seed compared with that under transplanted crop. Millable canes at higher planting density primarily consist of primary shoots, which have better quality than secondary shoots. The variable seed rates adopted in plant cane did not influence the sugar yield of the following ratoon crop.

Economics

In plant crop, trench planting with 8.0 t/ha seed recorded the highest net returns (Rs 29,500/ha), whereas conventional method gave the highest benefit : cost ratio

Table 2. Effects of planting methods and seed rate adopted in plant crop on growth, yield and quality of following ratoon crop (mean of 2005-06 and 2006-07)

Treatment (adopted in plant crop)	Shoots (x 10^3/ha)	Millable canes (x 10^3/ha)	Millable cane length (cm)	Single cane weight (kg)	Cane yield (t/ha)	Pol % juice	Brix (%)	CCS (%)	Sugar yield (t/ha)
Planting method									
Conventional	81	68.1	161	0.59	47.8	18.82	21.59	12.97	6.21
Trench	118	85.6	159	0.57	55.5	18.99	21.66	13.13	7.26
Pit	91	70.0	161	0.71	52.8	18.71	21.42	12.91	6.83
SEm±	3	3.2	4	0.03	1.67	0.30	0.26	0.23	0.24
CD (P=0.05)	13	7.4	NS	0.06	3.86	NS	NS	NS	0.56
Seed rate (t/ha)									
4.0 (transplanting)	90	71.2	164	0.59	49.4	18.62	21.42	12.81	6.34
8.0 (sett planting)	100	71.5	158	0.66	52.4	18.79	21.54	12.98	6.79
16.0 (sett planting)	99	81.0	161	0.63	54.4	19.12	21.81	13.21	7.17
SEm±	4	3.8	4	0.04	3.41	0.18	0.16	0.15	0.46
CD (P=0.05)	NS	NS	NS	NS	NS	0.38	0.32	0.30	NS

Table 3. Economics of sugarcane plant-ratoon system under different planting methods and seed rates (mean of 2 cropping seasons)

Planting method	*Seed rate (t/ha)*								
	Plant crop			Ratoon crop			Plant - ratoon system		
	4.0	8.0	16	4.0	8.0	16.0	4.0	8.0	16.0
Conventional method									
Cane yield (t/ha)	63.1	70.8	80.0	44.1	50.6	49.0	107.2	121.4	129.0
Cost of cultivation (x 10^3 Rs/ha)	50.6	51.5	71.6	25.5	26.4	26.2	76.2	78.0	97.8
Net returns (x 10^3 Rs/ha)	21.6	29.3	20.0	28.2	35.2	33.5	49.9	64.6	53.6
B : C ratio	0.42	0.56	0.28	1.10	1.33	1.28	0.65	0.82	0.54
Trench method									
Cane yield (t/ha)	72.0	73.0	79.6	51.4	57.6	57.8	123.4	130.6	137.4
Cost of cultivation (x 10^3 Rs/ha)	54.0	54.4	74.3	25.0	25.9	25.7	79.0	80.2	99.9
Net returns (x 10^3 Rs/ha)	28.0	29.5	17.2	37.6	44.3	44.8	65.7	73.8	62.0
B : C ratio	0.51	0.54	0.23	1.50	1.71	1.74	0.83	0.92	0.62
Pit method									
Cane yield (t/ha)	66.0	62.6	77.6	52.9	49.0	56.7	118.9	111.6	134.3
Cost of cultivation (x 10^3 Rs/ha)	64.4	64.1	84.7	26.3	26.0	26.8	90.7	90.1	111.5
Net returns (x 10^3 Rs/ha)	11.3	7.7	4.2	38.2	33.7	42.4	49.5	41.4	46.5
B : C ratio	0.17	0.12	0.04	1.45	1.29	1.58	0.54	0.46	0.41

(0.569) at the same seed rate (Table 3). The higher cost incurred at sowing in pit method reduced its net returns compared with other two planting methods. In ratoon crop, trench planting with 16.0 t/ha seed recorded the highest net returns (Rs 44,800/ha) and B : C ratio (1.744), followed immediately by the same method with 8.0 t/ha seed. In sugarcane plant- ratoon system, trench planting with 8.0 t/ha revealed the highest total net returns (Rs 73,800/ha) as well as benefit : cost ratio (0.920). Trench transplanting proved economically better than conventional sett planting with recommended seed.

It was concluded that planting sugarcane in trenches in paired rows with 8.0 t/ha seed could help in achieving the highest productivity and profitability from sugarcane plant-ratoon system. Trench transplanting with 4.0 t/ha seed could be the second best option.

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