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Effect of planting method and drought-management technique on growth, yield and quality of sugarcane (*Saccharum* hybrid complex) under limited irrigation

A.K. SINGH*, MENHI LAL, ISHWAR SINGH[1], R.L. YADAV AND D.V. YADAV

Division of Crop Production, Indian Institute of Sugarcane Research, Lucknow, Uttar Pradesh 226 002

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ABSTRACT

A field experiment was conducted during spring season of 2005-06 and 2006-07 to study the effect of planting method and drought-management technique on growth, yield and quality of spring-planted sugarcane (*Saccharum* hybrid complex) with limited irrigations on clay-loam soil at Lucknow. Results revealed that the highest germination (49.6%), cane length (253.2 cm), cane girth (3.09 cm), cane weight (1.30 kg) and cane yield (87.6 t/ha) as well as sugar yield (9.87 t/ha) were recorded under ring-pit (75 cm diameter and 45 cm depth at 120 cm spacing) planting method. This was closely followed by trench method (120 cm apart, 45 cm deep trenches). However, the highest number of tillers (242.8 thousand/ha) and millable canes (149.4 thousand/ha) were counted in sugarcane planted at 60 cm row spacing. The drought-management treatment involving lime soaking of setts + farmyard manure (FYM) in furrow + trash mulch at 60 days after planting (DAP) + KCl and urea spray + additional 49.8 kg K/ha at 170 DAP produced significantly highest cane yield (86.2 t/ha) and improved the juice quality like brix (18.70) and pol (16.44%). The relative leaf-water content significantly improved under the management treatment involving addition of 49.8 kg K/ha at 170 DAP. The highest K uptake occurred under ring-pit planting method. The physical properties of the soil like bulk density and infiltration rate were improved by the application of FYM. The treatment consisting of ring-pit planting method with sett soaked in saturated lime water + FYM + trash mulching + KCl and urea spray + additional 49.8 kg/ha K application fetched the highest net profit (Rs 62,791/ha). Thus the ring-pit planting method and sett soaking in saturated lime water followed by adequate K nutrition imparted endurance characteristics to sugarcane plants under drought spells during the grand growth period and improved the cane productivity, its quality and profitability.

Key words: Drought management, Lime soaking, Potassium uptake, Relative water content, Ring-pit planting, Soil moisture, Sugarcane

Sugarcane (*Saccharum* hybrid complex) being a high water demanding crop receives great setback in sub-tropical India due to unpredictable behaviour of monsoon with respect to its onset, distribution, amount and retreat. Dwindling water resources over the years have created its shortage in many parts of the sugarcane-growing belts. Moreover, in summer months due to closure of canals and diversion of electricity from tube-wells to threshers for urgent wheat threshing in north India, the water is not available for sugarcane crop. Nearly 75% area under sugarcane in subtropical belt experiences moisture stress at one or the other stages of crop growth (Singh, 1997). For efficient utilization of available soil moisture, several low-cost agro-technologies like trash mulching and foliar spray of nutrients have been advocated (Verma, 2004). However, research information on an integrated approach involving these drought-proofing technologies with newly developed high-producing sugarcane-planting methods is not available. Hence, the present investigation was undertaken to develop applicable sugarcane planting-cum-moisture conserving techniques for mitigating the drought spells - a common feature in sub-tropical belt of India.

***Corresponding author** (Email: shantaanil@yahoo.com)

MATERIALS AND METHODS

A field experiment was conducted during spring season of 2005-06 and 2006-07 at Indian Institute of Sugarcane Research, Lucknow. The climate of the region is characterized by hot and dry summer and cold winters. The average annual rainfall is 989 mm and nearly 75 to 85% of the total rainfall is received through north-west monsoon (second fortnight of June to September) in 30 to 35 rainy days. The average monthly minimum and maximum temperatures fluctuate from 6.5 to 7.8 and 20.6 to 22.5°C in

[1]Present Address: Directorate of Maize Research, Indian Agricultural Research Institute, New Delhi 110 012

winter and from 22.8 to 25.6 and 39.5 to 41.6°C in summer respectively. The soil was clay-loam (Inceptisol) with neutral pH (7.6), low in available N (187.3 kg/ha) and organic C (0.36%) and medium in available P (18.7 kg/ha) and K (206.5 kg/ha). The field experiment was laid out in strip-plot design consisting of four sugarcane-planting methods, viz. planting at (i) 60 and (ii) 90 cm row spacing; (iii) planting in 45 cm deep trenches 120 cm apart and (iv) in ring-pits (75 cm diameter, 45 cm deep at 120 cm spacing) superimposed with four drought-management practices, viz. (i) the control (recommended practice); (ii) soaking cane setts in saturated lime water + farmyard manure (FYM) @ 10 t/ha in the furrows + trash mulch 60 days after planting (DAP) + foliar spray of urea and KCl each @ 2.5 % at 90, 105 and 120 DAP, (iii) treatment (ii) + additional 49.8 kg K/ha with last irrigation, and (iv) treatment (ii) + additional 49.8 kg K/ha at 170 DAP), replicated thrice. Sugarcane ('CoSe 92423') was planted in the last week of February with pre-planting irrigation. The crop received 150 kg N + 26.2 kg P + 49.8 kg K/ha in addition to treatmental K.

Three irrigations were applied each in the first week of April, May and June, respectively till the onset of monsoon in addition to one at pre-planting out of the recommended eight (six pre-monsoon including pre- planting and two post-monsoon) irrigations. No irrigation was given during the rainy months and post-rainy period. The biometric observations were recorded at harvest based on five randomly selected millable canes. The quality parameters of sugarcane were determined as per the method of Meade and Chen (1977). Cane yield was recorded based on the net plot size. Soil physico-chemical properties were determined as per the standard procedures. The economics of different treatment combinations were calculated on the basis of existing market prices of the produce and inputs used in cultivation. The net benefit : cost ratio was calculated by dividing the net returns with cost of production.

RESULTS AND DISCUSSION

Growth and yield of sugarcane

Sugarcane is propagated by stalk setts containing two or three buds. Bud germination constitutes a key factor, because good germination means a good start of the crop, which ensures adequate plant population. Data (Table 1) revealed that significantly highest germination (49.6%) occurred in ring-pit planting method, followed by that in trench planting. The greater the soil covers over the sett, the greater the distance that the young shoot has to travel in order to reach the soil surface. As long as the shoot has not reached the soil surface, it thrives at the expense of sett reserve. With increase in the depth of soil-covering setts, the number of shoots failed to reach the soil surface and reduced the germination percentage in flat planting method both at 60 or 90 cm row spacing.

The management techniques involving soaking cane setts in saturated lime water + FYM @ 10 t/ha in the furrows + trash mulch 60 DAP + foliar spray of urea and KCl each @ 2.5% at 90, 105 and 120 DAP gave significantly high germination over the control. The increase in germi-

Table 1. Effect of planting methods and drought management practices on growth attributes and yield of sugarcane (pooled of 2 years)

Treatment	Germination (%)	No. of tillers in June (x10³ /ha)	Cane length (cm)	Cane girth (cm)	Cane weight (kg)	NMC (x10³ /ha)	Cane yield (t/ha)	RWC (%)	Soil moisture (%)
Planting methods									
*FP at 60 cm row spacing	41.8	242.8	232.6	2.33	0.85	149.4	77.5	74.8	16.13
FP at 90 cm row spacing	41.6	196.5	233.8	2.37	0.96	127.7	71.9	73.8	15.98
Trench planting	47.9	235.4	238.9	2.46	1.15	142.3	81.2	75.2	16.99
Ring-pit planting	49.6	206.5	253.2	3.09	1.30	136.8	87.6	75.1	16.29
SEm±	1.0	3.0	2.5	0.08	0.80	5.3	1.2	1.3	0.76
CD (P = 0.05)	3.4	10.4	8.7	0.28	0.28	18.2	4.3	NS	NS
Drought management practices									
Control (T_1)	42.6	182.2	228.9	2.38	0.92	130.4	72.7	63.2	12.98
Lime soaking + FYM + trash mulch + KCl and urea spray (T_2)	46.3	231.6	236.3	2.50	1.04	137.2	77.3	72.6	15.34
T_2 + additional 49.8 kg K/ha at last irrigation (T_3)	46.2	232.3	243.7	2.57	1.11	141.8	82.0	80.4	17.91
T_2 + additional 49.8 kg K/ha 170 DAP (T_4)	45.9	235.1	249.7	2.80	1.18	146.9	86.2	82.7	19.15
SEm±	0.7	3.3	2.0	0.07	0.03	2.6	1.8	3.1	1.12
CD (P = 0.05)	2.4	11.3	6.8	0.24	0.12	9.0	6.4	10.7	3.86

*FP: Flat planting, DAP: Days after planting, NMC: Number of millable canes, RWC: Relative water content

nation by soaking of setts in saturated lime water might be due to higher moisture. The high water content in the setts is responsible for accelerating the conversion of carbohydrates into reducing sugars, resulting in higher germination percentage.

The data on numbers of tillers at maximum tillering stage indicate significantly highest number of tillers in the treatment where sugarcane was planted at 60 cm row spacing in flat planting system, which was however on par with that of trench planting. Singh *et al.* (2002) also observed higher number of tillers at closer row spacing. Beside, all the yield-attributing characters, viz. cane length (253.2 cm), cane girth (3.09 cm), individual cane weight (1.30 kg) and cane yield (87.6 t/ha), were significantly highest in ring-pit planting method. Significantly higher number of millable canes was recorded with planting at 60 cm row spacing. However, it could not contribute to yield due to lower individual cane weight. Singh *et al.* (2005) also reported higher number of millable canes at high planting density.

The drought management treatment, viz. soaking of setts in saturated lime water + FYM application + trash mulching + spray of urea and KCl, significantly increased the yield attributes and yield of sugarcane (77.3 t/ha) compared with the control. Significantly highest number of tillers (235.1 thousand/ha), cane length (249.7 cm), cane girth (2.80 cm), and finally the cane yield (86.2 t/ha) were recorded with additional application of 49.8 kg K/ha at 170 DAP. The increase in yield of sugarcane under the treatment receiving FYM might be due to increase in moisture availability on account of improvement in soil-physical conditions caused by reduction in bulk density and making the rhizosphere friable for better root spread, enabling them to absorb greater amount of water and nutrients under moisture-stress conditions. Moreover, trash mulching reduces the evaporation loss by offering resistance to water-vapour flow from the soil surface to atmosphere and by increasing the thickness of relatively non-turbulent air zone above the soil. The increase in yield of sugarcane by additional application of potassium under moisture-stress conditions might be attributed to regulation of stomatal opening and closing in the plant system by potassium, which governs the transpiration losses. The presence of potassium maintains turgidity of plant cell and regulates the thermal regime. Perumal (1995) also reported that application of potassium before moisture stress under drought conditions significantly increased the cane yield.

The relative water content (RWC) in the leaves and soil moisture were not affected by the method of planting. However, tangent increase in these parameters was recorded under drought- management treatments. Significantly highest RWC in leaves (82.7%) and soil-moisture content in root zone (19.15%) in the last week of September were recorded under additional K application at 170 DAP, because potassium is known to maintain the cell turgidity and regulate the transpirational pull (Yadav, 1993). Stomatal resistance is regulated by sugarcane plant, which ensures that transpiration is proportional to the available energy without inducing excessive heating of leaves and stomata respond to the vapour-pressure gradient in the immediate vicinity of the guard cells and to photon-flux density (Inman-Bamber and Smith, 2005).

Juice quality and sugar yield

The final product of cane is sugar, which is governed by juice quality. The data (Table 2) on juice quality, viz. brix, pol, purity and CCS (%), clearly indicate that it was significantly affected by the method of planting. Ring-pit planting of sugarcane recorded significantly higher brix (18.67), pol % (16.22) and CCS % (11.12) than other planting methods. The sugar yield, which is a function of quality and cane production was significantly highest under ring-pit planting (9.87 t/ha). The juice extracted from sugarcane cultivated under ring-pit contained higher brix and pol % because in this method (also termed no-tiller technology) only the mother shoots are converted into millable canes.

The drought-management treatments involving KCl spray or additional K application produced significantly superior juice quality and ultimately the sugar yield. Significantly highest brix (18.70), pol % (16.44) and CCS % (11.34) were recorded with additional K application 170 DAP over and above lime-soaking of setts + FYM application in furrows + KCl and urea spray. Gawander *et al.* (2004) also reported increase in sugar yield on K application.

Potassium uptake

The uptake of K by sugarcane depends on soil characteristics, availability in the soil and efficiency of the root system. Significantly highest K uptake (185.8 kg/ha) occurred under ring-pit planting followed by trench method (Table 2). Uptake of K increased significantly with additional application of K 170 DAP compared with lime soaking + FYM application + KCl and urea spray. The uptake of potassium was associated with high crop yield and higher concentration with in the above-ground biomass.

Physical properties of soil

The physical properties of soil observed initially and after the harvest of plant crop (Table 2) clearly indicate that there was slight reduction in bulk density under

trench and ring-pit planted plots (0-15 cm). The rate of infiltration was also higher (4.24 mm/hr) under ring-pit planting system. The reduction in bulk density and increase in infiltration rate was more under plots in which FYM was applied. The positive build-up in the physical properties of soil may be due to deep tilling under trench and pit planting methods *vis-a-vis* inclusion of organic matter in the system. Singh *et al.* (2007) too reported improvement in physical properties of soil by addition of FYM.

Economics

The data on net returns of different treatment combinations (Table 3) clearly revealed that highest net returns (Rs 54,654/ha) was fetched by ring–pit method of planting, followed by trench method. The management treatment involving additional 49.8 kg K application /ha 170 DAP was reckoned as the most profitable with net returns of Rs 57,876/ha and benefit : cost ratio of 1.24 compared with other treatments. The treatment combination of ring-pit planting with sett soaking in saturated lime water + FYM + trash mulching+ urea and KCl spray + additional 49.8 kg K/ha 170 DAP gave the highest profit (Rs 62,791/ha). The increase in the profit margin under these treatments was due to increase in the productivity of sugarcane.

It is concluded that the ring-pit method of planting and

Table 2. Effect of different treatments on juice quality parameters, K uptake and physical properties of soil after harvest of sugarcane

Treatment	Brix	Pol (%)	Purity (%)	CCS (%)	CCS (t/ha)	K uptake (kg/ha)	Bulk density (Mg/m^3)	Infiltration rate (mm/hr)
Planting methods								
FP at 60 cm row spacing	18.21	15.74	86.5	10.80	8.40	146.5	1.34	3.95
FP at 90 cm row spacing	18.23	15.79	86.8	10.87	7.84	139.9	1.34	3.95
Trench planting	18.26	15.84	86.7	10.85	8.83	168.6	1.31	4.24
Pit-planting	18.40	16.18	87.9	11.16	9.87	185.8	1.33	4.14
SEm±	0.05	0.10	0.62	0.09	0.25	3.9		
CD (P=0.05)	0.17	0.36	NS	0.31	0.88	13.8		
Drought management practices								
Control (T_1)	17.60	15.08	85.7	10.31	7.51	122.4	1.34	3.94
Lime soaking + FYM + trash mulch + KCl and urea spray (T_2)	18.23	15.80	86.8	10.88	8.42	136.3	1.33	4.12
T_2 + additional 49.8 kg K/ha at last irrigation (T_3)	18.56	16.22	87.4	11.16	9.17	179.7	1.33	4.12
T_2 + additional 49.8 kg K/ha at 170 DAP(T_4)	18.70	16.44	88.1	11.34	9.85	202.4	1.33	4.11
SEm±	0.24	0.17	0.93	0.25	0.12	5.3		
CD (P=0.05)	0.83	0.58	NS	0.86	0.43	18.3		

Table 3. Economics of different treatment combinations (mean of 2 years)

Treatment	FP-60 cm	FP-90 cm	Trench planting	Pit planting	Mean
			Cost of production (x 10^3 Rs/ha)		
Control (T_1)	42.51	41.41	42.94	52.21	44.77
Lime + FYM + trash mulch + KCl and urea(T_2)	44.23	43.13	44.66	53.93	46.49
T_2 + 49.8 kg K/ha at last irrigation	44.69	43.59	45.12	54.39	46.95
T_2 + 49.8 kg K/ha at 170 DAP	44.69	43.59	45.12	54.39	46.95
Mean	44.03	42.93	44.46	53.73	
			Net returns (x 10^3 Rs/ha)		
Control (T_1)	40.23	33.40	46.62	46.59	41.71
Lime + FYM + trash mulch + KCl and urea(T_2)	43.57	35.80	48.27	51.93	44.89
T_2 + 49.8 kg K/ha at last irrigation	47.86	42.72	52.37	57.29	50.06
T_2 + 49.8 kg K/ha at 170 DAP	56.05	53.65	59.00	62.79	57.87
Mean	46.93	41.39	51.56	54.65	
			B : C ratio		
Control (T_1)	0.95	0.81	1.09	0.89	0.93
Lime + FYM + trash mulch + KCl and urea(T_2)	0.99	0.83	1.08	0.96	0.97
T_2 + 49.8 kg K/ha at last irrigation	1.07	0.98	1.16	1.05	1.07
T_2 + 49.8 kg K/ha at 170 DAP	1.25	1.23	1.31	1.15	1.24
Mean	1.06	0.96	1.16	1.02	

sett soaking in saturated lime water followed by adequate K nutrition impart endurance characteristics to sugarcane plants during grand growth period of the crop under drought spells and improve the productivity and quality of sugarcane.

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