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Optimizing plant population density for enhancing yield of ratoon sugarcane (*Saccharum* spp) in sub-tropical climatic conditions*

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An optimum plant population is vital for achieving potential yield of sugarcane (*Saccharum* spp). Yield losses associated with large gaps in the plant crop continue to the subsequent ratoons. The first step towards maintaining adequate stands in the multi-year crop cycle commences with the plant cane itself. In sub-tropical climatic conditions, germination of cane buds ranges between 30 and 35% when planting is done in optimum soil moisture condition in well prepared field using viable buds of fresh seed cane, free from pests and diseases. However, in-spite of taking utmost care in planting of commercial sugarcane, optimum plant population is not obtained due to poor germination. This gives rise to poor plant stand which increases further in subsequent ratoons if these gaps are overlooked. In addition to several other factors responsible for poor germination of cane buds, some field operations are not taken into consideration by the farmers. About 15% of the cane buds are damaged during harvesting, transportation and setts cutting (Dafaalla and Hummeida 1991). Germination of cane buds is also affected badly due to inadequate or excessive soil cover. Richard and Dalley (2006) demonstrated that in plant cane, reducing soil coverage from 10 cm to 5 cm increased gaps and accordingly reduced the yields of cane and sugar significantly. These gaps as such in plant cane along with those which originate in ratoon cane results in to low stubble population. Of the various constraints, poor sugarcane stands is the major yield impediments in sugarcane plant- ratoon system in this region. Low yield of ratoon cane which occupies about 55% of the total area under sugarcane (Sundara 1987), affects both, cane growers and sugar factories as this is a preferred choice by virtue of its reduced production cost (25–30%) and availability of raw material to run the mills with higher sugar recovery in the early part of crushing season.

Several agro-techniques like trash mulching, intercropping of potato and wheat, spraying of growth hormones on stubbles have not been successful in increasing the plant population up to the desired extent in ratoon crops. Planting of 3-bud setts in places of gaps spotted 45 days after planting could maintain desired planting density in plant cane itself. This may improve the stubble population in ratoons as well. Potassium plays significant role in enhancing reducing sugar contents and metabolic activities by regulating water balance in the stubbles (Shukla *et al*. 2009) which may increase sprouting of subterranean buds. Keeping these points in view for enhancing the productivity of sugarcane plant-ratoon system, field experiments were conducted for obtaining optimum plant population by way of minimizing the effects of poor sugarcane stands in the plant crop and K fertigation, one month prior to harvesting of plant cane, separately and in combination.

Field experiments were conducted for plant and ratoon crops as one crop cycle during 2007–08 and 2008–09 at the Indian Institute of Sugarcane Research, Lucknow, located at 26.56°N, 80.52°E and 111 meter above mean sea level with semi-arid sub-tropical climate having dry hot summers and cold winters. The experimental field was sandy loam (13.8% clay, 23.6% silt and 62.9% sand) in texture, moderately alkaline in reaction (*p*H 8.1), low in available organic carbon (0.43%) and nitrogen (193.5 kg/ha) and medium in available phosphorus (21.7 kg/ha) and potassium (239.7 kg/ha). The treatments, viz T_1 : no gap filling + no K application; T_2 : no gap filling + K @ 80 kg/ha with irrigation water before one month of plant cane harvesting; T_3 : gap filling at 45 days after planting (DAP) with 3-bud setts + no K application and T_4 : gap filling at 45 DAP with 3-bud setts + K @ 80 kg/ha with irrigation water before one month of plant cane harvesting, were tried in randomized block design with four replications using CoSe 92423 as a test variety. Before planting of experimental crop, soil samples from 0–15 cm depth were collected by core sampler of 8 mm diameter from

*Short note

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five spots in the field. These samples were pooled together and representative homogeneous samples drawn for determination of initial soil fertility status following Jackson (1973). The crop was planted using 40 000 three-bud setts/ ha on 3 March 2007. These cane setts were placed horizontally, end-to-end, in 10 cm deep furrows opened 75 cm apart with tractor-drawn furrow opener. Before placing setts in the furrows half the dose of required nitrogen, ie 150 kg N/ha and 60 kg each of P_2O_5 and K_2O were applied in furrows beneath the cane setts using urea (46.4% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively. Chlorphyriphos 20% EC @ 5 litres/ha dissolved in 1 600 litres of water was spayed over cane setts before covering them to guard against termite and early shoot borer. The field was irrigated after 45 DAP with 7.5 cm irrigation water. The crop received three pre-monsoon irrigations ie up to June. When soil moisture attained a workable stage, inter-row spaces were intercultured manually using hand hoe. In the last week of June, remaining dose of 75 kg N/ha through urea was top-dressed uniformly along cane rows. Gap filling, as per treatment schedule, by 3-bud setts was done at 45 DAP only when the distance between two adjoining clumps was more than 50 cm. For application of potassium @ 80 kg/ha with irrigation before one month of plant cane harvesting, an amount of 16.6 kg muriate of potash was dissolved in 50 litres of water. Plastic tank with MOP solution was placed over irrigation channel. Tap of tank was opened and flow was calibrated according to discharge rate and flow of irrigation channel. Thus, 132.8 kg MOP in 400 litres of water was required to supply 80 kg K_2O/ha. The above solution was stirred with a wooden stick during irrigation to avoid settling of particles.

The plant crop was harvested on 11 March 2008 close to the ground level by specially designed steel chopper. After irrigation, when soil moisture attained a workable condition, half the dose of required nitrogen, ie 200 kg/ha was applied along ratoon stubble rows as side dressing while remaining N dose was top-dressed in the first week of May as top-dressing. The crop was grown and maintained as per agronomical practices followed in plant cane.

Observations on germination of cane buds, stubbles population, gaps in between adjoining clumps, number of tillers and millable canes, yield and yield attributes etc. in plant and ratoon canes were recorded at their respective growth and harvesting stages following standard procedures. Moisture and K contents of stubbles were recorded at the time of ratoon initiation. Dry matter accumulation in plant and ratoon canes at maximum tillering, grand growth and harvesting stages were determined as per standard procedure. Uptake of N, P and K in plant and ratoon canes was also worked out following standard procedures. At harvest, five canes were selected randomly for determination of brix and sucrose per cent in juice and thereby CCS per cent (commercial cane sugar) cane was computed as per Meade

Table 1 Growth parameters, yield attributes and yield, dry matter accumulation and nutrients uptake of sugarcane plant crop as influenced by the combination of gap filling and K fertilization during 2007–08

Treatment	Germination (%)	Gaps at 45 DAP/ ha	Tillers ('000/ha)	Millable canes ('000/ha)	Cane weight (kg)	Cane girth (cm)	Cane length (cm)	Cane yield (tonnes/ha)	CCS cane (%)	Sugar yield (tonnes/ha)	Dry matter accumulation (tonnes/ha)			Uptake of nutrients (kg/ha)		
											Maximum tillering	Grand growth	At harvest	N	P	K
T_1	33.91	5 013	164	108	0.658	2.47	163	71.62	11.38	8.15	8.44	18.32	24.19	139.42	21.23	171.52
T_2	33.46	4 873	165	111	0.662	2.51	166	72.81	11.35	8.26	8.31	18.55	24.08	142.61	22.62	178.40
T_3	33.84	4 878	171	118	0.656	2.52	162	77.83	11.49	8.94	10.62	20.34	26.36	155.91	24.72	188.09
T_4	33.39	4 968	174	120	0.664	2.46	167	79.58	11.52	9.17	10.74	20.44	26.51	158.46	25.43	192.16
CD (P=0.5)	NS	NS	3.93	4.83	NS	NS	NS	3.99	NS	0.56	2.12	2.01	1.92	12.32	1.79	9.45

T_1, No gap filling + no K application; T_2, no gap filling + K @ 80 kg/ha with irrigation water before one month of plant cane harvesting, T_3, gap filling at 45 DAP (days after plating) with 3-bud setts + no K application; T_4, gap filling at 45 DAP with 3-bud setts + K @ 80 kg/ha with irrigation water before one month of plant cane harvesting; CCS, commercial cane sugar

Table 2 Growth parameters, yield attributes and yield, dry matter accumulation and nutrients uptake of sugarcane ratoon crop as influenced by the combination of gaps filling and K fertilization during 2008–09

Treatment	Stubble population ('000/ha)	Per cent of gaps	Moisture content of stubble (%)	K content of stubble (%)	Tillers ('000/ha)	Millable canes ('000/ha)	Cane weight (kg)	Cane girth (cm)	Cane length (cm)	Cane yield (tonnes/ha)	CCS (%)	Sugar yield (tonnes/ha)	Dry matter accumulation (tonnes/ha)			Uptake of nutrients (kg/ha)		
													Maximum tillering	Grand growth	At harvest	N	P	K
T_1	22.10	24.32	40.13	0.34	247	107	165	2.20	0.653	66.44	11.24	7.47	7.65	16.44	22.12	133.58	20.12	183
T_2	25.03	17.62	50.62	0.40	268	116	169	2.23	0.663	73.25	11.37	8.33	8.82	18.55	24.51	148.51	22.62	210
T_3	26.31	15.46	39.19	0.36	272	118	164	2.22	0.658	74.04	11.34	8.40	8.57	18.27	24.36	150.62	22.42	212
T_4	29.24	11.27	48.61	0.47	283	127	168	2.25	0.668	80.85	11.47	9.27	10.35	20.09	26.48	161.36	24.62	224
CD (P=0.5)	2.33	3.51	6.32	0.05	9.83	8.45	NS	NS	NS	5.68	NS	1.08	1.04	1.39	1.96	10.41	2.06	10.14

T_1, No gap filling + no K application; T_2, no gap filling + K @ 80 kg/ha with irrigation water before one month of plant cane harvesting; T_3, gap filling at 45 DAP (days after plating) with 3-bud setts + No K application; T_4, gap filling at 45 DAP with 3-bud setts + K @ 80 kg/ha with irrigation water before one month of plant cane harvesting; CCS, commercial cane sugar

and Chen (1977). Sugar yield was assessed after multiplying CCS per cent cane with the yield of plant and ratoon canes. The data of plant and ratoon canes were statistically analyzed separately. Various treatments were compared under randomized block design. The critical difference (CD) was computed to determine statistically significant treatment differences.

Experimental data presented in Table 1 clearly revealed that after attaining non-significant germination of cane buds (33.65%, on an average) at 45 DAP (days after plating), the gaps in between two adjoining cane plants were observed in the range of 4 873 as minimum to the maximum of 5 013/ha in different treatments. In general, such gaps in plant cane do occur due to one or other factors, viz insufficient or excess soil moisture, planting with stale cane, setts with damaged or no buds, depth and time of planting, attack of termite on cane setts, rains after planting, planting with shy germinator cane varieties, environmental temperature etc. which are practically not feasible to avoid or manage in commercial planting. The treatments, viz no gap filling + no K application (T_1) and no gap filling + K @ 80 kg/ha with irrigation water before one month of plant cane harvesting (T_2) did not show any significant difference in the growth and yield of sugarcane plant crop and were statistically at par. However, gap filing with 3-bud setts at 45 DAP + no K application (T_3) and gap filling with 3-bud setts at 45 DAP + K @ 80 kg/ha with irrigation water before one month of plant cane harvesting (T_4) being statistically at par with each other, produced significantly higher number of tillers and millable canes, yield of cane and sugar, dry matter accumulation and uptake of N, P and K as compared to T_1 and T_2 treatments. Gap filling by 3-bud setts at 45 DAP (T_3 and T_4) improved the cane yield significantly which was 8.25% higher than that obtained under no gap filling treatments (T_1 and T_2). Gap filling by fresh 3-bud cane setts at 45 DAP in T_3 and T_4 treatments, reduced the gaps between plants and increased the number of tillers and millable canes significantly as compared to T_1 and T_2 treatments. Yadav (1991) has opined that the number of millable canes (stalks) unit area is the most important factor for increasing cane yield.

Potassium application (T_2 and T_4) triggered to significant improvement in stubble population by reducing gaps and moisture and K contents of stubble buds of subsequent ratoon crop which favoured various metabolic activities during sprouting of buds (Table 2). This paved the way for significant increase in number of tillers and millable canes and yield of cane and sugar over no K application (T_1 and T_3). Potassium fertigation, thus enhanced the yield of cane and sugar by 8.82 and 9.77%, respectively over no K application (70.24 and 7.94 tonnes/ha). It was due to role of potassium as a co-factor and increase in synthesis of protein, lipid and cell wall in growing regions (Mengel and Haeder 1977). In addition, irrigation to the crop provided congenial atmospheric condition in the vicinity of root stubble that improved emergence and growth of tillers (Berding *et al.* 2005). K application might have imparted resistance against biotic stress (Krauss 2001) and increased organic acids and nitrate reductase activity. Similarly, gap filling in plant cane at 45 DAP proved instrumental in minimizing gaps of subsequent ratoon and thereby increased the number of tillers and millable canes and yield of cane and sugar, significantly over no gap filling treatments. The gap filled treatments were statistically at par with K fertigated plots on the above aspects, but the combination of both treatments (T_4) produced highest ratoon cane yield at 80.85 tonnes/ha which was significantly higher to the tune of 17.82, 9.40 and 8.42% than that obtained under T_1, T_2 and T_3 treatments, respectively.

SUMMARY

Gap filling with fresh 3-bud cane setts between adjoining cane plants 45 days after planting lowered the gaps and enhanced the growth and yield of plant cane and sugar yield, by increasing stubble population, tillers and millable canes in ratoon cane, significantly over no gap filling. Application of potassium @ 80 kg/ha with irrigation water before one month of plant cane harvesting improved bud sprouting in ratoon crop. It increased ratoon cane and sugar yield by 8.82 and 9.77%, respectively over no K application (70.24 and 7.94 tonnes/ha). The treatment comprising gap filling in plant cane at 45 DAP followed by application of K @ 80 kg/ha before one month of plant cane harvesting, gave the highest ratoon cane yield of 80.85 tonnes/ha which was significantly higher to the tune of 17.82, 9.40 and 8.42% than those obtained under T_1, T_2 and T_3 treatments, respectively.

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