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Effect of planting geometry, nitrogen and potassium application on yield and quality of ratoon sugarcane in sub-tropical climatic conditions

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ABSTRACT

A field experiment was conducted at Lucknow during 2005–08 to study the effect of planting geometry and N and K application on yield of ratoon sugarcane. The crop was planted using 4 planting geometries, ie single rows at 60, 75 cm spacing, paired rows at 75:45 and 105:45 cm spacing. Paired row planting at 75:45 cm gave significantly higher number of stubble with viable buds (32 280/ha), dry matter accumulation, millable canes (1 34 000/ha) and cane yield (76.44 tonnes/ha). Application of 200 kg N and 80 kg K/ha recorded significantly improved yield attributes, dry matter accumulation and cane yield over their respective control. The highest ratoon cane, sugar yield and net returns were obtained by paired row planting at 75:45 cm and application of 200 kg N and 80 kg K/ha.

Key words: Economics, Planting geometry, Ratoon yield, Shoot population, Viable stubble

The quintessence of ratoon cropping lies in reduced cost of production, saving of energy and early maturity by 4 to 5 weeks. In spite of this fact, the ratoon cane productivity at national level stands at 58 tonnes/ha against 85 tonnes/ha for plant cane (Lal and Singh 2008). The major yield impediments include poor crop stand and low nutrient-use efficiency, leaving much scope to refine the agro-techniques further, for yield improvement. The gaps arise mainly due to death of stubble bud, its failure to sprout owing to cold or mechanical injury and or bud damage by pests build-up (termites) at root zone.

Any short in 3 viable stubbles/m row length leads to gappy crop stand. When such gaps exceed more than 15%, the loss in cane yield becomes inevitable. Contrary, a flush of newly emerged shoots is witnessed just after harvesting of the plant crop leading to increased intershoots competition within same clump. Thus, sporadic clump's population with poor stalks vigour give rise thinner canes with low cane weight. The reduced nutrient-use efficiency owing to old root system and wider C: N ratio due to immobilization of nitrate-N results imbalanced nutritional state at rhizosphere and hinders proper supply of nutrients at the initial stage of the crop. These initial setbacks reflect in crop growth, shoot population, stalk weight and cane yield. An experiment was, therefore, undertaken to study the response on first and second ratoons to various planting geometries, N and K levels to find out an economically viable planting technique with optimum N and K schedules.

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MATERIALS AND METHODS

A field experiment was conducted during 2005–08, on sandy loam (sand 60.2, silt 24.4 and clay 15.4%) with bulk density of 1.28 Mg/m^3, *p*H 7.82, electrical conductivity 0.20 ds/m, well drained and classified as non-calcareous mixed hyperthermic *udic ustocrept* at the research farm of Indian Institute of Sugarcane Research, Lucknow (27.1° N latitude and 81.3° E longitude). The initial contents of organic carbon, available N, P_2O_5 and K_2O were 0.51%, 219.5, 38.7 and 285.6 kg/ha, respectively. After harvesting of each ratoon crop, the soil chemical analyses were done in various treatments.

The plant crop was planted on 18 February 2005 using 3 bud setts of 'CoSe 92423' sugarcane employing 4 planting geometry, viz planting at 60 cm, 75 cm, paired row planting at 75:45 and 105:45 cm. The setts were planted end-to-end in 10 cm deep furrows. The plot size was 45 m×9 m, replicated thrice and the crop was fertilized with recommended doses of 150 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha. A total number of 48 000 of 3-bud setts/ha were used under each planting at 60 cm and paired row planting at 75: 45 cm, while 38 800, 3-bud setts/ha were planted at 75 cm and paired row planting at 105:45 cm. The plant crop was harvested close to the ground with specially designed steel chopper during second fortnight of February 2006 and first ratoon crop was initiated. Each plot was divided into 9 subplots (9 m×5 m) where the combinations of N and K, viz N_0 K_0, N_0 K_{40}, N_0 K_{80}, N_{100} K_0, N_{100} K_{40}, $N_{100\ K80}$, N_{200} K_0, N_{200} K_{40} and N_{200} K_{80} were applied in first and again in second ratoon crops after 7–10 days of harvesting of plant crop and first ratoon. After harvesting the first ratoon crop on 15 February 2007, second ratoon crop was raised and harvested on 25 December 2008. These were replicated thrice and evaluated in split-plot design keeping crop geometry in main plots and combinations of N and K in subplots.

All the agronomic and plant protection operations were carried out uniformly irrespective of treatments on plant and ratoon crops. The incidence of pests and diseases was below economic threshold level. Viable stubbles were counted along the rows 15 days after ratoon initiation. Shoot population density was recorded at monthly interval in both ratoon crops. Five canes were selected at harvest and °brix, pol% juice and purity were determined. For economic analysis, the existing wages and cane price decided by the Government were taken into consideration. Cane length was recorded just before harvesting. The millable canes, cane weight and cane yield were recorded from net area and estimated on hectare basis.

RESULTS AND DISCUSSION

Viable stubbles

Different alterations in planting geometries which basically varied on inter-row spacing, row arrangement and planting density, differed significantly on stubbles counts in both first and second ratoon crops. The responses of both the ratoon crops were similar for all the treatments hence data was pooled and depicted through Fig 1. Paired row planting at 75:45 cm being at par with planting at 60 cm gave significantly higher (19.9 and 18.3%) number of viable stubbles over planting at 75 cm and paired row planting at 105:45 cm, respectively (Fig 1). The higher stubble population was mainly due to higher number of buds planted/ unit area and supported by suitable planting geometry. Planting at 60 cm gave 13.3% higher stubble population than planting at 75 cm. Application of 200 kg N/ha brought forth significantly higher (7.1%) number of stubbles than no-nitrogen, indicating that the soil-N was not sufficient to meet the requirement. Potassium is important for maintaining water balance in the bud, thereby regulating metabolic activities (Shukla *et al*. 2009). Application of 80 kg K/ha gave the highest number of clumps (29 780/ha).

Periodic shoot population

The underground branching in sugarcane give rise the tillers. After harvesting of the plant crop, a flush of newly emerged shoots was observed, this continued to increase exponentially up to first week of July in both the years. Thereafter, number of shoots/unit area declined due to tiller's mortality. Maximum numbers of shoots were observed in

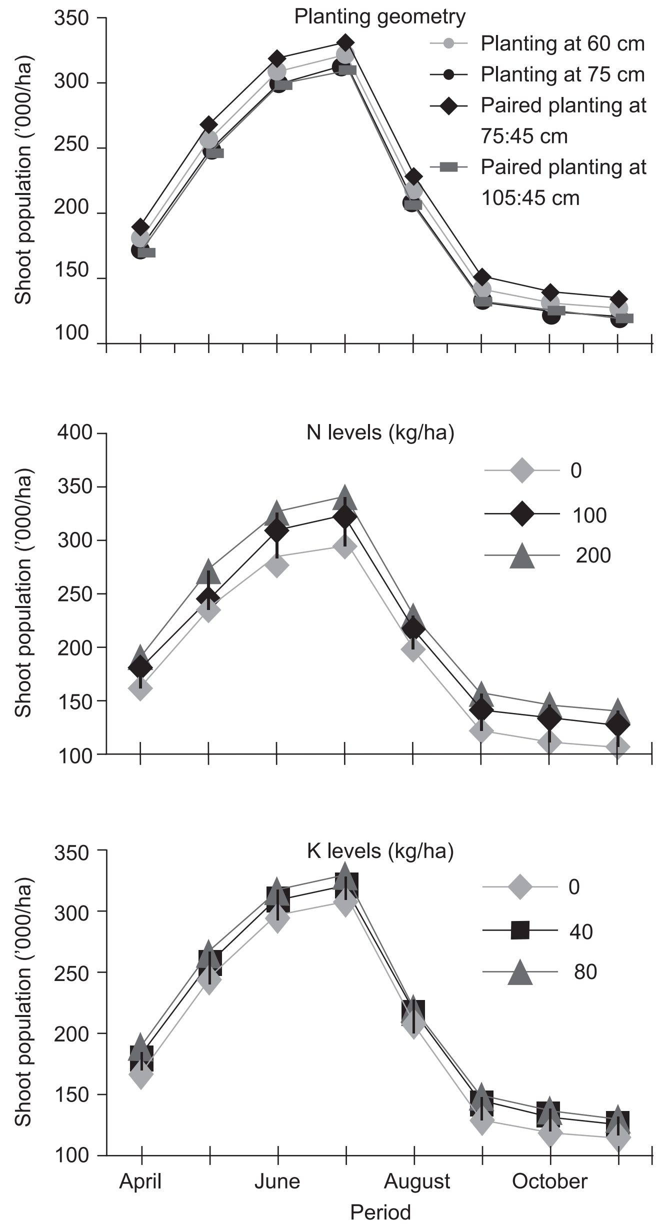

Fig 1 Shoot population density under various planting geometries, N and K levels

paired row planting at 75:45 cm, followed by planting at 60 cm at all the crop stages. These both crop geometries were at par until August and gave significantly higher shoot population than planting at 75 cm and paired row planting at 105:45 cm, followed by significantly higher stalk population with planting at 75:45 cm at later stages. Higher shoot population density in paired row planting at 75:45 cm was primarily due to more number of stubbles/unit area which recorded maximum shoot population/ha and minimized gaps.

The shoot population significantly increased by each increasing level of nitrogen at all the crop stages. At maximum tillering stage application of 100 and 200 kg N/ha gave 9.4% (321 700/ha) and 15.7% (340 200/ha) higher shoot population against control (no-N). At harvest, the increase in number of millable canes by application of 100 and 200 kg/ha was 16.8% (1 27 300/ha) and 31.86% (1 40 700/ha), respectively. There was an increase of 11% (920/ha) with 100 kg N/ha over no-nitrogen, whereas 7.5% population (1 100/ha), increased with 200 kg N/ha over 100 kg/ha. High concentration of nitrogen at initial stage is required for profuse tillering in sugarcane and this can be achieved by applying N fertilizer during the formative phase of the crop (Shukla 2003). Paired row planting at 75:45 cm after earthing-up became almost an equidistant 75 cm planting. It allowed penetration of light through out crop canopy and thus emerged a favourable planting geometry by retaining significantly higher number of shoots over closer planting at 60 cm. The least shoot population recorded in paired planting at 105:45 cm was attributed to lower number of stubble/unit area as compared to closer planting geometry (75:45 cm). Thus vacant space could not be fully utilized.

A consistent increase in shoot population density up to July was observed by increasing the potassium levels. Thereafter, the plots that received 80 kg K/ha retained more number of shoots/unit area. However the increase in shoot population with 40 kg K/ha to those supplied with 80 kg K/ha did not differ significantly during the first season. The effect of higher K doses on shoot population was significant in second season indicating the vital role of potassium in maintaining water balance in the stubble bud and imparting resistance to the plant against diseases and pests. This might have attributed to the synergistic effect of K with N and translocation of photosynthates in the plants in a relatively efficient manner. It facilitated the crop establishment with production of greater number of both primary and higher order of shoots. At later stages the higher number, tillers survived in the plots applied with 80 kg K/ha, followed by 40 kg K/ha. These results are in conformity with the findings obtained by Shukla *et al.* (2009).

The maximum rate of increase (20.3%) in shoot population was during May–June. A nominal increase in shoot population was noted in the first week of July thereafter, started to decline. In both the experimental crops, about 36% of the shoot population produced at peak tiller stage was observed to be converted in to millable canes at harvesting time. Remaining tillers either died or could not qualify to become millable canes. The shoot population remained static after first week of November in both the ratoon crops.

Cane yield and yield attributes

The various planting geometries influenced the cane yield significantly. The paired row planting (75:45 cm) recorded significantly the highest average cane yield of 2 subsequent ratoons (80.51 tonnes/ha) which was higher by 4.88 tonnes/ha (6.5%), 6.7 tonnes/ha (9.2%) and 10 tonnes/ha (14%) over planting at 60 cm, 75 cm and paired row planting (105:45 cm), respectively.

Of the different combinations of N and K doses, 200 kg N/ha and 80 kg K/ha applied on ratoon crops recorded the highest cane yield. However, the combined effect of planting at 75:45 cm, applied with 200 kg N/ha and 80 kg K/ha emerged the best combination recorded the highest mean cane yield of 2 subsequent ratoons (87.8 tonnes/ha), which was superior by 4 tonnes/ha (4.8%), 8.41 tonnes/ha (9.6%) and 11.5 tonnes/ha (15%) over planting at 60 cm, 75 cm and paired row planting at 105:45 cm, fertilized with same levels of N and K, respectively. Increase in cane yield under closer row spacing coupled with higher planting density was attributed to the production of more number of millable canes (Tables 1, 2) owing to higher number of viable stubble/ha. The paired row planting (75:45 cm) resulted in to combined positive blend of both narrow spacings (for more viable stubble in ratoon) and wider spacing which facilitated better interception of light, avoided shading effect, produced moderately thicker canes, unlike narrow spaced plants. In sugarcane, number of millable canes at harvest influences the average productivity of the crop. Studies at Karnal also revealed that closer planting of sugarcane was beneficial. Higher doses of N and K proved to be crucial for maintaining higher initial plant population by way of enhancing tillering and plant vigour at later stages. The ratoons are less efficient in utilizing soil nutrient owing to old and suberised roots hence higher dose of N gave positive results and so was true for K which, in addition to its positive effects also synergized the N utilization in comparison to N alone. The results revealed that paired row planting at 75:45 cm with higher planting density outyielded over single row planting (60 cm) with same planting density in both ratoons. The contribution of physiological parameters can also be analyzed in terms of yield and yield component's variations. The yield in sugarcane is cumulative function of mainly 2 basic components, ie number of millable canes/unit area and weight of millable cane. The number of millable canes, in turn, is governed by the number of shoots/unit area produced and weight of cane is governed by cane length and girth. Closer paired row planting with higher planting density resulted in to higher number of viable stubbles that gave rise to higher plant population which produced more number of millable canes. The paired row planting (75:45 cm) counteracted the ill effects of narrow planting as in 60 cm and harvested the benefits of accommodating higher shoot population by way of higher seeding rate. This favoured the crop development with proper anchorage.

Higher doses of N application improved the yield attributes, viz number of millable canes, cane length, cane diameter and cane weight, significantly. Application of 200 kg N/ha recorded 13.8 and 46.1% more number of millable canes than those of 100 kg N/ha and control (no-N), respectively. This, along with other improved attributes led to increased cane yield by 11% (63.94 tonnes/ha) and 41% (76.44 tonnes/ha) over same treatments, respectively.

Table 1 Dry matter accumulation (tonnes/ha) at harvest as influenced by different treatments (mean data of 1st and 2nd ratoon)

Geometry	N_0			N_{100}			N_{200}			Mean
	K_0	K_{40}	K_{80}	K_0	K_{40}	K_{80}	K_0	K_{40}	K_{80}	
Planting at 60 cm	13.94	17.00	19.00	18.47	21.52	23.52	21.53	23.00	25.00	20.33
Planting at 75 cm	12.56	15.25	17.19	17.02	19.84	21.71	19.85	23.00	23.18	18.68
Paired row plantingat 75:45 cm	16.33	19.15	21.54	20.83	24.19	26.07	23.87	25.08	27.32	22.79
Paired row plantingat 105:45 cm	11.71	14.72	17.25	16.25	19.15	21.82	19.67	25.80	24.54	18.26
Mean	13.63	16.53	18.74	18.14	21.17	23.28	21.23	23.04	24. 46	
S Em±	C G = 0.62N×K = 0.80, G×N×K= 1.39									
CD (*P* = 0.05)	C G = 2.15N×K = 2.26, G×N×K = 3.93									

Table 2 Yield attributes, juice quality parameters and economics of sugarcane ratoon as influenced by various juice treatments

Treatment	Millable canes ('000/ha)	Cane length (cm)	Cane diameter (cm)	Cane weight (g)	°Brix	Pol (%)	Purity (%)	Sugar yield (tonnes/ha)	Net profit (/ha)	B:C ratio
Crop geometry										
Planting at 60 cm	115.7	194.1	2.07	682.4	17.12	15.24	87.85	7.08	59 873	2.14
Planting at 75 cm	110.7	184.2	2.19	698.9	17.50	15.70	87.67	6.96	55 802	2.18
Paired planting at 75:45 cm	123.5	190.8	2.15	695.4	17.58	15.70	87.30	7.95	65 460	2.55
Paired planting at 105:45 cm	108.1	183.7	2.21	705.0	17.66	15.70	87.39	6.75	52 356	2.04
S Em±	1.64	2.40	0.02	3.50	0.24	0.10	0.28			
CD (*P*=0.05)	6.81	5.37	0.09	12.10	0.43	0.52	NS	0.36		
N levels (*kg/ha*)										
0	91.69	168.0	2.06	672.4	17.54	15.51	88.42	5.91	43 784	1.79
100	117.8	188.5	2.18	699.4	17.33	15.61	89.06	7.34	61 328	2.38
200	134.0	208.1	2.24	714.5	17.53	15.63	88.25	8.29	69 797	2.60
S Em±	1.62	2.26	0.03	3.69	0.24	0.14	0.16	0.13		
CD (*P*=0.05)	5.39	6.40	0.09	10.45	0.43	0.34	0.45	0.35		
K levels (kg/ha)										
0	109.1	170.0	2.06	679.3	17.40	15.08	87.68	6.55	50 847	1.99
40	115.5	191.8	2.17	695.3	17.44	15.67	88.83	7.18	59 185	2.29
80	118.8	202.9	2.23	706.8	17.56	16.01	89.22	7.82	64 877	2.49
S Em±	1.62	2.26	0.03	3.69	0.24	0.15	0.16	0.13		
CD (*P*=0.05)	5.39	6.40	0.09	10.45		0.34	0.45	0.35		

Optimum availability of nutrients is an essential factor for greater shoot sustenance/unit area and nitrogen is the prime promoter of tillering. High shoot population obtained either in narrow row spacing or modified crop geometry must have a support of higher N doses (Yadav 2007). Ratoon cane yield responded significantly to K application up to 80 kg K/ha. It was due to more number of vigorous tillers formed in ratoon cane with 80 kg K/ha and subsequently more number of millable canes. Primary and secondary tillers in sugarcane get larger duration for growth and food from stubble and when facilitated with optimum dose of N and K resulted in to millable canes of higher length, diameter and weight. Application of 200 kg N along with 80 kg K/ha proved its superiority by recording the highest cane yield (81.83 tonnes/ha).

Juice quality and sugar yield

The observations on quality parameters of cane juice, viz brix, pol and purity were recorded at maturity in both the experiments and results are summarized in Table 2. The data indicated that different crop geometries and nitrogen and potassium levels did not cause variation on these traits, significantly. However, pol and purity showed improvement by increasing K levels from 0 to 80 kg/K ha.

The sugar yield was affected significantly by different crop geometries and nitrogen and potassium treatments. The paired row planting at 75:45 cm gave significantly higher sugar yield (7.95 tonnes/ha) over rest of the treatments. The lowest sugar yield (6.75 tonnes/ha) was obtained with paired row planting at 105:45. Among the nitrogen treatments, 200 kg N/ha recorded the highest sugar yield (8.29 tonnes/ha).

Table 3 Ratoon cane yield (tonnes/ha) as influenced by different treatments (mean data of 1st and 2nd ratoon)

Geometry	N_0			N_{100}			N_{200}			Mean
	K_0	K_{40}	K_{80}	K_0	K_{40}	K_{80}	K_0	K_{40}	K_{80}	
Planting at 60 cm	50.93	55.87	59.72	62.84	70.80	75.75	70.80	78.78	83.80	67.7
Planting at 75 cm	45.80	51.76	61.38	60.30	67.23	71.30	67.80	75.30	79.39	64.47
Paired row plantingat 75:45 cm	50.82	59.70	68.80	64.30	76.79	80.77	75.77	82.86	87.86	71.96
Paired row planting at 105:45 cm	44.37	50.83	53.79	58.75	63.75	69.32	66.24	72.35	76.33	61.75
Mean	47.98	54.54	60.92	61.55	69.64	74.29	70.15	77.32	81.85	
S Em ±	C G = 0.96 N×K = 1.53, G×N×K= 3.01									
CD (P = 0.05)	C G = 3.30 N×K = 4.91, G×N×K = 8.50									

Similarly, the highest dose of 80 kg K/ha recorded significantly highest sugar yield (7.82 tonnes/ha). However, higher sugar yield was mainly due to higher yield of ratoon obtained under these treatments.

Economics

The highest net profit of ₹ 65 460/ha was obtained with paired row planting at 75:45 cm which also fetched the highest B:C ratio (2.55). Application of 200 kg N and 80 kg K/ha, respectively gave the highest income in terms of net profit and B: C ratio. The profit followed almost similar trend as was obtained in cane yield. Increased monetary returns due to higher cane yield under relatively costlier treatments overtook the higher cost of production and resulted into higher net profit and B: C ratio as well.

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