Indian Journal of Agronomy **52** (2) : 164–167 (June 2007)

Productivity and economics of high-sugar genotypes of sugarcane (*Saccharum officinarum* hybrid complex) in plant-ratoon system under various planting seasons and fertility levels

S.K. SHUKLA*

Indian Institute of Sugarcane Research, Lucknow, Uttar Pradesh 226 002

Received : February 2005

ABSTRACT

A field experiment was conducted during cropping seasons of 2002–03 and 2003–04 at Lucknow, to evaluate 3 sugarcane genotypes ('CoLk 9411', 'CoLk 9412' and 'CoLk 94184') under 3 levels of N, P and K (150, 19.6, 37.4; 200, 26.2, 49.8; and 250, 32.8, 62.2 kg/ha) in 2 seasons (spring and summer) with plant-ratoon system. Genotype 'CoLk 94184' recorded the highest cane yield and commercial cane sugar (CCS) across the seasons as well as plant and ratoon crops. Genotype 'CoLk 94184' showed the highest brix (21.21) and pol (18.49%) reading at 10-month stage in spring-planted cane. Individual cane length and cane weight increased significantly up to 200, 26.2 and 49.8 kg N, P and K/ha. Ratoon of the genotype, 'CoLk 94184' produced the highest number of millable canes (133,900/ha), cane length (186.8 cm), cane yield (70.46 t/ha) and CCS (9.39 t/ha). The plant-ratoon system indicated that genotype 'CoLk 94184' gave the maximum net returns (Rs 98,558/ha) and benefit : cost ratio (2.99) in the spring-planted cane. Genotype CoLk 94184 gave better yield, sucrose and net profit, hence could be adopted in the region for optimizing sugar productivity and regulating crushing schedule at factory level. Fertility level of 200, 26.2 and 49.8 kg N, P and K/ha was optimum for growth and cane yield during spring as well as summer planting.

Key words : Sugarcane, Genotypes, Planting season, Commercial cane sugar, NPK level, Net return

In subtropical India, sugarcane (*Saccharum* spp. hybrid complex) is planted in autumn, spring and summer seasons. Productivity of different genotypes is greatly influenced by genetic make up and agro-techniques. Role of nitrogen in increasing tillering and growth is well recognized. Heavy application of nitrogen decreases the juice quality. Ratooning capacity of different sugarcane genotypes varies differently (Tripathi, 1998). Optimum nutrient management for sugarcane plant crop plays key role, as it establishes vigorous stubble, which affects the ratoon yield (Shukla, 2007). Tillering period in sugarcane is the most important growth phase which governs the cane yield in subtropical India. Normally sugarcane germination under subtropical conditions is 30-35% as compared to 80-85% in tropical part of the country. When sugarcane planting is delayed from February to April/May, it gets lesser time for tillering and reduces productivity (Pandey and Shukla, 2001). Thus, time of planting is a key component for obtaining high sugarcane productivity, which is liable to change as per genotypes and environment. Keeping this in view, a field experiment was conducted to study the performance of sugarcane genotypes under different planting seasons and nutrient levels in subtropical India.

***Corresponding author** (Email: sudhirshukla151@yahoo.com)

MATERIALS AND METHODS

A field experiment was conducted during 2002–03 and 2003–04 at the Indian Institute of Sugarcane Research, Lucknow, Uttar Pradesh, using 3 sugarcane genotypes and 3 NPK levels to identify suitable genotypes under various planting seasons. Loamy soil of experimental field with pH 7.6 was low in organic carbon (0.41%) and available N (190 kg/ha), and medium in P (14.5 kg P/ha) and K (215 kg K/ha). Nine treatment combinations were tested in a 3 times replicated randomised block design. Separate trials were conducted for spring and summer seasons. Planting of spring (February planted) and summer cane (April planted) was done at 75 and 60 cm row spacing respectively. After harvesting of sugarcane plant crop, ratoon crop was raised.

Ratoon was initiated in February. Recommended package of practices were followed for ratoon crop. Treatments were not applied to the ratoon crop, rather carry-over effects of the treatments were studied in the ratoon crop harvested in December. Five canes were randomly selected from each plot for estimation of growth attributes and juice-quality parameters (brix, pol % juice and purity coefficient). Juice purity and commercial cane sugar (CCS) were calculated.

Sucrose content in juice was determined (Chen and Chou, 1993). Millable cane stalks were counted in November in the plant and ratoon crops. Cane-growth attributes (length, diameter, and weight) were measured before harvesting at the time of juice analysis.

RESULTS AND DISCUSSION

Growth, yield and quality of plant crop

Spring planting : Mean data of 2 cropping seasons indicated that genotype 'CoLk 9412' showed higher germination (41%) than 'CoLk 9411' and 'CoLk 94184' (Table 1). Maximum numbers of millable canes were found with 'CoLk 94184', owing to its higher tillering capacity. Cane length of 'CoLk 9411' and 'CoLk 94184' were statistically at par but 'CoLk 9412' produced thicker canes than the other 2 genotypes. Overall mean individual cane weights (690.2 g) of 'CoLk 9412' and 'CoLk 94184' (683.9 g) were at par. It showed that although 'CoLk 9412' produced thicker canes than 'CoLk 94184', contribution of cane length in cane weight compensated the effect of diameter, so 'CoLk 9412' was at par with 'CoLk 94184'. Higher cane yield was harvested with genotypes 'CoLk 94184' owing to higher number of millable canes and optimum cane weight. Genotype 'CoLk 94184' showed the highest brix (21.21%) and pol (18.49%) reading at 10-month stage in spring cane (Table 1). It was observed that maximum benefit from high sugar genotype, 'CoLk 94184' could be harvested in December under spring-planting situation.

Germination of spring-planted crop remained unaffected due to fertility levels. Number of millable canes and individual cane length increased significantly up to 200, 26.2, 49.8 kg NPK/ha. Moreover, higher dose of NPK also reduced the tiller mortality, indicating that besides production of millable canes higher nutrition level helped in maintaining retention of tillers. The role of nitrogen in chlorophyll formation and carbohydrate metabolism and positive interaction of nitrogen and phosphorus and nitrogen with potassium is well known. It was main reason in improving millable canes, growth and vigour of sugarcane plant. Higher cane weight was obtained up to 200, 26.2 and 49.8 kg N, P and K/ha, as it had positive effect on growth and development processes (Pandey and Shukla, 2001). Thus, cane yield and CCS were also higher at this

Table 1. Influence of genotypes and fertility levels applied in spring and summer crop on growth, yield and commercial cane sugar (CSS) of sugarcane plant crop (mean data of 2 cropping seasons)

Treatment	Germination (%)	Milliable canes ('000/ha)	Cane length (cm)	Cane diameter (cm)	Cane weight (g)	Cane yield (t/ha)	Pol % juice	CCS (t/ha)	Nutrient uptake		
									N	P	K
Genotype					*Spring-planted crop*						
'CoLk 9411'	40	123.5	211.5	1.87	652.2	71.03	16.95	8.29	139.9	34.8	184.7
'CoLk 9412'	41	100.7	191.7	2.05	690.7	60.11	17.74	7.35	120.8	30.0	158.1
'CoLk 94184'	34	128.2	205.7	1.95	683.9	77.42	18.49	9.84	150.9	37.2	198.9
SEm±	1.4	2.7	4.5	0.04	13.2	1.5	0.19	0.15	2.2	0.8	1.9
CD (P=0.05)	4.2	8.2	13.2	0.12	38.5	4.5	0.6	0.48	6.5	2.5	5.8
Fertility level (NPK kg/ha)											
150 + 19.6 + 37.4	39	110.2	199.7	1.91	635.5	64.22	17.63	7.79	123.9	29.5	163.1
200 + 26.2 ± 49.8	40	122.2	207.4	2.00	693.8	73.37	17.96	9.08	146.0	35.9	190.8
250 + 32.8 + 62.2	36	120.4	201.8	1.99	697.1	70.97	17.58	8.57	145.5	36.9	188.8
SEm±	1.4	2.7	4.5	0.04	13.2	1.5	0.19	0.15	2.2	0.8	1.9
CD (P=0.05)	NS	8.2	13.2	NS	38.5	4.5	0.6	0.48	6.5	2.5	5.8
Genotype					*Summer-season crop*						
'CoLk 9411'	31	100.7	189.1	1.80	568.6	59.61	16.79	7.18	117.4	27.4	154.9
'CoLk 9412'	33	75.9	172.2	1.94	588.1	54.81	17.37	6.55	113.3	27.4	144.2
'CoLk 94184'	27	90.9	183.9	1.86	617.2	59.84	18.35	7.49	116.7	28.7	153.8
SEm±	0.9	2.01	3.5	0.05	14.6	1.32	0.22	0.13	2.7	0.4	2.1
CD (P=0.05)	2.9	6.03	10.5	NS	42.6	3.83	0.69	0.4	5.2	1.4	6.1
Fertility level (NPK kg/ha)											
150 + 19.6 + 37.4	30	83.3	177	1.85	550.5	53.4	17.47	6.65	103.1	24.5	135.6
200 + 26.2 ± 49.8	32	90.7	186	1.83	597.3	58.82	17.54	7.31	117.1	28.8	152.9
250 + 32.8 + 62.2	29	93.6	182.2	1.89	626.1	62.04	17.51	7.51	127.2	32.2	165.5
SEm±	0.9	2.0	3.5	0.05	14.6	1.32	0.22	0.13	2.7	0.4	2.1
CD (P=0.05)	NS	6.0	10.4	NS	42.6	3.83	NS	0.40	5.2	1.4	6.1

fertility level. CCS was the function of cane yield and quality. The higher cane yield contributed greater share in improving CCS than cane quality parameters.

Summer planting: Summer (April)-planted crop exhibited lower germination (30%) than spring-planted one (38%). 'CoLk 9412' maintained its superiority for higher germination during both the seasons. Summer cane produced lesser number of tillers over the period due to less time available for tillering. These results are in close conformity with the results obtained by Pandey and Shukla (2003). 'CoLk 9411' produced the highest number of millable canes, while 'CoLk 9412' relatively longer and thicker canes. Cane yields of 'CoLk 9411' and 'CoLk 94184' were at par during summer planting, indicating better competitive ability of former genotype when planted in summer season compared to spring season. Highest CCS was obtained with 'CoLk 94184'. It was owing to higher cane yield and quality of 'CoLk 94184'. Planting of various high sugar genotypes in summer (April) exhibited variation in sucrose accumulation pattern over spring cane, so through selection of genotypes the high sugar of good quality could be harvested even in the summer season under north Indian conditions.

Various fertility levels could not influence germination of sugarcane significantly (Table 1). Production of millable canes and cane length increased significantly up to 200, 26.2 and 49.8 kg N, P and K/ha. Thus, significantly higher cane weight and cane yield were obtained up to 200, 26.2 and 49.8 kg N, P and K/ha. Higher cane yield was obtained because of production of millable canes and cane weight and it led to finally higher CCS at similar fertility level. Nutrient application beyond 200, 26.2 and 49.8 kg N, P and K/ha could not show significant impact on cane yield and CCSin summer planted cane.

Correlation coefficient among various major growth and yield-contributing characters indicated highly positive relationship between these character (r=0.97) and millable cane to cane yield (r=0.95), indicating higher contribution

Table 2. Influence of genotypes and fertility levels on spring and summer plant crop on growth, yield, nutrient uptake of sugarcane ratoon and economics of plant-ratoon system

Treatment	Milliable canes ('000/ha)	Cane length (cm)	Cane diameter (cm)	Cane weight (g)	Pol % juice	Cane yield (t/ha)	CCS (t/ha)	Nutrient uptake (kg/ha) N	P	K	Plant-ratoon system* Gross returns (×10³ Rs/ha)	Net returns (×10³ Rs/ha)	Benefit : cost ratio
						Ratoon of spring cane							
Genotype													
'CoLk 9411'	116.8	180.9	1.81	525.5	18.11	60.34	7.56	116.4	28.9	153.3	131.4	82.0	2.66
'CoLk 9412'	90.6	158.0	2.08	571.1	17.97	57.0	7.13	111.2	28.5	146.5	117.1	67.3	2.37
'CoLk 94184'	133.9	186.8	1.78	554.4	19.24	70.46	9.39	134.6	32.4	176.8	147.9	98.6	2.99
SEm±	2.6	3.2	0.05	10.2	0.27	2.16	0.27	1.8	0.6	2.1			
CD (P=0.05)	7.8	9.5	0.15	30.5	0.78	6.4	0.80	4.3	1.8	6.2			
Fertility level (NPK kg/ha)													
150+19.6+37.4	105.4	179.4	1.92	551.1	18.34	64.30	8.18	121.5	29.6	147.8	128.5	80.1	2.65
200+26.2+49.8	115.5	172.9	1.89	556.6	18.58	58.19	7.48	112.3	27.9	161.4	131.6	82.3	2.67
250+32.8+62.2	120.5	173.4	1.85	544.4	18.41	64.30	8.23	126.7	32.2	165.3	135.3	85.0	2.69
SEm±	2.6	3.2	0.05	10.2	0.27	2.16	0.27	1.8	0.6	2.1			
CD (P=0.05)	7.8	NS	NS	NS	NS	NS	NS	4.3	1.8	6.2			
						Ratoon of summer cane							
Genotype													
'CoLk 9411'	130.9	207.7	2.02	584.4	17.09	77.08	9.03	148.8	36.9	195.8	136.7	87.4	2.77
'CoLk 9412'	100.5	202.5	2.25	625.1	16.98	64.50	7.52	125.8	32.3	165.8	119.3	68.9	2.42
'CoLk 94184'	148	215.4	2.15	502.2	18.65	83.55	10.70	159.6	38.4	209.7	143.4	94.1	2.91
SEm±	2.2	3.1	0.06	16.1	0.21	1.85	0.22	1.6	0.6	2.1			
CD (P=0.05)	6.8	9.2	0.17	46.5	0.60	5.50	0.6	4.9	1.8	6.4			
Fertility level (NPK kg/ha)													
150+19.6+37.4	117.8	206.6	2.12	536.6	17.76	70.78	8.73	133.8	32.6	177.7	124.2	75.7	2.56
200+26.2+49.8	126.2	212.2	2.1	581.1	17.87	74.21	9.11	143.2	35.6	188.5	133.0	83.7	2.70
250+32.8+62.2	135.4	206.8	2.2	593.3	17.47	80.24	9.60	158.1	40.1	206.2	142.3	93.0	2.83
SEm±	2.2	3.1	0.06	16.1	0.21	1.85	0.22	1.6	0.6	2.1			
CD (P=0.05)	NS	NS	NS	NS	NS	5.50	0.60	4.9	1.8	6.4			

*Cost of production of plant cane, Rs 28,300/ha; cost of production of ratoon cane, Rs 21,022/ha of millable cane and cane length in cane yield. Millable cane contribution was higher to that of cane weight, which showed importance of earlier formed tillers in increasing cane productivity in north Indian conditions. Cane yield and CCS in December were positively correlated (r=0.78), whereas contribution of cane yield to CCS in February decreased (r=0.57). It was due to increase in cane quality parameters in all the genotypes.

Ratoon of spring cane

Ratoon of summer planted cane produced higher number of millable canes than of spring cane (Table 2), owing to higher number of millable canes. Lower cane diameter of these genotypes increased the extent of millable cane in yield contribution. 'CoLk 94184' produced the highest number of millable canes and higher cane length, while cane weight was higher with 'CoLk 9412' owing to more cane diameter than with the other genotypes (Table 2). Higher pol per cent juice was recorded in 'CoLk 94184'. Cane yield and CCS were maximum with 'CoLk 94184'. Various fertility levels applied in plant crop influenced ratoon growth, yield and quality significantly.

Ratoon of summer cane

Highest number of millable canes and cane length were obtained with 'CoLk 94184'. 'CoLk 9412' produced thicker canes (cane diameter, 2.25), which led to higher individual cane weight (625.1 g). Juice quality parameters indicated higher quality with 'CoLk 94184' than 'CoLk 9411' and 'CoLk 9412'. Ratoon yield was also highest with 'CoLk 94184'. Maximum CCS was obtained with 'CoLk 94184'. It was because of higher number of millable cane, cane yield and cane quality. Fertility levels of plant crop could not influence individual cane length, diameter and weight significantly. Vigorous stubble in ratoon at higher rate of application of nutrients contributed significantly in production of millable canes. Besides, it also received minimum number of gaps in field under higher fertility condition. Similar results were also obtained by Pandey and Shukla (2003) at Lucknow. Thus significant increase in ratoon yield and commercial cane sugar was obtained up to 200, 26.2, 49.8 kg NPK/ha.

Nutrient uptake and economics

Nutrient uptake by plant and ratoon crops determined (Tables 1, 2) at harvest stage showed that. 'CoLk 94184' removed the maximum NPK from soil during both the cropping seasons. Spring-planted crop analysed higher mean values (137.2 kg N, 34 kg P and 180.6 kg K/ha) of nutrient removal compared to counterpart summer planted cane (114.8, 27.85 and 151.0 kg NPK/ha) due to higher tonnage harvested. Increasing levels of NPK showed increase in nutrient removal through plant and ratoon cane. However, greater differences were observed in plant cane than in ratoon cane. Residual effect of P and K application to plant crop was observed on ratoon crop. It might be due to fixation of these nutrients in soil and release in next ratoon crop after wetting and drying under seasonal changes. Nutrient removal through plant and ratoon canes depicted positive balance with N and P in soil and negative balance with K. Spring cane (plant crop) showed higher nutrient uptake than its ratoon but the trend was reversed in summer-planted cane. Singh and Yadav (1992) also reported similar results.

Higher benefit : cost ratio was observed with 'CoLk 94184'. In spring-planted cane, benefit : cost ratio increased up to 200, 26.2 and 49.8 kg N, P and K/ha. Ratoon cane showed higher benefit : cost ratio than plant cane. It was due to lower cost of production (Rs 21,022/ha) of ratoon cane compared to plant cane (Rs 28,300/ha). Ratoon of summer-planted cane gave higher net returns than spring cane. Plant-ratoon system indicated that 'CoLk 94184' gave the highest net returns and benefit : cost ratio in the spring-planted cane (Table 2). The fertility level of 200, 26.2 and 49.8 kg N, P and K/ha resulted in higher benefit : cost ratio in summer cane than inspring cane.

Thus, high sugar genotype, 'CoLk 94184', could be adopted for optimizing sugar productivity and regulating crushing schedule at factory level. Fertility level of 200, 26.2 and 49.8 kg N, P and K/ha is optimum for growth, quality and yield during spring as well as summer seasons.

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