



Nutrient uptake, sugarcane yield and economics of high sugar early genotypes of sugarcane (*Saccharum* sp hybrid complex) under various planting seasons and fertility levels in Bihar

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ABSTRACT

A field experiment was conducted for 3 consecutive years (2006-2010) in two seasons (autumn and spring) on sandy loam soil of Bihar, Pusa (Samastipur), to find out the impact of early maturing high sugar genotypes and level of N-P and K fertilization on performance of sugarcane (*Saccharum* sp hybrid complex). The performance indicated significant superiority of CoSe 95422 to CoP 9301 in terms of germination (35.5 and 34.4 %), tillers (152 700 and 141 400/ha), cane length (204 and 201 cm) and cane diameter (2.32 and 2.25 cm) in autumn and spring season, respectively. CoSe 95422 exhibited significantly higher dry matter accumulation and leaf area index at all the growth stages during both the cropping seasons. Net assimilation rate increased substantially at the initial crop growth stages and declined thereafter. Genotype CoP 9301 achieved higher NAR (6.34 and 5.66 g/m²/day) during June- August, though it was failed to reach the level of significance during August-October. Number of millable canes exhibited marked variation among the genotypes in both the seasons. CoSe 95422 produced significantly highest cane yield during autumn (81.0 tonnes/ha) and spring season (73.2 tonnes/ha) respectively. The percentage increase in mean cane and sugar yield by autumn planted sugarcane over spring planted sugarcane was 9.7 and 11.27 %, respectively. However, maximum sugar yield was obtained by CoSe 95422. Further, it showed significantly higher N (206.8 and 176.5 kg/ha), P (18.5 and 16.9 kg/ha), K uptake (239.4 and 204.0 kg/ha), net return (₹ 55 430 and ₹ 46 500) and benefit: cost ratio (1.86 and 1.75) during autumn and spring season, respectively. Fertility level had significant impact on drymatter accumulation and leaf area index across the season as well as stages of growth. Significantly higher tillers (140 300 and 131 000/ha), cane length (208 and 204 cm), cane diameter (2.34 and 2.26 cm), millable cane (102 100 and 100 300/ha) and cane yield (85.2 and 77.6 tonnes/ha) were obtained with the application of 187.5 N + 46.4 P + 62.3 K kg/ha in autumn and spring season, respectively. Though all of these parameters except cane diameter in spring season were statistically similar to 150 N + 37.1 P + 49.8 K kg/ha. A significant increase in cane and sugar yield was observed up to 150 N + 37.1 P + 49.8 K kg/ha. The magnitude of increase in cane yield at 187.5 N + 46.4 P + 62.3 K, 150 N + 37.1 P + 49.8 K kg/ha over 112.5 N + 27.8 P + 37.4 K kg/ha were 37.6 and 30.9%, respectively, during autumn season. Whereas, these increased 35.7 and 28.0% respectively during spring season. Though, significant variation in sugar yield up to 150 N + 37.1 P + 49.8 K kg/ha was noticed during both the season. There was a significant increase in net return by increasing level of N+P+K/ha during both the season. Though, marked variation in benefit: cost ratio (1.87 and 1.75) was observed only up to 150 N + 37.1 P + 49.8 K kg/ha during autumn and spring season, respectively.

Key words: Fertility levels, Planting season, Productivity, Profitability, Sugarcane genotypes

Sugarcane (*Saccharum* sp hybrid complex) is the second most important industrial crop in the country grown over diverse environment and geographical ranges for sweeteners, ethanol, cogeneration, paper and other allied products. Thus, the demand for sugarcane for its varied uses has gone up in the present time which could be met only through high sugar genotypes and balanced fertilization. In India the

sugarcane is cultivated on an area of 50.9 lakh hectares with cane production of 3 576.7 lakh tonnes and sugar production of 263.42 lakh tonnes (ISMA 2013). The average cane yield in the country is low when compared to yield level of other countries under similar conditions. Of the many production constraints, unavailability of suitable genotypes for particular situation and inadequate or imbalanced fertilization are some of the reasons responsible for low yield of sugarcane. The response of particular genotypes depends upon its genetic potential and the prevailing environmental condition where it is exposed during the developmental phases. In subtropical region the availability of sugarcane varieties with high sugar

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accumulation early in the crushing season is an important strategy to fetch high sugar recovery in the mills (Singh *et al.* 2002). The efficiency with which a crop produces a harvestable product per unit of available nutrient also varies with the genotypes of a particular species. Application of major plant nutrients in right proportion and in optimum quantity through correct method for specific soil-climatic condition is the key input for sustainable sugarcane production. Determination of optimum level of fertilizer is therefore of great importance for increasing fertilizer use efficiency. Studies showed positive response of sugarcane genotypes to fertility level under diverse planting seasons (Shukla 2007). An increase in cane productivity is the interaction of varieties and amount of nutrients applied to the crop. Thus, it is important to select sugarcane varieties along with its appropriate fertilizer doses for sustainable sugarcane production. In view of the above, the present study was undertaken to find out the effect of early genotypes and fertility levels on growth, yield, economics and quality of sugarcane under autumn and spring seasons.

MATERIALS AND METHODS

A field experiment was conducted for autumn and spring seasons of 2006-07 to 2009-10 at Sugarcane Research Institute, Rajendra Agricultural University, Pusa, Bihar. The experimental soil was sandy loam in texture with alkaline in reaction (*pH* 8.2), free CaCO_3 (29.7), EC (0.28 dS/m), bulk density (1.47 g/cc), low in mean available N (193 kg/ha), P (6.5 kg/ha) and available K (85 kg/ha). Treatment consisted of three early genotypes (CoSe 95422, BO 145 and CoP 9301) and 3 fertility levels (112.5 N + 27.8 P + 37.4 K, 150 N + 37.1 P + 49.8 K and 187.5 N + 46.4 P + 62.3 K kg/ha) under various planting seasons. There were 9 treatment combinations replicated thrice in randomized block design. The recommended dose of fertilizer was 150 N, 37.1 P and 49.8 kg K/ha. Urea, diammonium phosphate and muriate of potash were taken as sources of N, P and K, respectively. Full dose of P and K and half dose of N as per treatments were applied at the time of planting, while remaining N was top dressed in two equal splits at the first irrigation and just before the earthingup (early July) respectively. Separate trials were conducted for autumn and spring seasons. The autumn and spring planting was done at 90 cm row spacing in the second fortnight of October and February, respectively and both season crops were harvested in third week of January during all the years. During the crop period, a total rainfall of 2519.9, 1392.9 and 967.3 mm was received during the first, second and third year, respectively. The irrigation and other packages of practice were adopted as per recommendations, except treatments during the crop-growth period in all the years.

Observations on germination of cane buds, drymatter accumulation, leaf area index, net assimilation rate and tillers counts were recorded at their respective growth stages following standard procedures. Five canes were randomly selected from each plot for estimation of yield attributes

and juice quality parameters. Fibre % cane was estimated by rapi pol extractor. The concentration of N, P and K in plant was analyzed using standard procedure. Total uptake by sugarcane plant was calculated by multiplying the concentration (%) with cane yield (q/ha) and a correction factor, i.e. 0.375. While working out the economics of various treatments, the prevailing market prices of inputs and output of the respective years were considered.

RESULTS AND DISCUSSION

Growth and yield attributes

Autumn planting: Growth and yield attributes of autumn sugarcane differed significantly under various genotypes (Table 1). Mean data of 3 cropping seasons revealed that genotype CoSe 95422 registered significantly higher germination (35.5%) than CoP 9301 (32.4%) and statistically at par with BO 145 (Table 1). The variation in germination percentage was owing to chemical composition of soluble solids in juice as well as enzymes and hormones present in cell sap, which varies from genotype to genotype. Drymatter accumulation in sugarcane increased progressively from June until December (Fig 1). The rate of increase of drymatter and leaf area index were higher during the initial crop growth stages and declined at the advancement of crop age due to natural senescence of vegetative parts. At all the growth stages, genotype CoSe 96436 produced highest total drymatter and LAI compared to BO 145 and CoP 9301 (Fig 2). However, significantly higher net assimilation rate during June-August was recorded under the genotype CoP 9301 (6.34 g/m²/day). However, non-significant variation noticed during later stages (Fig 2). Maximum number of tillers (152 700/ha), cane length (204 cm) and cane diameter (2.32 cm) was recorded due to the genotype CoSe 95422 and was significantly superior to CoP 9301 on mean basis. Growth of genotypes is the outcome of genomic, environmental and agronomic interactions. Since all the genotypes were grown under identical agronomic environment, the observed variation in overall growth of genotypes could be ascribed to their biochemical activities and external environmental factors to which these were exposed during the course of development. Significantly higher number of millable canes were found with CoSe 95422 (109 700/ha) was significantly superior to BO 145 (95200/ha). Later was also significantly superior to CoP 9301 (84 100/ha). The marked increase in millable cane appears due to higher germination and maximum tillering capacity of this genotype.

Sugarcane under the influence of fertility levels had significant impact on drymatter accumulation, LAI, NAR (Fig 1, 2), tillers, cane length, cane diameter and millable cane (Table 1). The amount of drymatter at 187.5 + 46.4 + 62.3 kg N+P+K/ha during June, August, October and December were 11.8, 22.5, 27.4 and 29.4 tonnes/ha, respectively (Fig 1) though it was statistically similar to 150.0 + 37.1 + 49.8 kg N+P+K/ha during October and December. Similarly higher LAI was recorded at higher fertility level and was statistically similar to 150.0 + 37.1 +

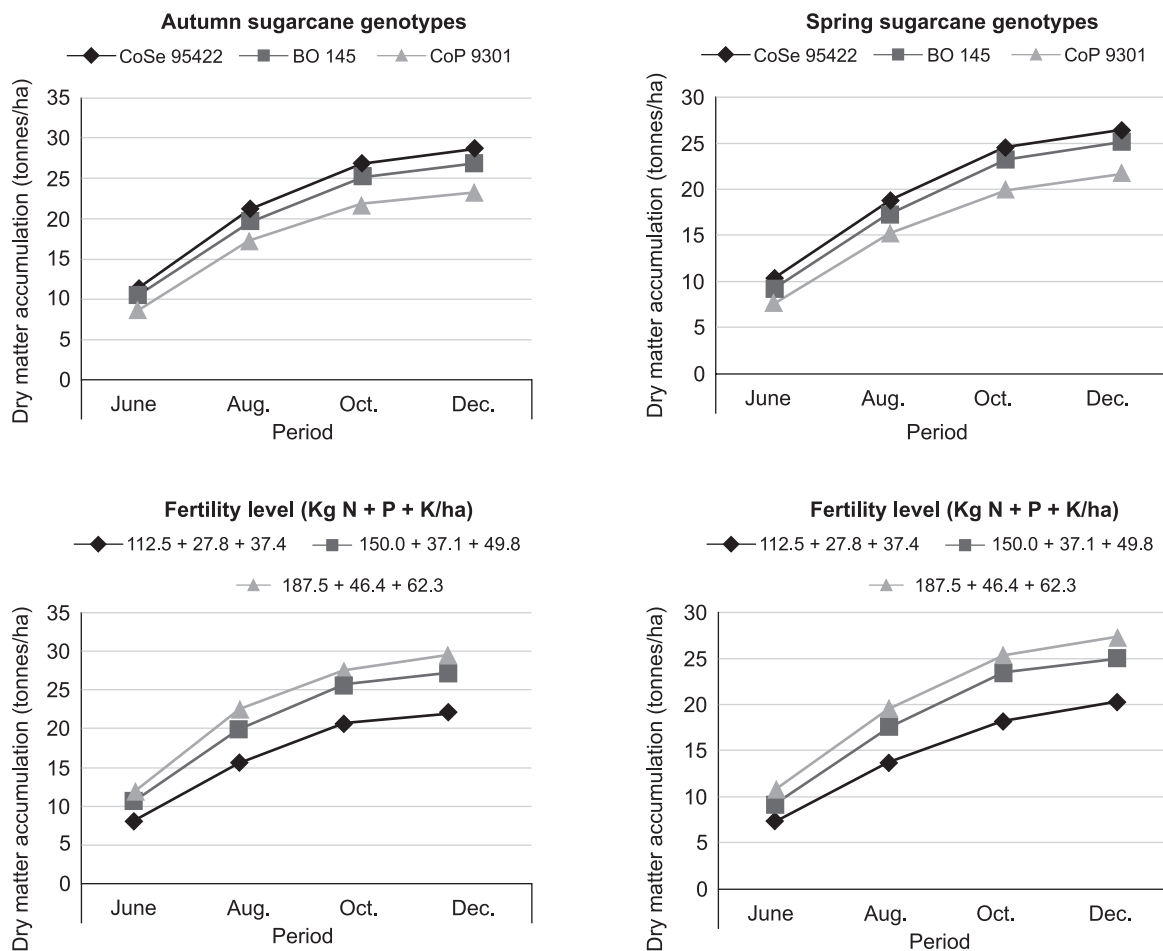


Fig 1 Effect of genotypes and fertility levels on total drymatter accumulation in sugarcane

49.8 kg N + P + K/ha at all the stages of growth (Fig 2). Increase in LAI values owing to fertility level was because of favourable synthesis of growth promoting constituents in plants as a result of better nutrient supply which resulted in enlarged leaf area. A significant increase in NAR ($6.39 \text{ g/m}^2/\text{day}$) during June- August was recorded at higher level of fertilization. Though, reverse was the trend during August-October (Fig 2). Significantly more number of tillers at 125 DAP was recorded in the plots receiving $187.5 \text{ N} + 46.4 \text{ P} + 62.3 \text{ K kg/ha}$, though it was statistically at par with $150 \text{ N} + 37.1 \text{ P} + 49.8 \text{ K kg/ha}$. This might be due to increase in the rate of biosynthesis of various plant metabolites in the system leading to increased rate of tiller initiation. An increase in fertility levels up to $150 \text{ N} + 37.1 \text{ P} + 49.8 \text{ K kg/ha}$ significantly increased the cane length (198 cm) and cane diameter (2.26 cm) though both of them were statistically similar to $187.5 \text{ N} + 46.4 \text{ P} + 62.3 \text{ K kg/ha}$. Significantly higher cane height, diameter and millable cane with higher level of N+P+K was mainly due to improved fertility status of soil created congenial environment for cane growth. Singh *et al.* (2010) also observed marked variation in growth and yield attributes of sugarcane by N and K application.

Spring planting: Data recorded on spring (February) planted crop on growth and yield attributes, viz. germination,

drymatter accumulation, LAI, NAR, tillers at 125 DAP, cane length, cane diameter as well as number of millable cane of sugarcane (Table 1) exhibited significant differences among the genotypes. Spring planted cane recorded comparatively lower germination (32.3 %) than autumn planted cane (33.8 %). The genotype CoSe 95422 showed higher drymatter accumulation and LAI at all the stages of growth followed in order by BO 145 and CoP 9301 (Fig 1). Though significantly higher NAR ($5.66 \text{ g/m}^2/\text{day}$) during June-August was recorded due to the genotype CoP 9301. CoSe 95422 also maintain superiority in respect to tiller formation. Spring cane had comparatively lower number of tillers in respect to autumn cane. This might be due to comparatively lesser time available for tillering. These results are in conformity with the findings of Pandey and Shukla (2003). Higher cane length (201 cm) and diameter (2.25 cm) was also obtained due to the genotype CoSe 95422 was significantly superior than BO145 and CoP 9301. Higher number of millable canes ($108800/\text{ha}$) was recorded by the genotype CoSe 95422 which was significantly superior to BO 145 and CoP 9301. This could be attributed to genetic variation existing among the genotypes.

Germination % of spring cane remained unaffected due to the different levels of N, P and K fertilization.

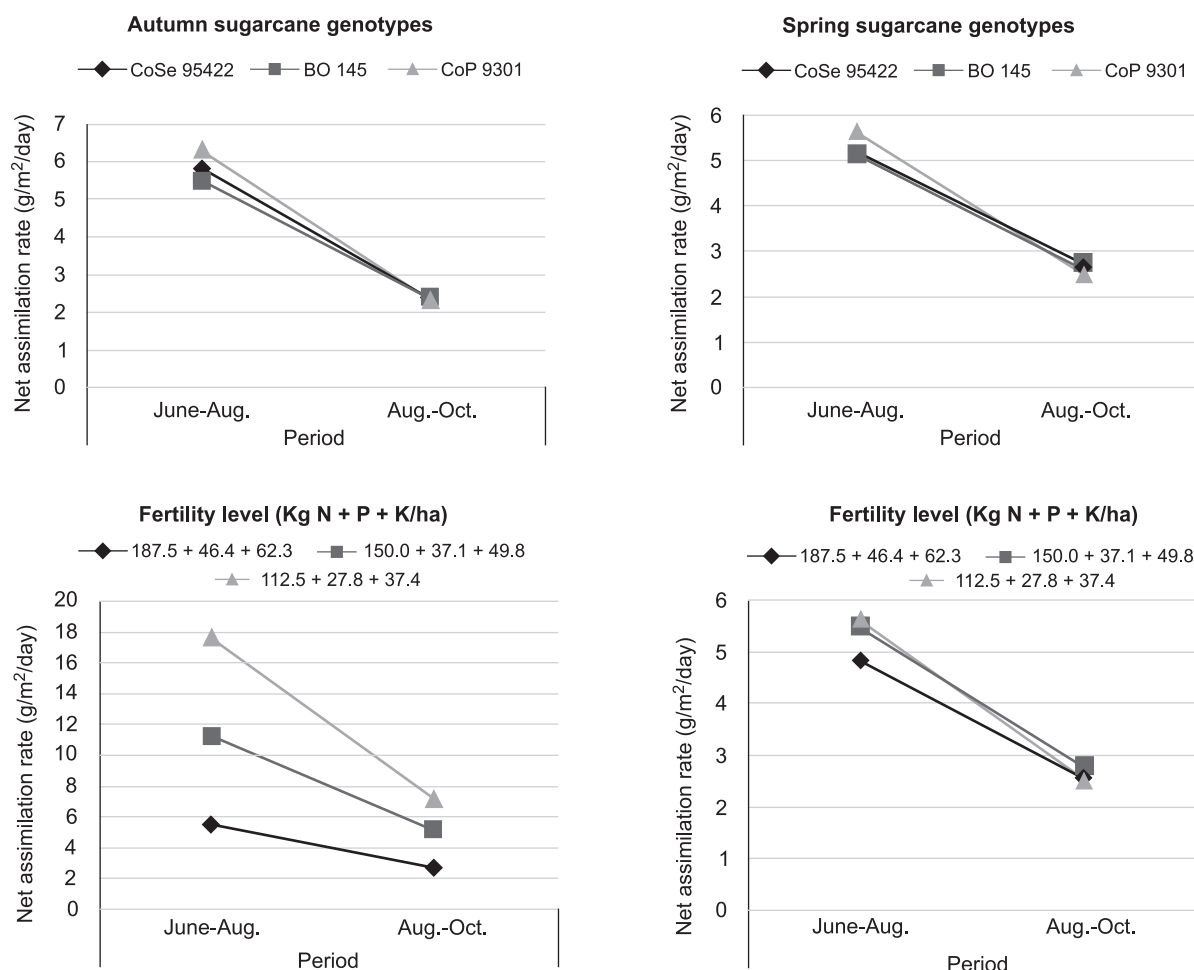


Fig 3 Effect of genotypes and fertility levels on net assimilation rate in sugarcane

Fertility level had significant and positive influence on drymatter accumulation, LAI and NAR at all the stages of growth. Each successive increase in fertility level significantly enhanced total drymatter accumulation up to 187.5 + 46.4 + 62.3 kg N+P+K/ha during June to August, which was however on par with that of 150.0 + 37.1 + 49.8 kg N+P+K/ha during October and December (Fig 1). This was attributable to increase in drymatter accumulation with simultaneous increase in nutrient concentration in plants. Fertility level also enhanced the LAI at all the stages of growth and maximum being recorded at 187.5 + 46.4 + 62.3 kg N+P+K/ha, but was statistically similar to 150.0 + 37.1 + 49.8 kg N+P+K/ha. The highest NAR values were recorded in between June-August and lowest in between August-October indicating higher assimilation and growth during earlier phases (Fig 2). Leaves are the net assimilatory parts and they degenerate and die off at the later growth stage resulting in the decline in NAR. The application of 187.5 + 46.4 + 62.3 kg N+P+K/ha increased the NAR by 16.56% over 112.5 + 27.8 + 37.4 kg N+P+K/ha (Fig 2).

There was no definite trend on NAR during August – October though significantly higher NAR (2.78 g/m²/day) at that stage was recorded at 150.0 + 37.1 + 49.8 kg N+P+K/ha. Significantly higher number of tillers (131 000/ha) was recorded under 187.5 N + 46.4 P + 62.3 K kg/ha though it

was statistically similar to 150 N + 37.1 P + 49.8 K kg/ha. The role of nitrogen in chlorophyll formation, carbohydrate metabolism, positive interaction of nitrogen and phosphorus and nitrogen with potassium is well known. It was the main reason in improving the tillers of sugarcane. Significantly higher cane length was noticed due to the plots receiving 187.5 N + 46.4 P + 62.3 K kg/ha, though it was statistically similar to 150 N + 37.1 P + 49.8 K kg/ha. This might be due to increase in the rate of biosynthesis of various plant metabolites and physiological process in the plant system leading to taller cane. Improvement in cane diameter and number of millable cane was recorded due to increased metabolic processes in plant, resulting in greater meristematic activity thereby improving the sink size which manifested into thicker canes. These results confirm the findings of Pandey and Shukla (2003).

Yield and quality

Autumn planting: In 3 years average, genotype had significant impact on cane yield (Table 1), brix, pol, fibre, CCS and sugar yield (Table 2). Among the genotypes, CoSe 95422 gave significantly higher cane yield (81.0 tonnes/ha). However, differences between CoSe 95422 and BO 145 were not significant. The cane yield is the function of number of millable cane/unit area and its weight. The number

Table 1 Influence of early genotypes and fertility levels on growth, yield attributes, yield and economics of autumn and spring season sugarcane (Mean data of 3 cropping seasons)

Treatment	Germination (%)	Tillers at 125 DAP ($\times 10^3/\text{ha}$)	Cane length (cm)	Cane diameter (cm)	Millable cane ($\times 10^3/\text{ha}$)	Cane yield (tonnes/ha)	Gross return ($\times 10^3 \text{ ₹/ha}$)	Cost of production ($\times 10^3 \text{ ₹/ha}$)	Net return ($\times 10^3 \text{ ₹/ha}$)	B : C ratio
<i>Autumn season crop</i>										
<i>Genotype</i>										
CoSe 95422	35.5	152.7	204	2.32	109.7	81.0	118.27	62.84	55.43	1.86
BO 145	33.5	126.6	197	2.27	95.2	77.8	112.99	62.84	50.36	1.79
CoP 9301	32.4	115.7	180	2.02	84.1	69.3	101.36	62.84	38.53	1.60
SEm \pm	0.68	5.48	4.9	0.049	3.05	2.44	3.064		1.245	0.046
CD ($P=0.05$)	2.1	16.9	15	0.15	9.0	7.5	9.19		3.73	0.14
<i>Fertility level (Kg N + P + K/ha)</i>										
112.5 + 27.8 + 37.4	34.7	122.1	175	2.01	90.0	61.9	90.29	61.91	28.38	1.45
150.0 + 37.1 + 49.8	33.8	133.3	198	2.26	96.9	81.0	118.16	62.84	55.32	1.87
187.5 + 46.4 + 62.3	32.9	140.3	208	2.34	102.1	85.2	124.17	63.77	60.61	1.93
SEm \pm	0.68	5.48	4.9	0.049	3.05	2.44	3.064		1.245	0.046
CD ($P=0.05$)	NS	16.9	15	0.15	9.0	7.5	9.19		3.73	0.14
<i>Spring season crop</i>										
<i>Genotype</i>										
CoSe 95422	34.4	141.4	201	2.25	108.8	73.2	107.10	60.60	46.50	1.75
BO 145	32.8	118.6	190	2.02	92.9	69.7	101.39	60.60	40.80	1.66
CoP 9301	29.7	110.0	170	1.94	81.0	65.1	91.94	60.60	34.68	1.56
SEm \pm	0.52	3.88	4.6	0.042	2.84	2.54	2.752		1.119	0.039
CD ($P=0.05$)	1.5	12	14	0.13	8.6	7.8	8.25		3.36	0.12
<i>Fertility level (Kg N + P + K/ha)</i>										
112.5 + 27.8 + 37.4	33.0	113.5	165	1.91	87.3	57.2	83.65	59.67	23.99	1.39
150.0 + 37.1 + 49.8	32.1	125.5	192	2.03	95.1	73.2	103.56	60.60	46.30	1.75
187.5 + 46.4 + 62.3	31.7	131.0	204	2.26	100.3	77.6	113.22	61.53	51.69	1.83
SEm \pm	0.52	3.88	4.6	0.042	2.84	2.54	2.752		1.119	0.039
CD ($P=0.05$)	NS	12.0	14	0.13	8.6	7.8	8.25		3.36	0.12

Table 2 Effect of genotypes and fertility levels on quality and nutrient uptake of sugarcane

Treatment	Brix % juice	Pol % juice	Purity % juice	Fibre % cane	CCS % juice	Sugar yield (tonnes/ha)	Nutrient uptake (Kg/ha)		
							N	P	K
<i>Genotype</i>									
<i>Autumn sugarcane</i>									
CoSe 95422	18.92	16.48	87.03	14.6	11.30	9.15	206.8	18.5	239.4
BO 145	18.45	16.23	87.90	11.1	11.18	8.70	189.8	17.5	227.0
CoP 9301	19.74	17.29	87.50	10.7	11.89	8.23	166.3	15.1	194.2
SEm ±	0.190	0.112	0.848	0.14	0.098	0.133	4.24	0.42	5.58
CD (P= 0.05)	0.57	0.33	NS	0.4	0.29	0.40	12.7	1.3	16.7
<i>Fertility level (Kg N+P+K/ha)</i>									
112.5 + 27.8 + 37.4	19.23	16.80	87.37	15.2	11.55	7.14	143.4	13.2	168.3
150.0 + 37.1 + 49.8	19.08	16.67	87.37	11.0	11.46	9.27	199.8	18.2	235.3
187.5 + 46.4 + 62.3	18.80	16.49	87.70	10.2	11.36	9.66	219.7	19.8	257.0
SEm±	0.190	0.112	0.848	0.14	0.098	0.133	4.24	0.42	5.58
CD (P=0.05)	NS	NS	NS	0.4	NS	0.40	12.7	1.3	16.7
<i>Genotype</i>									
<i>Spring sugarcane</i>									
CoSe 95422	18.55	16.30	87.31	14.2	11.14	8.14	176.5	16.9	204.0
BO 145	18.30	16.07	87.74	10.8	11.07	7.71	165.4	15.3	191.5
CoP 9301	19.40	16.95	87.30	9.5	11.64	7.58	152.1	13.5	177.4
SEm ±	0.189	0.098	0.849	0.13	0.090	0.109	3.47	0.33	4.75
CD (P= 0.05)	0.57	0.31	NS	0.4	0.27	0.32	10.4	1.0	14.2
<i>Fertility level (Kg N+P+K/ha)</i>									
112.5 + 27.8 + 37.4	18.84	16.53	87.74	15.0	11.39	6.51	128.8	11.4	150.2
150.0 + 37.1 + 49.8	18.80	16.44	86.97	10.2	11.22	8.20	175.8	16.2	203.3
187.5 + 46.4 + 62.3	18.61	16.31	87.65	9.3	11.24	8.72	189.4	18.1	219.4
SEm ±	0.189		0.849	0.13	0.090	0.109	3.47	0.33	4.75
CD (P= 0.05)	NS	NS	NS	0.4	NS	0.32	10.4	1.0	14.2

of millable cane in turn, is governed by cane length and girth. The genotype CoP 9301 was recorded significantly higher brix (19.74%), pol (17.29%) and CCS (11.89%) content juice. While purity per cent juice was not varied significantly due to genotypes. The sugar yield was significantly affected by different genotypes. CoSe 95422 produced significantly higher sugar yield (9.15 tonnes/ha) than BO 145 (8.70 tonnes/ha) and CoP 9301 (8.23 tonnes/ha). Sugar yield is function of CCS % and cane yield. Though, higher cane yield contributed greater extent in improving sugar yield than other quality parameters.

Fertility level cause significant impact on cane and sugar yield (Table 1). Significantly higher cane and sugar yield on autumn season was recorded at 187.5 N + 46.4 P + 62.3 K kg/ha, though it was statistically similar to 150 N + 37.1 P + 49.8 K kg/ha and both of them were out yielded to 112.5 N + 27.8 P + 37.4 K kg/ha. The increase in cane and sugar yield by 187.5 N + 46.4 P + 62.3 K and 150 N + 37.1 P + 49.8 K kg/ha over 112.5 N + 27.8 P + 37.4 K kg/ha were 37.6 and 35.29, 30.9 and 29.83%, respectively. The marked increase in the yield of sugarcane at 150 N + 37.1 P + 49.8 K kg/ha over 112.5 N + 27.8 P + 37.4 K kg/ha could ascribed to cumulative effect of growth and yield attributes, which ultimately led to greater tonnage/unit area. No marked response of N+P+K beyond 150 N + 37.1 P + 49.8 K kg/ha might be attributed to nutrient imbalance and consequent metabolic disturbances. Vasistha and Sinha

(2004) have reported increase in cane yield with corresponding increase in levels of fertilization. The higher sugar yield (9.66 tonnes/ha) at highest level of N+P+K was mainly due to higher cane obtained by these treatment.

Spring planting: Variation among genotypes in respect to cane yield (Table 1) and quality parameters (brix, pol, fibre, CCS % and sugar yield) were found to be significant (Table 2). CoSe 95422 out yielded (73.2 tonnes/ha) than CoP 9301 (65.1 tonnes/ha), though both of them were statistically similar to BO 145 (69.7 tonnes/ha). The percentage increase in cane yield by CoSe 95422 and BO 145 over CoP 9301 was 12.4 and 5.0% respectively. Significant variation in cane yield was probably due to the capacity of particular genotypes to greater dry matter partitioning per unit area, caused by better nutrient absorption from the soil, and the increased rate of metabolic processes, light interception and photosynthetic activity, resulting in comparatively higher yield. The genotype CoP 9301 recorded significantly higher brix (19.40%), pol (16.95%) and CCS (11.64%) than other genotypes. However, higher fibre content (14.2%) cane was recorded due to the genotype CoSe 95422, though it was significantly superior to BO 145 (10.8%) and CoP 9301 (9.5%). Later two were also varied significantly to each other. CoSe 95422 produced significantly higher sugar (8.14 tonnes/ha) compared to BO 145 (7.71 tonnes/ha) and CoP 9301 (7.58 tonnes/ha) which were statistically at par with one another. As sugar yield is

also the function of CCS% and cane yield, the expression of these in order was also reflected in sugar yield of the genotypes.

Fertility levels resulted in significant improvement in cane yield (Table 1). An increase in fertility levels increased the cane yield significantly up to 150 N + 37.1 P + 49.8 K kg/ha, beyond which the increase was marginal and non significant. The improvement in mean cane yield with application of 150 N + 37.1 P + 49.8 K and 187.5 N + 46.4 P + 62.3 K kg/ha was significantly higher by 16.0 tonnes/ha (28.0%) and 20.4 tonnes/ha (35.7%), respectively when compared with application of 112.5 N + 27.8 P + 37.4 K kg/ha. The 25% increment from 112.5 N + 27.8 P + 37.4 K kg/ha to 150 N + 37.1 P + 49.8 K kg/ha resulted in 160.0 q increase in cane yield, but its further increase from 150 N + 37.1 P + 49.8 K to 187.5 N + 46.4 P + 62.3 K kg/ha only 44.0 q increase in cane yield was noticed. This follows the Mitscherlich's equation, which states that the increase in growth with each successive addition of nutrients in question was progressively smaller. Fertility levels did not cause significant variation in brix, pol, purity and CCS % juice. However, fibre % cane and sugar yield were varied significantly (Table 2). Similar observations were made by Singh *et al.* (2008). Each successive increase in N+P+K levels significantly decreased fibre % and minimum being recorded with 187.5 N + 46.4 P + 62.3 K kg/ha. Balanced nutrient status created favourable condition for lower fibre content. This was in accordance with the findings of Kumar *et al.* (2008). The sugar yield increased significantly with successive rise in fertility levels up to 187.5 N + 46.4 P + 62.3 K kg/ha and mean values were 6.51, 8.20 and 8.72 tonnes/ha at 112.5 N + 27.8 P + 37.4 K, 150 N + 37.1 P + 49.8 K and 187.5 N + 46.4 P + 62.3 K kg/ha, respectively. Shukla (2007) have reported significant increase in sugar yield of autumn planted sugarcane by N+P+K fertilization.

Nutrient uptake

Autumn sugarcane: Genotype varied significantly in N, P and K uptake (Table 2). CoSe 95422 removed higher N (206.8 kg/ha) was significantly superior to BO 145 (189.8 kg N/ha) and CoP 9301 (166.3 kg N/ha). Later two were also differed significantly to each other. The marked increase in N uptake among the genotypes appears due to higher cane yield. CoSe 95422 and BO 145 being on par in total P and K uptake, were significant edge over CoP 9301. The CoSe 95422 removed 22.5 and 5.7% higher P and 23.3 and 5.5% higher K than CoP 9301 and BO 145, respectively.

The data on N, P and K uptake indicated a significant and progressive increase with corresponding increase in fertility levels (Table 2). The highest N uptake of 219.7 kg N/ha was recorded at 187.5 N + 46.4 P + 62.3 K kg/ha and minimum 143.4 kg N/ha when 112.5 N + 27.8 P + 37.4 K kg/ha was applied. The P uptake also increased significantly with successive rise in N+P+K levels up to 187.5 N + 46.4 P + 62.3 K kg/ha and mean values were 13.2, 18.2 and 19.8 kg P/ha at 112.5 N + 27.8 P + 37.4 K, 150 N + 37.1 P + 49.8 K and 187.5 N + 46.4 P + 62.3 K kg/ha respectively. This

was attributable to increase in cane yield with simultaneous increase in P concentration in plants, which markedly increase P uptake. Kumar *et al.* (2010) have also reported increase in P concentration in plant tissues by application of P. The marked increase in K uptake by fertility level was obtained and the mean values of uptake ranged between 168.3, 235.3 and 257.0 kg K/ha at 112.5 N + 27.8 P + 37.4 K, 150 N + 37.1 P + 49.8 K and 187.5 N + 46.4 P + 62.3 K kg/ha. This might be due to fact that plants to maintain a balanced NPK ratio absorbed proportionate amount of K which resulted in significant increase in K uptake by NPK fertilization.

Spring season: The genotypic differences for N,P and K uptake in spring sugarcane were found to be significant (Table 2). The highest N (176.5 kg/ha) and P (16.9 kg/ha) uptake was due to CoSe 95422 which was significantly higher than BO145, which, in turn, was also significantly higher than CoP 9301. Genotype CoSe 95422 was removed significantly higher K (204.0 kg/ha) than CoP 9301 (177.4 kg/ha), though it was statistically similar to BO 145 (191.5 kg K/ha). It is well established that uptake of nutrients is largely depends on cane yield and concentration of nutrients in the plant parts at cellular level.

Nutrient uptake by spring sugarcane was differed significantly due to fertility levels (Table 2). The uptake of N, P and K by sugarcane increased significantly with successive increase in fertility level, which led to maximum N,P and K at 187.5 N + 46.4 P + 62.3 K kg/ha, that was significantly higher than that of 150 N + 37.1 P + 49.8 K and 112.5 N + 27.8 P + 37.4 K kg/ha. The increase was mainly due to increased cane yield and higher concentration of respective applied nutrients (NPK).

Economic analysis

The cost of cultivation for all the genotypes was found similar. It was because of similar seed cane cost of all the genotypes.

Autumn planting: Genotypes differed significantly for gross return, net return and benefit: cost ratio (Table 1). CoSe 95422 recorded highest gross income (₹ 118 270) followed by BO 145 (₹ 112 990) though the differences were significant only between CoSe 95422 and CoP 9301. Based on cost analysis all the genotypes varied significantly to each other in respect to net realization and CoSe 95422 gave significantly higher net returns (₹ 55 430) followed by BO 145 (₹ 50 360) and CoP 9301 (₹ 38 530). The highest benefit: cost ratio of 1.86 was observed with CoSe 95422 though it was statistically similar to BO 145 (1.79) and both of them were significantly superior to CoP 9301 (1.60).

Fertility levels had significant impact on gross return, net return and benefit: cost ratio (Table 1). The highest gross income of ₹ 124 170 was obtained at 187.5 N + 46.4 P + 62.3 K kg/ha, though it was statistically comparable to 150 N + 37.1 P + 49.8 K kg/ha and both of them were significantly superior to 112.5 N + 27.8 P + 37.4 K kg/ha. Net return increased significantly with each successive increase in fertility level and highest being recorded at 187.5 N + 46.4 P + 62.3 K kg/ha and lowest at 112.5 N +

27.8 P + 37.4 K kg/ha. The magnitude of increase in net return by 187.5 N + 46.4 P + 62.3 K and 150 N + 37.1 P + 49.8 K kg/ha over 112.5 N + 27.8 P + 37.4 K kg/ha was to the extent of 113.6 and 94.9% respectively. The benefit: cost ratio was increased with increase in fertility levels and was significant (1.87) up to 150 N + 37.1 P + 49.8 K kg/ha only.

Spring planting: In spring sugarcane higher gross return (₹ 107 100) was due to CoSe 95422 had statistically similar to BO 145 (Rs 101 390) and both of them were significantly superior to CoP 9301 (₹ 91 940). Significantly highest net return was recorded due to the genotype CoSe 95422 followed by BO 145 and CoP 9301. The percentage increase in net return and benefit : cost ratio of spring sugarcane by CoSe 95422 and BO 145 over CoP 9301 was 34.1 and 12.2 and 14.0 and 5.4% respectively. This might be due to higher cane yield in the respective genotype.

Fertility levels cause significant impact on monetary return (Table 1). Gross as well as net return increased with increase in fertility levels and highest returns were obtained at 187.5 N + 46.4 P + 62.3 K kg/ha. The impact of nutrients on improvement in cane yield might have helped in accruing higher profit. However, benefit: cost ratio exhibited non responsiveness beyond 150 N + 37.1 P + 49.8 K kg/ha. This was in accordance with the law of diminishing return.

From the results of the 3 years experimentation on autumn and spring sugarcane and discussion it may be concluded that sugarcane genotype CoSe 95422 should be fertilized with 150 N + 37.1 P + 49.8 K kg/ha for getting optimum growth and yield of sugarcane.

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