Indian Journal of Agronomy **57** (2): 180–185 (June 2012)

Productivity and profitability of different genotypes of sugarcane (*Saccharum* spp. hybrid complex) as affected by fertility levels and planting seasons

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Received : November 2011; Revised accepted : January 2012

ABSTRACT

A field experiment was conducted for three consecutive years (2007-10) on calcareous soil at Pusa (Bihar) to evaluate 3 sugarcane (*Saccharum* spp. hybrid complex) mid–late genotypes ('BO 147', 'BO 146' and 'CoP 022') at 3 levels of fertilizer *viz*; 75% RDF, RDF (150 kg N + 37.1 kg P + 49.8 kg K/ha) and 125% of RDF in two seasons (autumn and spring). Higher growth, yield attributes and cane yield in terms of tillers (170.4 and 149.3 thousand/ha), cane length (211 and 204 cm), total dry matter accumulation (33.2 and 30.0 t/ha), number of millable cane (112.0 and 109.6 thousand/ha), cane yield (82.9 and 75.2 t/ha) and sugar yield (9.6 and 8.5 t/ha) were recorded in 'BO 147' in autumn and spring season, respectively. However, genotype 'BO 146' showed significantly higher values of brix and pol % juice across the planting season. Nutrient uptake followed the yield pattern of the varieties. Genotype 'BO 147' gave higher net returns and benefit: cost ratio across the season. Significantly higher tillers (158.5 and 140.8 thousand/ha), cane length (213 and 208 cm), dry matter accumulation (33.9 and 30.9 t/ha), cane diameter (2.38 and 2.18 cm), number of millable canes (107.1 and 105.0 thousand/ha) and cane yield (86.0 and 79.9 t/ha) were obtained with the application of 125% recommended dose of fertilizer in autumn and spring season, respectively. Though all of these parameters except dry matter in both the season and cane diameter during spring season were statistically similar to 100% RDF. Autumn planted sugarcane recorded 9.8 and 11.1% higher sugar over spring planted sugarcane. Nutrient uptake increased significantly with each successive increase in fertility level upto 125% RDF, resulting in 59.6; 53.2% increase in N uptake, 46.9; 51.2% increase in P uptake and 48.5; 50.9% increase in K uptake due to application of 125% RDF over 75% RDF during autumn and spring season respectively. Similarly, the available N, P and K content of soil was found to be higher due to the enhanced levels of applied nutrients to the soil. Significant increase in net returns was obtained by increasing levels of N, P and K during both the seasons. Sugarcane 'BO 147' can be grown for higher sugar yield and economic returns with application of 187.5 kg N + 46.4 kg P + 62.3 kg K/ha (125% RDF) during autumn as well as spring season.

Key words : Fertility level, Genotype, Planting season, Productivity, Profitability, Sugarcane

Sugarcane is an important cash crop of India grown in an area of 4.9 million ha with a annual production of 339.2 million tonnes and the average yield is 68.6 t/ha. In Bihar, it occupies an area of 0.3 million ha, with the production of 15.0 million tonnes and productivity is 50.0 tonnes/ha (ISMA, 2011). Despite all the attempts, productivity of sugarcane in state is quite less than the national productivity. This situation may be overcome by using high yielding genotypes having better production potential and also adopting proper nutrient management practices. It is an input – intensive crop needs high quantities of N, P and K during the period of its efficient utilization, particularly at formative and grand growth stages for higher productivity. Earlier studies showed positive response of sugarcane genotypes to fertility level under diverse planting season (Shukla, 2007). 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 sustained crop production. There is differential response of the genotypes to higher levels of nutrients due to differential genetic potentiality of the particular genotypes (Sinha *et al*., 2005). For high yielding genotypes with high rate of biomass production and matching high rates of nutrients uptake such as sugarcane soil must be able to supply nutrients at the rate for maximum growth that should be met through combination of inherent soil fertility and externally added nutrients. The Sugarcane Research Institute, Pusa, Bihar, released many high yielding sugarcane genotypes. Since there are differential response to applied nutrients, it is imperative to evaluate the

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performance of recently released or pipeline genotypes for their efficiency and response to nutrients. With this objective, the present investigation was carried out to study the impact of high yielding sugarcane genotypes to varying level of nutrients under diverse planting seasons in calcareous soil of Bihar.

MATERIALS AND METHODS

An experiment was conducted during autumn and spring seasons of 2007 to 2010 at Sugarcane Research Institute, Rajendra Agricultural University, Pusa (Samastipur), Bihar to find out the suitable mid late genotype with level of fertilization for Bihar condition. The soil was sandy loam in texture, alkaline in reaction (pH of 1:2 soil water extract 8.3), 0.43% organic carbon, 29.7% free $CaCO_3$, low in nitrogen, medium in phosphorus and poor in potassium, contained, 198, 19.6 and 83 kg/ha available N, P and K, respectively. Three mid late genotypes of sugarcane ('BO 147', 'BO 146' and 'CoP 022') were evaluated in two sets of experiments under three levels of fertilization *viz.*,75% recommended dose of fertilizer (RDF) (112.5 kg N + 27.8 kg P + 37.4 kg K/ha), RDF (150.0 kg N + 37.1 kg P + 49.8 kg K/ha) and 125% RDF (187.5 kg N + 46.4 kg P + 62.3 kg K/ha) in randomized block design with 3 replications during autumn and spring season. Urea, diammonium phosphate and muriate of potash were taken as sources of nitrogen, phosphorus and potassium, respectively. Full dose of P and K and half the dose of N were applied as basal at the time of planting and the rest N in two equal splits after first irrigation and at the time of earthing up during both the seasons in each year. Other recommended packages of practices were adopted as and when required by the crop. The sugarcane was planted in second week of November and February during autumn and spring season respectively and harvested on first week of January during all the years. The mean rainfall received during the crop growth period was 1,626.7 mm. Whole cane samples were taken at the time of harvest and cane juice was extracted with power crusher and juice quality was estimated as per method given by Spencer and Meade (1955). Sugar yield was calculated as; sugar yield (t/ha) = [S – 0.4 (B - S) x 0.73] x cane yield (t/ha)/100; where S and B are sucrose and brix per cent in cane juice respectively. The concentration of N, P and K in plant and soil were analyzed using standard procedures (Jackson, 1973). The total N, P and K uptake in sugarcane was calculated by multiplying the percent content of these nutrients with their respective dry matter accumulation. Net returns was calculated by deducting the total cost of cultivation from the gross returns for each treatment and expressed as ₹/ha on the basis of cost of inputs and prices of outputs in experimentation year. The benefit: cost ratio was calculated as ratio of gross return to cost of cultivation.

RESULTS AND DISCUSSION

Growth and yield attributes

Autumn planting

Growth and yield attributes like tillers, cane length, dry matter accumulation, cane diameter and number of millable cane under study were significantly influenced by the genotype (Table 1). Maximum number of tillers at 125 days after planting (pre-monsoon) was observed due to the genotype 'BO 147'. The significant variations in tillers count were owing to chemical composition of soluble solids in juice as well as enzymes and hormones present in cell sap, which differs from genotype to genotype. 'BO 147' gave the longer cane of 211 cm was significantly superior by 14.7% to genotype 'CoP 022' which may be attributed to its growth habit governed by genetic traits. Among genotypes, 'BO 147' recorded higher dry matter accumulation (32.2 t/ha), cane diameter (2.34 cm) and number of millable cane (112.0 thousand/ha) when compared with 'BO 146' and 'CoP 022'. Growth and development of genotypes are the outcome of genetic, environmental and agronomic interferences. Since all the genotypes were grown under similar agronomic situation, 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. Moreover, Variation in growth and yield attributes of genotypes indicate their genetic behaviour towards these characters.

Regarding the fertility levels, 125% RDF recorded the maximum number of tillers, cane length, dry matter accumulation, cane diameter and number of millable canes (Table 1). Significant improvement in number of tillers (151.5 thousand/ha) was observed only up to 100% fertility level and it remained at par with 125% fertility level. Sugarcane recorded significantly taller plant with the increase in fertility level up to 100% RDF (203 cm). Further increase in fertility level to 125% RDF also recorded longer cane (213 cm) over 100% RDF but the differences were not significant. A significant increase in total dry matter production at 275 DAP was observed up to 125% RDF (33.9 t/ha). The magnitude of increase in dry matter at 125 and 100% RDF over 75% RDF were 37.2 and 23.5%, respectively. This might be due to increase in the rate of biosynthesis of various plant metabolites in the plant system leading to increased rate of dry matter accumulation. Fertility level of 125% RDF (2.38 cm) and 100% RDF (2.26 cm), being at par recorded significantly thicker cane than 75% RDF (2.02 cm). Similarly, the application of 100% RDF (103.1 thousand/ha), being at par on millable canes with 125% RDF (107.1 thousand/ha) and 75% RDF (95.4 thousand/ha). Singh *et al* (2010) also observed marked improvement in growth and yield attributes of sugarcane by N, P and K fertilization.

Spring planting

Pooled data of 3 cropping seasons indicated that genotype 'BO 147' showed maximum number of tillers (149.3 thousand/ha) was significantly superior to 'BO 146' (132.3 thousand/ha) and 'CoP 022' (115.2 thousand/ha). Significantly higher cane length was recorded due to the genotype 'BO 147' (204 cm) was statistically on a par with 'BO 146' (195 cm) and both of them were significantly superior to 'CoP 022' (177 cm). The variation in growth and yield attributes among the genotype might be due to variation in partitioning of photosynthates by the different genotypes. The genotype 'BO 147' exhibited significantly higher dry matter accumulation (30.0 t/ha) and it was accumulated 9.1 and 28.8% more dry matter than 'BO 146' and 'CoP 022', respectively. The increase in total dry matter accumulation of 'BO 147' was due to its fast growth habits and nice tillering capacity as compared to 'BO 146' and 'CoP 022' (Table 1). The other yield attributes, *i.e.*, cane diameter and number of millable cane has shown the similar trend as in dry matter accumulation.

Fertility level had significant impact on growth and yield attributes (Table 1). Significantly higher tillers (140.8 thousand/ha) and cane length (208 cm) was recorded due to 125% RDF, though it was statistically at par with 100% RDF. The role of nitrogen in chlorophyll formation, carbohydrates metabolism, positive interaction of nitrogen and phosphorus and nitrogen with potassium is well known. It was the main reason in improving the tillers and cane length of sugarcane. Each successive increase in fertility level from 75 to 125% RDF significantly increased the total dry matter accumulation and cane diameter. However, higher number of millable canes (105.0 thousand/ha) were recorded by 125% RDF, though it was on par with 100% RDF (99.9 thousand/ha). Later was also statistically similar to 75% RDF. Improvement in yield attributes of sugarcane was recorded due to increased metabolic processes in plants, resulting in greater meristematic activity thereby improving the sink size which manifested into higher values of growth and yield contributing characters. Pandey and Shukla (2003) observed

Table 1. Effect of genotypes and fertility levels on growth, yield attributes, yield and quality of autumn and spring planted sugarcane (Pooled data of 3 cropping seasons)

Treatment	Tillers at 125 DAP ($\times 10^3$/ha)	Cane length (cm)	Total DMA* at harvest (t/ha)	Cane diameter (cm)	Millable cane ($\times 10^3$/ha)	Cane yield (t/ha)	Brix (%)	Pol (%)	Purity (%)	CCS (%)	Sugar yield (t/ha)
Genotype					*Autumn season crop*						
'BO 147'	170.4	211	33.2	2.34	112.0	82.9	18.2	16.5	90.6	11.6	9.6
'BO 146'	151.2	199	30.4	2.28	101.5	76.4	19.2	17.1	89.5	11.9	9.1
'CoP 022'	123.6	184	25.5	2.04	92.1	71.6	18.5	16.7	90.2	11.6	8.3
SEm±	3.8	6	0.8	0.05	3.4	2.5	0.2	0.1	0.9	0.1	0.1
CD (P=0.05)	11.0	16	2.5	0.13	9.8	7.6	0.5	0.3	NS	NS	0.4
Fertility level (% RDF)											
75%	135.2	178	24.7	2.02	95.4	63.3	18.7	16.9	90.5	11.8	7.5
100%	151.5	203	30.5	2.26	103.1	81.6	18.6	16.8	90.0	11.7	9.5
125%	158.5	213	33.9	2.38	107.1	86.0	18.6	16.7	89.8	11.6	10.0
SEm±	3.8	6	0.8	0.05	3.4	2.5	0.2	0.1	0.9	0.1	0.1
CD (P=0.05)	11.0	16	2.5	0.13	9.8	7.6	NS	NS	NS	NS	0.4
Genotype					*Spring season crop*						
'BO 147'	149.3	204	30.0	2.16	109.6	75.2	18.1	16.2	89.6	11.3	8.5
'BO 146'	132.3	195	27.5	2.02	98.1	69.6	19.0	16.9	89.4	11.8	8.2
'CoP 022'	115.2	177	23.3	1.85	88.5	65.6	18.4	16.5	90.0	11.5	7.6
SEm±	4.5	5	0.7	0.04	2.9	2.1	0.1	0.1	0.9	0.1	0.1
CD (P=0.05)	12.8	14	2.0	0.12	8.8	6.4	0.4	0.3	NS	0.3	0.4
Fertility level (% RDF)											
75%	121.0	171	22.2	1.81	91.3	57.2	18.6	16.7	90.0	11.7	6.7
100%	135.0	197	27.8	2.04	99.9	73.3	18.5	16.5	89.6	11.5	8.4
125%	140.8	208	30.9	2.18	105.0	79.9	18.4	16.4	89.4	11.4	9.1
SEm±	4.5	5	0.7	0.04	2.9	2.1	0.1	0.1	0.9	0.1	0.1
CD (P=0.05)	12.8	14	2.0	0.12	8.8	6.4	NS	NS	NS	NS	0.4

DMA : Drymatter accumulation

similar results.

Yield and quality

Autumn planting

Pooled data of 3 cropping seasons indicated that genotype 'BO 147' showed higher cane yield (82.9 t/ha) than 'BO 146' and 'CoP 022' (Table 1) owing to its higher length, diameter and number of millable canes. Genotype 'BO 146' showed the highest brix (19.2%) and pol (17.1%) percent in juice was significantly superior to 'BO 147' and 'CoP 022'. Higher sugar yield (9.6 t/ha) was harvested with genotypes 'BO 147' was significantly superior to 'BO 146' and 'CoP 022'. Later two were also differed significantly among themselves. The higher cane yield contributed greater extent in improving sugar yield than other quality parameters.

Increasing fertilizer dose from 75 to 100% of recommended dose significantly increased cane yield (Table 1). However, further increase in fertilizer dose to 125% of recommended dose didn't increase the cane yield significantly. This may be due to optimum supply of nutrients to the sugarcane crop upon use of recommended dose of fertilizers thereby resulting in better growth and development of the crop. Vasistha and Sinha (2004) have reported increase in cane yield with corresponding increase in fertility levels. Sugar yield was found to be significantly highest at 125% fertility level than 100 and 75% fertility level (Table 1). In turn, 100 % fertility level also produced significantly higher sugar yield than 75% fertility level. The percentage increase in sugar yield by 125 and 100% RDF over 75% RDF was 32.9 and 26.7% respectively.

Spring planting

Cane yield, brix, pol, CCS% and sugar yield were significantly influenced by the genotypes, 'BO 147' recorded significantly higher cane yield (75.2 t/ha) when compared to 'CoP 022' (65.6 t/ha). The higher cane yield in genotype 'BO 147' was mainly attributed to higher growth and yield attributes, which represents efficient utilization of the resources due to higher leaf area. Genotype 'BO 146' gave significantly higher pol % juice (16.9%) when compared to 'CoP 022' (16.5 %) and 'BO 147' (16.2%). Significantly higher sugar yield was recorded due to the genotype 'BO 147' (8.5 t/ha) was statistically similar to 'BO 146' (8.2 t/ha) and both of them were significantly superior to 'CoP 022' (7.6 t/ha).

The effect of fertility level on cane yield was positive and significant (Table 1). Increased cane yield by corresponding increase in fertility level from 75 to 125% recommended dose might be due to improved nutrition and assimilation of nutrients which increased photosynthetic efficiency and synthesized growth promoting substances as well as protoplasm. Fertility levels did not cause significant variation in brix, pol, purity and CCS % juice (Table 1). Similar observations were made by Singh *et al.* (2008). Though, sugar yield was significantly higher with each successive rise in fertility level from 75% RDF. The increase in sugar yield was due to increased cane yield under the treatment. These results were supported by Shukla (2007).

Nutrient uptake and residual soil fertility

Nutrient uptake by sugarcane plants varied significantly due to the genotypes and fertility levels (Table 2). The uptake of nutrients due to genotypic variation and fertility level were greater in autumn season than their respective uptake during spring season. 'BO 147' removed significantly higher N (231.9 and 198.2 kg/ha), P (20.6 and 18.4 kg/ha) and K (261.0 and 230.3 kg/ha) than 'BO 146' and 'CoP 022' during autumn and spring season respectively. This may be due to higher growth and yield contributing characters and ultimately cane yield. The minimum uptake was recorded in 'CoP 022'. K uptake was recorded higher than N and P uptake showing the higher K requirement of the sugarcane.

The data on N, P and K uptake noticed a significant and progressive increase with corresponding rise in fertility level from 75 to 125% RDF (Table 2) during both the seasons. The highest N uptake of 242.6 and 203.2 kg N/ha was recorded at 125 % RDF and minimum 152.0 and 132.6 kg N/ha when 75% RDF was applied autumn and spring season crop, respectively. P uptake also increased significantly with successive rise in N+P+K levels up to 125% RDF and mean values were 14.3, 18.8 and 21.0 kg P/ha during autumn and 12.5, 16.7 and 18.9 kg P/ha in spring season at 75, 100 and 125% RDF, respectively on mean basis. This was attributable to increase in cane yield as well as P concentration in plants, which markedly increase P- uptake. Navnit Kumar *et al*. (2010) have also reported increase in P concentration in plant tissues due to P application. Similarly, the marked variation in K uptake by fertility level was obtained during both the seasons (Table 2). 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 fertility levels.

Higher N, P and K status in post harvest soil during autumn and spring seasons was recorded due to the genotype 'CoP 022' and minimum under the genotype 'BO 147.' Minimum N, P and K content in post harvest soil due to the genotype 'BO 147' was due to higher tonnage of this genotype, which removed higher proportion of nutrients than other genotypes leading to lower N, P and K status in post harvest soil. Spring planted crop analyzed

Table 2. Nutrient uptake, post harvest nutrient status in soil and economic analysis of sugarcane as influenced by genotypes and fertility levels under different planting season (Pooled data of 3 cropping seasons)

Treatment	Nutrient uptake (kg/ha)			Post harvest nutrient status in soil (kg/ha)			Cost of cultivation (×10³ ₹/ha)	Net returns (×10³ ₹/ha)	Benefit : cost ratio
	N	P	K	N	P	K			
Genotype					*Autumn season*				
'BO 147'	231.9	20.6	261.0	214	8.5	101	62.84	57.78	1.90
'BO 146'	203.2	18.5	233.0	228	10.1	109	62.84	48.25	1.75
'CoP 022'	165.4	15.0	192.9	242	11.3	114	62.84	40.53	1.63
SEm±	5.2	0.4	5.5	5	0.3	3	-	1.35	0.05
CD (P=0.05)	15.6	1.3	16.5	15	0.8	8	-	4.02	0.15
Fertility level (% RDF)									
75%	152.0	14.3	181.4	204	7.6	96	61.91	30.40	1.48
100%	206.0	18.8	236.2	232	10.8	110	62.83	55.36	1.87
125%	242.6	21.0	269.4	248	11.5	118	63.77	60.80	1.94
SEm±	5.2	0.4	5.5	5	0.3	3	-	1.35	0.05
CD (P=0.05)	15.6	1.3	16.5	15	0.8	8	-	4.02	0.15
Genotype					*Spring season*				
'BO 147'	198.2	18.4	230.3	215	8.6	105	60.60	48.46	1.78
'BO 146'	173.1	16.3	205.1	236	11.3	114	60.60	40.80	1.66
'CoP 022'	144.5	13.4	171.6	252	12.5	120	60.60	34.63	1.56
SEm±	4.2	0.4	4.6	5	0.3	3	-	1.03	0.04
CD (P=0.05)	12.4	1.1	13.8	15	0.8	8	-	3.07	0.11
Fertility level (% RDF)									
75%	132.6	12.5	158.4	210	7.9	101	59.67	23.40	1.38
100%	180.0	16.7	209.5	239	11.7	116	60.59	45.96	1.75
125%	203.2	18.9	239.1	254	12.8	122	61.53	54.52	1.88
SEm±	4.2	0.4	4.6	5	0.3	3	-	1.03	0.04
CD (P=0.05)	12.4	1.1	13.8	15	0.8	8	-	3.07	0.11

Sale price: ₹1,400/tonne of cane; Initial available N: 198, P: 19.6 and K: 83.0 kg/ha

higher values of available N, P and K in post harvest soil compared to autumn planted cane due to lower harvest.

Fertility level brought significant improvement in N, P and K status; there was a increasing trend of nutrient availability up to 125% RDF (Table 2). Increase in the level of fertilization also assured the availability of these nutrients to sugarcane in sufficient amount and remained in soil in substantial quantity after fulfilling the crop requirement that ultimately improved the soil fertility status.

Economics

Sugarcane 'BO 147' recorded significantly higher net returns (₹57,777 and 48,457) and B: C ratio (1.90 and 1.78) during autumn and spring season, respectively. Net returns and benefit: cost ratio was significantly influenced by various levels of fertilization (Table 2). Net returns increased significantly with each successive increase in fertility level from 75 to 125% RDF during autumn and spring seasons. The differences in net returns and benefit: cost ratio of different genotypes and fertility levels were primarily due to variations in cane yield and cost of cultivation.

It was concluded that to get maximum sugar yield and economic returns from sugarcane genotype 'BO 147' in Bihar, the autumn and spring season crop should be fertilized with 125% RDF *i.e.,* 187.5 + 46.4 + 62.3 kg N+P+K/ha.

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