Indian Journal of Agronomy **60** (1): 126–131 (March 2015)

Research Paper

Performance of early-maturing sugarcane (*Saccharum* spp. hybrids complex) genotypes grown with and without organics in sub-tropical India

A.K. SINGH[1], R.L. YADAV[2], A.D. PATHAK[3] AND ARCHNA SUMAN[4]

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

Received : April 2014; Revised accepted : November 2014

ABSTRACT

A field experiment was conducted during the spring seasons of 2007–08 and 2008–09 at Lucknow, Uttar Pradesh, to identify maximum nitrogen-use efficiency of early-maturing sugarcane (*Saccharum* spp. hybrids complex) genotypes for higher productivity with low-input supply. The experimental treatment consisted of 8 early-maturing genotypes, viz. 'CoS 95270', 'CoS 96258', 'CoH 92201', 'BO 130', 'CoS 96268', 'CoPt 98224', 'BO 128' and 'CoLk 94184'. The genotypes were planted in furrows during the spring season (in February) along with 4 nitrogen levels, viz. control, 150 kg N/ha, farm yard manure (FYM) @ 10 t/ha and 150 kg N/ha + FYM@ 10 t/ha. The highest nitrogen-use efficiency (NUE) was observed with 'CoLk 94184' (260.9 kg cane/kg N applied) at 150 kg N application. The genotype 'CoLk 94184' grown with 150 kg N + 10 t FYM yielded 66.1 t/ha followed by 'BO 128'. Significant variation in the germination percentage of different genotypes was observed. The highest germination (%) was noticed in 'CoLk 94184' followed by 'CoS 96258'. Significantly highest number of millable canes (133.7 thousand/ha) were observed in genotype 'CoLk 94184'. Increase in number of millable canes was recorded with the application of nitrogen and its fortification with organic matter (FYM). In general, the productivity of sugarcane enhanced at 150 kg + 10 t FYM/ha as compared to 150 kg N/ha alone. The genotypes 'CoS 95270', 'CoLk 94184', 'CoS 96258', 'CoS 96268', 'CoH 92201' and 'BO 130' recorded significantly higher and at par commercial cane sugar. However, 'CoLk 94184' gave significantly highest sugar yield (8.35 t/ha), which was statistically at par with those produced by 'CoS 95270', 'CoS 96268' and 'BO 128'. The sugar yield was enhanced with application of N along with FYM. The higher root volume (71.9 cc) and root length (33.1 cm) were recorded by the genotype 'CoLk 94184' however 'BO 128' blessed with higher root spread.

Key words : Apparent recovery, Early maturing, Genotypes, Organics, Nitrogen-use efficiency, Root, Sugarcane

Sugarcane is an important agro-industrial annual crop involves more than 50 million skilled and unskilled workers for various activities (Singh *et al*., 2013). Competing sinks of vegetative growth fibre and stored sucrose in sugarcane undergoes complex physiological regulations that largely depends on crop nutrition. Sugarcane is a high biomass-producing crop that requires substantial quantities of nitrogen from soil (Singh and Yadav, 1992; Peter, 2005). Primary function of nitrogen in sugarcane is to increase the photosynthetic apparatus like leaf development, leaf expansion, tiller formation, leaf surface area and functional duration of leaves. The yield of different genotypes varies with their in-built genetical potential. Consequently, the uptake of nitrogen by different genotype also varies.

Sugarcane being a long duration and huge biomass accumulating crop removes substantial amount of plant nutrients from the soil. A crop of 100 t/ha exhausts 208 kg N, 53 kg P and 280 kg K besides 3.4 kg Fe, 1.2 kg Mn, 0.6 kg Zn, 0.2 kg Cu and 30 kg S (Lal and Singh, 2002). Since Indian soils are universally deficient in N, the nitrogen application rate is much higher except in some parts of north eastern region. Nearly 50% soils are deficient in P and 20% in K. Sulphur has become critical in low organic matter coarse-textured soils under S-exhausting oilseed-based cropping systems. Simultaneously, low-fertilizer N recovery has been reported from many sugar areas (Hartemink, 2008). More so, sugarcane genetic variations concerned with yield and quality along with the environmental impact on crop production, efficient use of fertilizers N is therefore critical (Uribelarrea *et al.,* 2006). All these point out to greater opportunity for using more balanced fertilizers for enhancing cane yield, improving produce quality and maintaining system sustainability. Hence

[1]**Corresponding author Email:** shantaanil@yahoo.com
[1]Principal Scientist (Agronomy), [2]Ex-Director; [3]Head, Division of Crop Improvement; Indian Institute of Sugarcane Research, Lucknow, Uttar Pradesh; [4]Principal Scientist (Microbiology), Indian Agricultural Research Institute, New Delhi 110 012

present experiment was carried out to study the growth, yield and NUE of different genotypes under varying N levels with and without organics.

MATERIALS AND METHODS

The field experiment was conducted during 2007–08 and 2008–09, starting from February 2007 at the Research Farm of the Indian Institute of Sugarcane Research, Lucknow (26°50' N, 80°52' E and 111 m above mean sea-level in central part of Uttar Pradesh falling in subtropical belt of sugarcane cultivation). The soil of experimental site is categorized in Order inceptisols under the group Udic Ustochrepts, neutral in reaction (pH 7.4), low in organic carbon (0.34%) and available N (158.5 kg/ha), medium in available P (16.6 kg/ha) and K (265.9 kg/ha). Texture of experimental field was sandy loam (15.2% clay, 21.4% silt and 63.4% sand) of Gangetic alluvial origin.

The field experiment was laid out in split-plot design. The treatment consisted of 8 early-maturing genotypes, viz. 'CoS 95270', 'CoS 96258', 'CoH 92201', 'BO 130', 'CoS 96268', 'CoPt 98224', 'BO 128' and 'CoLk 94184' in main plots and nitrogen levels (control, 150 kg N/ha, farm yard manure (FYM) @ 10 t/ha and 150 kg N/ha + FYM 10 t/ha) in as sub-plot treatment. The genotypes were planted in furrows at 75 cm spacing during the spring season (in February) along with 4 nitrogen levels, replicated thrice. The recommended doses of P and K were 60 kg P_2O_5 and K_2O/ha each. The sources of P and K were diammonium phosphate-DAP (18% N and 46% P) and muriate of potash (60% K). Full amount of P and K fertilizers and one-third N were applied basal. Remaining nitrogen was applied in 2 equal splits-at initial (60 days after planting) and final stages (120 days after planting) of tillering in sugarcane. Other agronomic practices such as plant population management, water management and pest management were followed as per the recommendations.

Three healthy clumps (stools) per treatment were selected for root studies. Each stool was dugout carefully making all efforts to minimize loss of roots. The entire stool was then suspended in a water tank to wash-off the clinging soil. After washing, horizontal and vertical spread of roots was measured from base. Thereafter, the root mass was separated from the stalk and the fresh weight of the roots was recorded. The measurement of vertical/horizontal root spread as described by Kapur *et al.,* (2004), led to derivation of a cone-shaped 'feeding zone' and was calculated by the volume of a cone represented as:

$$\text{Feeding zone} = 1/3\pi\, h^2 V \quad \text{... (1)}$$

where h = one way (1/2 of the diameter) horizontal spread from the core/stalk base to the tip of longest lateral root and V is the vertical spread

'Root intensity' which encompasses vertical and horizontal spread of the roots and the roots mass was calculated on fresh weight basis as :

$$\text{Root intensity} = \frac{\text{Root mass}}{\text{Feeding zone}} \quad \text{.. (2)}$$

The ratio of above-ground plant weight to the weight of below ground plant part (i.e. root mass) taken as measure of shoot: root ratio and also termed as 'root efficiency' computed as:

$$\text{Root efficiency} = \frac{\text{Above ground plant fresh weight}}{\text{Below-ground plant fresh weight}} \quad \text{.. (3)}$$

Five millable canes (ripen canes ready to send to sugar mills) were randomly sampled for observations on yield attributed (length, girth and average cane weight) and juice quality parameters (brix, pol and purity). Juice purity and commercial cane sugar (CCS) were calculated by the formulae as described by Gupta (1977):

$$\text{Juice purity (\%)} = \text{Sucrose (\%) in juice/corrected brix} \times 100 \quad \text{…(4)}$$

$$\text{CCS (\%)} = \{S-(B-5) \times 0.4\} \times 0.73 \quad \text{... (5)}$$

where S is sucrose % in juice, and B is corrected sucrose (%) was determined as per the method of Meade and Chen (1977)

The apparent N recovery and nitrogen-use efficiency were calculated as per Yadav *et.al.* (1997). The data were statistically analyzed for various characters as described by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Growth and yield

There was significant variation in germination of the genotypes, being with highest in 'CoLk 94184' genotype, followed by 'CoS 96258' (Table 1). However, low germination percentages of the genotypes were only due to genotypic variation (Singh *et al*., 2002). Highly significant and large variations were recorded among the genotypes with for their tillering pattern. Genotypes 'CoLk 94184', 'CoS 96258', 'CoPt 98224', 'CoS 96258', were found as high-order tillering genotypes, while 'CoH 92201', 'BO 130' and 'Bo 128' were of shy-tillering character. The number of millable canes which is the exact measure of tiller performance, also showed significant variation. Significantly highest number of millable canes (NMC) were recorded in 'CoLk 94184' (133.7 thousand/ha). Increase in the number of tillers and number of millable canes were noted with the application of nitrogen and its fortification with organic matter (FYM). In tufted grass which include sugarcane, the under-ground branching is limited and is followed by formation of a number of erect stalks (shoots), which makes individual plants (Yadav, 1993). Higher tillering in the genotype 'CoLk 94184' in early-maturing genotypes are due to their high nitrogen-use efficiency (NUE) capability which may also owing to enhanced photosynthetic rate, stomatal conductance, transpiration ratio and ultimately leaf-area index.

Yield variability among the genotypes was significantly the highest at P≤0.05. The genotype 'CoLk 94184' yielded 66.1 t/ha followed by 'CoS 95270'. However, overall productivity of 'BO 128' was found better than 'CoS 95270'. The productivity of sugarcane also enhanced at 150 kg + 10 t FYM in general.

Quality parameters

Pertinent genotypic variations were recorded in the quality parameters of sugarcane like pol, purity and commercial cane sugar. Similar pol (%) were recorded for the genotypes 'CoS 95270' and 'CoLk 94184'. The purity of juice was significantly improved by application of optimum doses of nitrogen. Genotypes 'CoLk 94184', 'CoS 95270', 'CoS 96258', 'CoH 92201' and 'CoS 96268' were having statistically similar sucrose content. The significantly highest sugar yield was recorded from 'CoLk 94184', which was comparable to 'CoS 95270', CoS96268 and 'BO 128' genotypes. The sugar yield was enhanced by N application along with FYM. The quality parameters of the genotypes were again a part of varietal character. Sugar yield is a function of CCS (%) and cane yield. The higher sugar yield of the genotype 'CoLk 94184' and 'CoS 95270' were due to higher CCS% and cane yield.

Uptake, use-efficiency and apparent recovery of nitrogen

The highest N uptake and nitrogen-use efficiency (NUE) was observed with 'CoLk 94184' at 150 kg N application. However, the highest apparent recovery harnessed by genotype 'CoS 95270' (Table 2). Photosynthesis, growth and yield are strongly linked to N availability in grass crops (Ranjith and Meinzer, 1997). The increase in NUE of the genotypes with the application of FYM in the treatment was owing to improvement in soil conditions (Singh *et al.,* 2007). The number of root hairs in upper and lower portions of roots may also play an important role in increasing the NUE. Yadav *et al.* (1997) demonstrated that the responses and N recovery declined sharply with the increase in N dose from 75 to 300 kg/ha to sugarcane grown in subtropical region. It is to be noted that the highest response and N recovery were obtained at lower level of N dose (75 kg/ha). It is admitted that N recovery barely exceeds 30 to 40%. After application, a part is used by plants, a part remains in the soil, and remaining is depleted through gaseous loss and leaching.

Sugarcane prefers N in NO_3^- form and also takes the

Table 1. Effect of nitrogen levels on growth, yield and quality of early-maturing sugarcane genotypes (mean data of 2 years)

Treatment	Germination (%)	Tillers/ha ('000) May	June	July	Aug.	NMC (000/ha)	Yield (t/ha)	Brix (%)	Pol (%)	Purity (%)	CCS (%)	CCS (t/ha)
Genotypes												
'CoS 95270'	35.5	102.4	125.4	190.9	188.9	89.9	58.8	20.9	18.15	87.07	12.46	7.34
'Co S96258'	38.4	129.0	135.5	208.2	190.9	87.5	45.8	20.6	18.13	88.09	12.51	5.74
'CoH 92201'	23.1	72.0	105.1	155.4	151.8	67.8	40.4	20.5	17.89	87.19	12.29	4.94
'BO 130'	25.6	79.7	117.8	174.8	165.2	73.4	48.1	20.9	17.84	85.49	12.14	5.85
'CoS 96268'	36.8	133.3	136.3	218.9	196.0	95.1	54.2	20.9	18.23	87.00	12.52	6.73
'CoPt 98224'	35.9	126.5	120.3	154.5	158.0	101.9	49.3	21.1	17.54	83.12	11.75	5.81
'BO 128'	35.4	101.8	127.4	165.8	156.9	112.6	60.2	20.4	17.40	85.35	11.82	7.15
'CoLk 94184'	42.1	144.6	144.2	220.9	210.9	133.7	66.1	20.3	18.15	89.31	12.61	8.35
SEm±	1.10	4.50	4.69	6.14	6.57	4.27	2.70	0.67	0.15	0.44	0.21	0.67
CD (P=0.05)	3.97	13.65	14.24	18.63	20.65	12.97	8.17	NS	0.46	1.36	0.63	2.05
N levels												
Control	33.8	85.9	98.1	142.7	139.4	75.5	37.5	20.8	17.80	85.77	12.13	4.54
150 kg N/ha	33.1	124.0	143.1	214.1	199.1	103.7	59.6	20.4	17.64	86.45	12.07	7.20
10 t FYM/ha	34.9	94.3	108.2	153.2	150.9	84.6	48.1	20.9	18.10	86.69	12.39	5.95
150 kg N + 10 t FYM/ha	34.7	140.4	156.6	234.8	219.9	117.2	66.4	20.8	18.13	87.40	12.47	8.27
SEm±	0.95	2.81	3.18	3.64	3.52	2.61	1.95	0.52	0.63	0.29	0.59	0.44
CD (P=0.05)	NS	7.86	8.92	10.21	9.86	7.31	5.46	NS	NS	0.82	NS	1.25

CCS, Commercial cane sugar

Table 2. Effect of nitrogen levels on nitrogen uptake, use efficiency, apparent recovery and root characters of early-maturing sugarcane genotypes (mean data of 2 years)

Treatment	N uptake (kg/ha)*	NUE (kg cane/kg N)*	Apparent N recovery (%)*	Root spread (cm)	Feeding zone (m^3/stool)	Root intensity (g/m^3)	Root volume (cc)	Root length (cm)	Number of root hairs/cm root length/ clump
Genotypes									
'CoS 95270'	95.20	220.77	33.08	23.9	0.020	13,049.2	53.08	32.68	529.83
'CoS 96258'	76.60	201.84	25.53	23.2	0.017	15,559.3	42.25	28.18	284.87
'CoH 92201'	49.19	169.25	18.72	21.3	0.010	25,296.8	39.58	19.33	317.02
'BO 130'	59.72	156.96	15.51	22.4	0.015	16,297.6	31.29	27.05	283.74
'CoS 96268'	81.08	199.70	24.22	24.1	0.017	15,642.6	43.89	26.86	393.97
'CoPt 98224'	73.89	166.81	23.98	19.8	0.012	19,673.8	38.59	28.32	291.24
'BO 128'	81.50	161.81	25.11	25.3	0.023	11,581.7	65.40	32.04	694.77
'CoLk 94184'	99.97	260.99	31.63	20.9	0.016	16,012.6	71.91	33.09	915.95
SEm±	-	-	-	1.11	0.010	1,440.9	2.85	4.14	88.7
CD (P=0.05)	-	-	-	3.36	NS	43,66.2	8.65	12.55	263.8
N levels									
0 control	-	-	-	20.6	0.014	19,053.1	39.54	21.33	383.80
150 kg/Nha	-	-	-	23.2	0.015	17,853.1	51.55	30.43	482.64
10 t FYM/ha	-	-	-	21.8	0.018	14,742.0	45.97	26.86	473.03
150 kg N +10 t FYM	-	-	-	24.8	0.019	14,908.5	55.93	35.16	516.23
SEm±	-	-	-	0.51	0.013	949.2	1.90	3.08	42.40
CD (P=0.05)	-	-	-	1.41	NS	2,658.2	5.36	8.63	118.6

*****Observed at 10 t FYM/ha + 150 Kg N/ha

Table 3. Combined effect of genotypes and level of N application on number of millabel canes and yield (mean of 2 years)

Treatment	*NMC (000/ha)	Cane Yield (t/ha)	Sugar yield (t/ha)	NMC (000/ha)	Cane Yield (t/ha)	Sugar yield (t/ha)
Genotypes	N levels					
	0 (control)			150 kg N/ha		
'CoS 95270'	60.7	40.6	5.03	102.2	64.8	7.92
'CoS 96268'	64.2	30.4	3.81	100.7	53.0	6.64
'CoH 92201'	50.8	28.6	3.56	74.7	44.9	5.17
'BO 130'	63.2	34.9	4.09	73.7	56.5	6.84
'CoS 96268'	80.3	40.2	5.09	102.3	60.0	7.37
'CoPt 98224'	81.7	35.4	4.02	109.5	57.4	6.44
'BO 128'	93.3	46.9	5.29	118.8	65.7	7.76
'CoLk 94184'	109.7	43.2	5.39	146.8	74.2	9.41
	10 t FYM/ha			150 kg N+10 t/FYM		
'CoS 95270'	81.7	56.1	7.01	114.9	73.8	9.38
'CoS 96268'	76.3	39.2	4.85	108.7	60.7	7.65
'CoH 92201'	57.7	34.4	4.25	88.2	54.0	6.78
'BO 130'	65.1	42.8	5.21	91.5	58.4	7.25
'CoS 96268'	85.2	46.5	5.90	112.6	70.2	8.55
'CoPt 98224'	88.4	43.9	5.36	128.1	60.5	7.41
'BO 128'	101.7	57.1	6.81	136.8	71.2	8.72
'CoLk 94184'	121.1	64.6	8.20	157.1	82.4	10.38
'Genotype × N	NMC		Cane yield		Sugar yield	
SEm±	8.10		6.86		1.22	
CD (P=0.05)	22.73		19.29		3.47	

*NMC, Number of millable canes

NH_4^+ form. The latter is subject to microbial attack that depletes NH_4^+ – N. In Brazil, cane is grown on low-N inputs, rarely exceeding 60 kg/ha for plant crop and 80–120 kg/ha for ratoons. The yield pattern is 65–70 t/ha with an N uptake of 100–200 kg/ha. (Urquiaga *et al*., 1992). In the alluvial soils of Texas, USA, the plant crop receives 56 kg N/ha (Wiedenfeld, 1998). Higher rates are applied to clayey soils than loamy soils.

Root growth and feeding zone

The root spread, feeding zone and root intensity varied for different genotypes. Maximum root spread and feeding zone was observed in genotype 'BO 128'; however, highest root intensity was observed in 'COH 92201'. Sugarcane genotype 'CoLk 94184' produced bulky, longer roots and higher number of hairs bearing roots. This was followed by 'BO 128'. Genotype 'BO 130' with the lowest root volume beared less number of root hairs. The root length increased may be due to higher apparent recovery. The root biomass is observed to be the function plant genotype and management factor.

Table 4. Effect of different treatments on physical properties of soil at harvest of sugarcane (mean of 2 years)

N levels	$^*N_1$	N_2	N_3	N_4	Mean
Genotypes	Bulk Dendity (Mg/m) 0–30 cm				
'CoS 95270'	1.34	1.33	1.30	1.29	1.32
'CoS 96268'	1.33	1.34	1.32	1.30	1.32
'CoH 92201'	1.33	1.34	1.30	1.28	1.31
'BO 130'	1.34	1.34	1.34	1.32	1.34
'CoS 96268'	1.33	1.33	1.31	1.28	1.31
'CoPt 98224'	1.33	1.33	1.32	1.28	1.32
'BO 128'	1.33	1.33	1.33	1.31	1.33
'CoLk 94184'	1.33	1.34	1.32	1.29	1.32
Mean	1.33	1.34	1.32	1.29	-
Initial			1.36 Mg/m^3		
	Infiltration rate (mm/hr)				
'CoS 95270'	3.73	3.34	3.96	4.12	3.79
'CoS 96268'	3.74	3.73	3.89	4.10	3.87
'CoH 92201'	3.75	3.74	3.87	4.10	3.87
'BO 130'	3.73	3.72	3.92	4.17	3.89
'CoS 96268'	3.70	3.70	3.97	4.21	3.90
'CoPt 98224'	3.67	3.71	3.89	4.22	3.87
'BO 128'	3.69	3.71	3.89	4.11	3.85
'CoLk 94184'	3.72	3.73	3.94	4.00	3.85
Mean	3.72	3.67	3.92	4.13	-
Initial		3.61 mm/hr			
	Organic carbon (%) 0–30 cm				
'CoS 95270'	0.33	0.33	0.36	0.39	0.35
'CoS 96268'	0.32	0.32	0.36	0.40	0.35
'CoH 92201'	0.33	0.32	0.36	0.39	0.35
'BO 130'	0.34	0.33	0.37	0.41	0.36
'CoS 96268'	0.33	0.34	0.37	0.40	0.36
'CoPt 98224'	0.32	0.33	0.36	0.39	0.35
'BO 128'	0.33	0.32	0.36	0.40	0.35
'CoLk 94184'	0.33	0.32	0.37	0.41	0.36
Mean	0.33	0.33	0.36	0.40	-
Initial		0.30			

$^*N_1$, 0 (control); N_2, 150 kg N/ha; N_3, 10 t FYM/ha; N_4, 150 kg N + 10 t FYM

Combined effect of genotypes and nitrogen levels

The combined effect of genotypes and nitrogen levels was found significant for many attributes, but the data on number of millable cane, cane yield and sugar yield are presented in Table 3. Significantly highest number of millable canes, cane yield and sugar yield were recorded in 'CoLk 94184' genotype applied with 150 kg N + 10 t FYM/ha. The genotypes 'CoS 95270', 'BO 128' and 'CoS 96268' also performed similar to 'CoLk 94184'. The addition of FYM in the field reflected with 3 fold improvement in the soil-plant system, i.e. pool of plant nutrients which have direct effect on plant growth, increased organic matter content of soil that improved the physical properties of soil and it provides food for many microorganisms essential for increase in their activity which in turn help convert unavailable plant nutrients into available form. The change in soil physical properties *viz*. bulk density, infiltration rate and organic carbon are presented in Table 4. It is clear from the data that plots receiving FYM @ 10 t/ha played major role in reducing bulk density, increasing infiltration rate and organic carbon, which ultimately resulted in higher productivity of cane and sugar both. Similar observations were also reported by Singh *et al.* (2007).

It may be concluded that nitrogen-use efficiency varies with the genotypes and application of organics proved beneficial for enhancing the growth, yield and quality of sugarcane. Root growth is solely decides the genotypic ability to grow and uptake of nutrient.

REFERENCES

Gupta, A.P. 1977. Method for assessment of sugarcane quality. *Indian Sugar Crop Journal* **4**: 87–88.

Hartemink, A.E. 2008. Sugarcane for bioethanol: Soil and environmental issues. *Advances in Agronomy* **99**:125–82.

Kapur, R., Srivastava, B.L. and Duttamajumdar, S.K. 2004. Root characteristics of some subtropical sugarcane genotypes from a breeder's perspective. *Sugarcane International* **22**(5): 27–31.

Lal, M. and Singh, A.K., 2002. Importance of plant nutrient management in sugarcane. *Fertiliser News* **47**(11): 91–98.

Meade, G.P. and Chen, J.C.P., 1977. *Cane Sugar Hand Book*. Edn 10, 405 pp. John Wiley & Sons, New York.

Panse, V.G. and Sukhatme, P.V. 1985. *Statistical Methods for Agricultural Workers*. Indian Council of Agricultural Research, New Delhi.

Peter, J.T., Elizabeth, A.M. and Mervyn, E.P., 2005. Modelling nitrogen dynamics in sugarcane systems: Recent advances and applications. *Field Crops Research* **92**(2–3): 337–51.

Ranjith, S.A. and Meinzer, F.C., 1997. Physiological correlates of variation in nitrogen-use efficiency in two contrasting sugarcane cultivars. *Crop Science* **37**: 818–25.

Singh, A.K., Lal, M. and Prasad, S.R. 2002. Enhancing productivity of early maturing high sugarcane genotypes through management of crop geometry and nitrogen nutrition. *Indian Journal of Sugarcane Technology* **17, (**1–2): 43–46.

Singh, A.K., Kumari, V.V. and Singh, K.P. 2013. Role of Indian women in sugarcane planting. (In:) *Proceedings* of *National Conference on Women in Sugarcane Agriculture and Industry*, held at Indian Institute of Sugarcane Research, Lucknow, held during 29–31 August 2013, , pp. 167.

Singh, G.B. and Yadav, D.V. 1992. Integrated nutrient supply system in sugarcane and sugarcane based cropping systems. *Fertiliser News* **37**(4): 15–22.

Singh, K.P., Suman, A., Singh, P.N. and Lal, M. 2007. Yield and soil nutrition balance of sugarcane plant-ratoon system with conventional and organic nutrient management in subtropical India. *Nutrient Cycling in Agro-ecosystem* **79:** 209–19.

Uribelarrea, M. Moose, S.P. and Below, F.E. 2006. Divergent selection for grain protein affects nitrogen use in maize hybrids. *Field Crops Research* **100**: 82–90.

Urquiaga, S., Katiya, H.S. and Boddey, R.M. 1992. Contribution of nitrogen fixation to sugarcane: Nitrogen-15 and nitrogen balance estimates. *Soil Science Society of America Journal* **56**: 105–14.

Widenfeld, R.P. 1998. Effect of irrigation and N fertilizer application on sugarcane yield and quality. *Field Crops Research* **43**: 101–18.

Yadav, R.L., 1993. *Agronomy of Sugarcane*. Edn 1, pp.31. IBH Publication, Lucknow.

Yadav, R.L., Singh, R.V., Singh, R., and Srivastava, V.K. 1997. Effect of planting geometry and fertilizer N rates on nitrate leaching, nitrogen use efficiency and sugarcane yield. *Tropical Agriculture,* Trinidad **74**(2): 115–20.