ISSN 0970-3233 Volume 31, No. 2 December 2016

Indian Journal of Sugarcane Technology

The Association of Sugarcane Technologists of India
Lucknow 226 002 (UP) India

The Association of Sugarcane Technologists of India

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INDIAN JOURNAL OF SUGARCANE TECHNOLOGY

Frequency of Publication	:	Half Yearly (June & December)
Address for Correspondence	:	Secretary, The Association of Sugarcane Technologists of India, ICAR-Indian Institute of Sugarcane Research, Dilkusha P.O., Lucknow - 226002, Uttar Pradesh, India E-mail: secretaryasti@gmail.com; Web: www.iisr.nic.in

INDIAN JOURNAL OF SUGARCANE TECHNOLOGY

ISSN 0970-3233 Issue: Volume 31 No.2 December 2016

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Indian Journal of Sugarcane Technology **31(02)**: 41-45, December 2016

Sugarcane: A poverty reducing crop for rural population of India

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ABSTRACT

About 12.337 million sugarcane workers are engaged in the cultivation of sugarcane in India, which accounts for 1.427 % of total rural population of India. Nearly 82.82 % are marginal and small sugarcane land holdings, which occupy nearly 54.44 % sugarcane area. Five lakhs skilled and unskilled workers including highly qualified and trained technologists are engaged in the manufacturing of sugar. In India, the average size of holdings for all operational classes (small & marginal, medium and large) has declined over the years and the same for all classes put together has come down to 1.15 hectare in 2010-11 from 2.82 hectare in 1970-71, where as in case of sugarcane, picture is entirely reverse. The average size of holdings for all operational classes of sugarcane farmers in the country (small, marginal, medium and large) has increased over the years and the same for all classes put together has increased to 0.82 hectare in 2010-11 from 0.60 hectare in 1995-96. The same trends were also indicated in all the classes of sugarcane farmers (small, marginal, medium and large). During last fifteen years (1995-96 to 2010-11), importance of sugarcane has increased in the country drastically among all classes of sugarcane farmers (small, marginal, medium and large). Area under sugarcane in case of medium and large farmers is increasing. Sugarcane is more important than the other crops as it is more remunerative. It contributed nearly 0.69% in GDP of the country in the year 2014-15 at current price with area of nearly 5.14 million hectare and same trend is expected to follow in coming years also. Out of 451 sugarcane growing districts in the country, forty three most important sugarcane growing districts contribute nearly 75% cane area & cane production and approximately 24% is contributed by the next 109 districts. In high priority 43 sugarcane growing districts of the country, marginal (less than 1.0 ha) and small (1.0 to 2.0 ha) farmers contribute nearly 60 % of each category of priority area. Whenever, the policies to be framed for farmers of 6.26 million sugarcane land holdings, these 43 high cane spread districts should be given greater thrust on technology development and extension activities. It is interesting to note that districts with high spread cane area and total production are very powerful in reducing the rural poverty. It denotes that sugarcane helps in reducing the poverty of rural population through enhancing income of rural farmers.

Key words: Cane productivity, rural poor population, poverty**,** operational classes of sugarcane farmers

It is estimated that about 5.568 million sugarcane cultivators/ farmers and 6.769 sugarcane labourers (total of about 12.337 million sugarcane workers) are engaged in the cultivation of sugarcane in India, which accounts for 1.427 % of total rural population of India. Out of 6.26 million sugarcane land holdings of the country, 82.82 % are marginal (less than 1.0 ha) and small (1.0 to 2.0 ha) which occupy nearly 54.44 % sugarcane area. Five lakhs skilled and unskilled workers including highly qualified and trained technologists are engaged in the manufacturing of sugar. In India, the average size of holdings for all operational classes (small & marginal, medium and large) have declined over the years and the same for all classes put together has come down to 1.15 hectare in 2010-11 from 2.82 hectare in 1970-71, whereas in case of sugarcane, picture is entirely reverse. The average size of holdings for all operational classes of sugarcane farmers in the country (small, marginal, medium and large) have increased over the years and the same for all classes put together has increased to 0.82 hectare in 2010-11 from 0.60 hectare in 1995-96. The same trend was also indicated in all the classes of sugarcane farmers (small, marginal, medium and large). During last fifteen years (1995-96 to 2010-11), importance of sugarcane has increased in the country drastically among all classes of sugarcane farmers (small, marginal, medium and large). Area under sugarcane in case of medium and large farmers is increasing which indicates that it is shifting towards large size holding of the country and occupies a commanding position as an agro-industrial crop. In addition, the sugarcane supports a large number of unorganized open pan *khandsari* and jaggery units in the rural sector. Unlike textile industry, where agricultural and manufacturing wings are separated, the sugar industry is totally rural and has helped in improving the rural economy in several parts of the country.

Sugarcane is more important than the other crops as it is more remunerative. It contributed nearly 0.69% in GDP of the country in the year 2014-15 at current prices with area of nearly 5.14 million hectare and same trend is expected to follow in coming years also (Table 1), whereas paddy crop having largest area (44.10 million hectare) contributed 2.01% in GDP of overall economic activity of the country during 2014-15, which is 21.99 % of the gross cropped area of the country. Similarly area under wheat crop was the second largest area (31.50 million hectare) contributing 1.13% in GDP of overall economic activity of the country with 15.66% of the gross cropped area of the

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country. Cotton, another important commercial crop of the country contributes less than sugarcane *i.e.* 0.62% in GDP of overall economic activity of the country but having more than double area (11.96 million hectare) than sugarcane in the country and also having nearly 5.96% of the gross cropped area of the country (Table 1), whereas sugarcane had only 2.56% of the gross cropped area of the country.

India by contributing 19.08% in area and 18.18% in production ranks second among sugarcane growing countries of the world for both area and production of sugarcane (Kumar *et al.* 2015). In fact, sugar manufacturing is the second largest agro-based processing industry in our country. The turnover of the sugarcane, sugar and other related economic activities were approximately of Rs. 104.104 thousand crores per annum during 2014-15 at constant price, out of which, nearly Rs. 55-60 thousand crores is paid to the sugarcane farmers by the sugar mill as prices for its supply. In India, sugar industry which has more than 556 sugar factories in operation, is the second largest agro-based industry (next to cotton textile) located in rural areas. The industry is instrumental in generating sizeable employment in rural sector directly and through ancillary industries. It is estimated that farmers of about 6.26 million sugarcane land holdings are engaged in the cultivation of sugarcane and another five lakhs skilled and unskilled workers including highly qualified and trained technologists are engaged in the manufacturing of sugar.

Global production for marketing year 2017-18 is up by 9 million tons producing a record 180 million tons by gain in Brazil, China, European Union, India and Thailand. India's production is forecast to rebound by 18% to 25.8 million tons due to higher area and yield. Imports are forecast lower while consumption is forecast edge higher to 26.0 million tons (Anonymous 2017a).There were expectations in the market that global sugar output will be short by about 7 to 8 million tones over the demand in 2016-17, mainly due to anticipated lesser output in India. Market did expect that India would import 2.0 to 2.5 million tons of sugar to meet its domestic requirement. Traders across the world were expecting early announcement by Indian Government about sugar import in the initial months of the season itself (Anonymous 2017b). But delayed Indian Government's decision had resulted in to fall in prices in global market and expected to go down as due to good sugar production in next season. International sugar trade is of strategic importance to India as it helps to maintain stability in the domestic sugar prices despite the cyclic nature in production. Also, the potential for expanding sugar production in India exists and can be fully exploited if adjustments were introduced to ensure a market driven relationship between sugar and sugarcane prices (Balasaheb 2013). Prevailing sugarcane production scenario in India needs immediate attention to adopt measures for sustaining sugar production and productivity at higher level to meet the escalating demands of sweeteners in coming years and also framed policies for farmers of 6.26 million sugarcane land holdings in the country. In this paper, we have analyzed and discussed some of the important issues of sugarcane at district level for further planning of sugarcane in India.

MATERIALS AND METHODS

Variation in sugarcane production and productivity in India has been studied most often at the State level, though a few district-level studies have also been conducted. Recognizing the importance of district level approach, an analysis has been attempted to identify the districts with respect to cane area, cane productivity and cane production. The analysis is based on district-wise data of sugarcane for the period 2011-2012 available with data of DES, Govt. of India. Main purpose of this study was to classify districts according to levels of productivity, spread of sugarcane crop and on some other topologies into homogeneous groups to study the impact of sugarcane in relation to importance of sugarcane in districts and poverty in rural population of India.

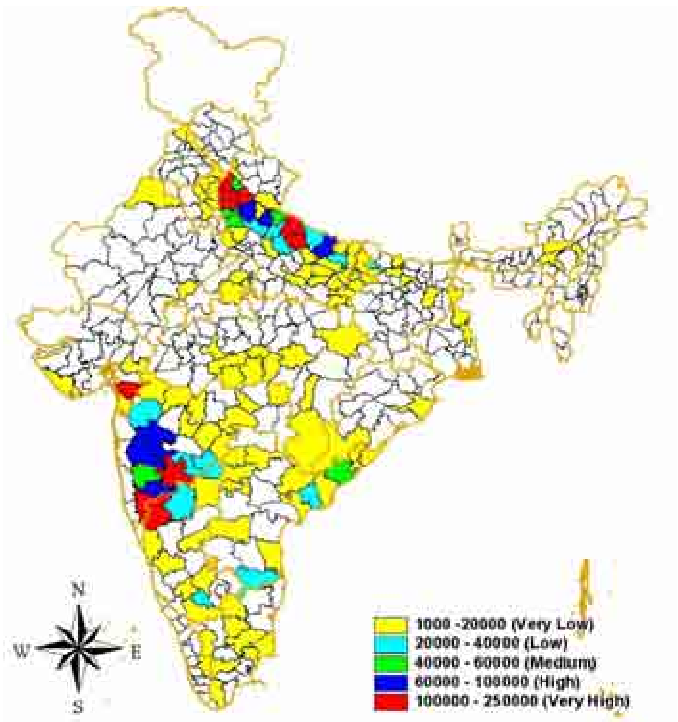
District level analysis

- Classify districts according to levels of productivity and spread of sugarcane crop and on some other topologies into homogeneous groups.
- Impact of sugarcane on poverty of the rural population in different sugarcane growing districts of India.
- So that it may be used by the policymakers and planners to develop strategy for sugarcane growth and development of low productivity regions.

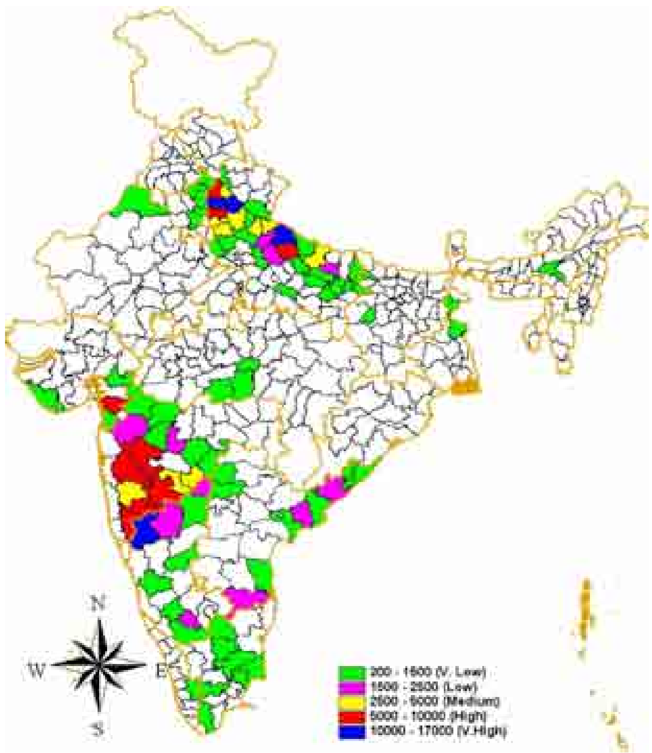
RESULTS AND DISCUSSION

Out of 622 districts in the country, sugarcane is grown in around 451 districts; 152 districts having spread index (percentage of sugarcane area to net sown area in a district) of sugarcane more than one were considered for analysis of cross sectional data. These potential sugarcane growing districts (152) had more than 95.58 % sugarcane area with 96.33 % of cane production of the country (Table 2). All these 152 districts were further classified into five different categories as very low, low, medium, high and very high for sugarcane area (Map 1), production (Map 2) and yield (Map 3) and mapped on district wise map of India.

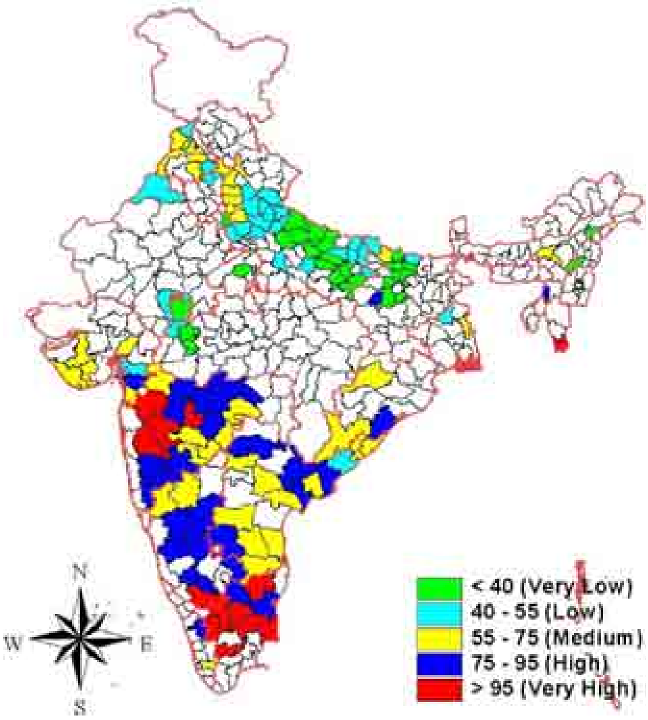
Out of 6.26 million sugarcane land holdings of the country, in high priority 43 sugarcane growing districts of the country, marginal (less than 1.0 ha) and small (1.0 to 2.0 ha) farmers contribute nearly 60 % of each category of priority area. Out of 451 sugarcane growing districts in the country, forty three most important sugarcane growing districts contribute nearly 75% cane area & production of the country and rest 25 % is contributed by the next 109 districts. These forty three districts were mapped on the map of India (Map 4). These district formed three distinct clusters in the country. One cluster is located in the Uttarakhand, North West and Central Uttar Pradesh, which is having high spread of cane the districts with medium yield. Another cluster of the districts is located mostly in Tamil Nadu having very high cane yield and very low spread of cane in



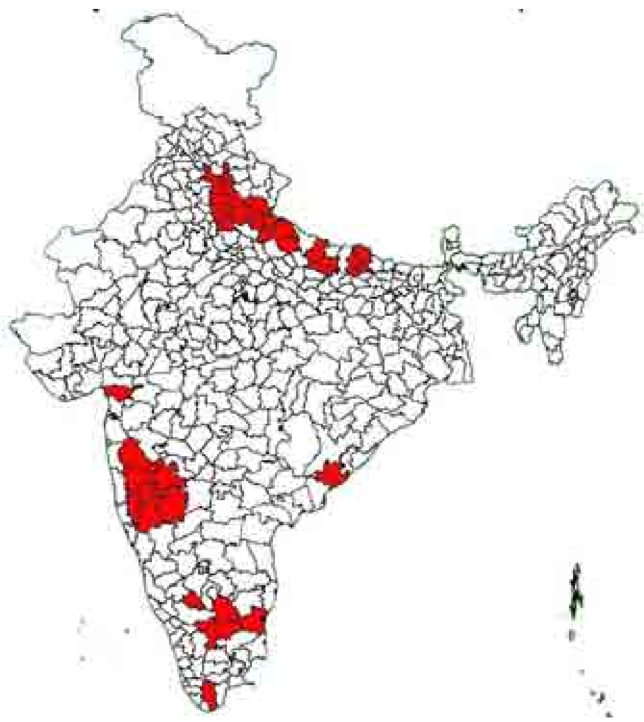
Map 1. Distribution of sugarcane area (ha) in India



Map 2. Distribution of sugarcane production ('1000 tonnes) in India



Map 3. Distribution of sugarcane yield (t/ha) in India



Map 4. Most important forty three sugarcane growing districts in India

the districts. Third cluster of districts is in Maharashtra which is having very high sugar recovery with good cane yield in the districts. Whenever, the policies to be farmed for sugarcane, these 43 high cane spread districts should be given greater thrust on technology development and extension activities. It is interesting to note that districts with high spread cane area and total production are very powerful in reducing the rural poverty. It denotes that sugarcane helps in reducing the poverty of rural population through enhancing income of rural farmers. Sugarcane also sustains the second largest organized agro-industry in the country.

Variations in sugarcane crop

Although the area under sugarcane is maximum in the alluvial soil tract of subtropics, the cane yield is the highest in the humid tropics of peninsular India. The most favorable sugar recoveries are generally obtained in the arid Deccan plateau. These regional variations have remained a subject of concern for couple of reasons. Large variation in productivity leads to regional disparities and is generally considered as discriminatory

Major findings of the study

- 21 districts contribute nearly 50% cane area and 45% cane production of the country (Table 2 and 3).
- 43 districts contribute nearly 75% cane area & cane production of the country (Table 2 and 3).
- 109 district contribute nearly 24% cane and cane production of the country (Table 2).
- When cane spread is high/very high, cane yield is low (61 to 63 t/ha).
- When cane spread is medium, cane yield is high (84 t/ ha).
- When cane spread is low / very low, cane yield is medium (around 70 t/ha).

Sugarcane as a poverty reducing crop in India

- Overall poverty level in the country is as high as 28.1% in rural population.
- Poverty in rural population of sugarcane growing 152 districts is 20.9%.
- Poverty in rural population in the district having sugarcane spread more than 10% is 17.77%.
- When sugarcane spread is high, poverty in rural population is very low.
- When sugarcane spread is >40 %, average productivity/ ha is >Rs.64231.00 and crop intensity is >151 % in sugarcane growing districts, then poverty is low (<15.91%) in rural population of India (Table 4).
- When sugarcane spread is <5 %, average productivity/ ha is <Rs.31842.00 and crop intensity is <138 % in sugarcane growing districts, then poverty is high is (>22.4 %) in rural population of India (Table 4).
- When sugarcane production is high, poverty in rural population is also very low.
- Sugarcane helps in reducing the poverty in rural population of the country.

CONCLUSION

It is interesting to note that districts with high spread cane area and high total production of cane are very powerful in

Table 1 Gross Domestic Product by important crops in India during 2014-15 at current prices

Crop	In agriculture (%)	In overall economic activity(%)	Area under crops (in million hectare)	Percentage of crop to gross cropped area
Paddy	15.04	2.01	44.11	21.96
Wheat	8.44	1.13	31.50	15.66
Cotton	4.62	0.62	11.96	5.95
Sugarcane	5.11	0.69	5.14	2.56

Table 2 Sugarcane area, production and yield in different class interval of sugarcane spread

Percentage of sugarcane area to net sown area in a district – Spread Index	Districts	Area (hectare)	Production (tons)	Yield (t/ha)
> 40 (Very high)	9	1130018 (28.57)	71360092 (25.79)	63.15
20– 40 (High)	12	823010 (20.81)	50513410 (18.26)	61.38
10 – 20 (Spread index)	22	991321 (25.06)	83733699 (30.27)	84.47
5 – 10 (Low)	29	524994 (13.27)	37460289 (13.54)	71.35
1 – 5 (Very low)	80	485773 (12.28)	33581530 (12.14)	69.13
Total	152	3955116 100	276649020 (100)	69.95

Table 3 Distribution of high priority forty three important sugarcane growing districts in different states of India

Spread index	State Represented	District Represented
> 40 (Very High)	Uttar Pradesh	Bagpat , Bijnor, J.B.Phule Nagar, Kheri, Meerut, Muzaffarnagar, Saharanpur
	Uttarakhand	Haridwar, Udham Singh Nagar
	Bihar	West Champaran
	Gujarat	Surat
20 – 40 (High)	Haryana	Yamuna Nagar
	Maharashtra	Kolhapur
	Uttar Pradesh	Balrampur, Bareilly, Ghaziabad, Gonda, Kushi Nagar, Moradabad, Pilibhit, Sitapur
	Andhra Pradesh	Visakhapatnam
	Bihar	Gopalganj
10 – 20 (Medium)	Gujarat	Navsari
	Uttarakhand	Dehradun
	Karnataka	Bagalkote, Belgaum, Mandya
	Maharashtra	Pune, Sangli, Satara, Solapur
	Tamil Nadu	Cuddalore, Dharmapuri, Erode, Namakkal, Tiruvannmalai, Villupuram
	Uttar Pradesh	Basti, Bullandshahar, Faizabad, Rampur, Shahjahanpur

Table 4 Cane productivity and rural poor population in India

Sugarcane spread (%)	Cane Yield (t/ha)	*Rural poor (%)	*Av. Prod./ ha (Rs.)	*No. of Ag. Worker/ KM^2	*Net sown area (1000 ha)	*Crop Intensity (%)
> 40	63.1	15.91	64231	186	2074	151
20 – 40	61.3	18.04	44486	221	3461	149
10 – 20	84.4	15.13	35907	257	7723	132
5 – 10	71.3	22.29	33715	227	7998	137
1 – 5	69.1	22.40	31842	231	20735	138
Total	69.9	20.79	35704	231	41991	138

*Source of the data : Chand, R., Garg, S. & Pandey, L. (2009): Regional Variations in Agricultural Productivity A District Level Study, *Discussion Paper NPP 01/2009.* ICAR-National Centre for Agricultural Economics and Policy Research, New Delhi.

reducing poverty in rural population of India. The resource poor type of agriculture is being practiced in majority of cases. About 54.44% of the total sugarcane area in the country is owned by 81.82% of marginal and small farmers. The resource poor small-farmers function differently than the resource rich large-farmers. The determinants of the appropriateness of a technology for small-farms are more complex than simple yield maximization per unit land, a common target for most agriculture researches. The technology heavily dependent on purchased inputs and sensitive to environmental variations will not be sustainable on small-farms. Therefore, there exists a wide technology gap. When sugarcane spread is >40 %, average productivity Rs./ha is >Rs.64231.00 and crop intensity is >151 % in sugarcane growing districts, then poverty is low (<15.91%) in rural population of India.When sugarcane spread is <5 %, average productivity Rs./ha is <Rs.31842.00 and crop intensity is <138 % in sugarcane growing districts, then poverty is high (>22.4%) in rural population of India. Whenever the policies are farmed for 5.568 million sugarcane cultivators/ farmers and 6.769 sugarcane labourers (total of about 12.337 million sugarcane workers), 43 high cane spread districts should be given greater thrust on technology development and extension activities. However other cane producing districts (109) also need location specific attention for improving overall cane productivity and quality. It would be more logical to concentrate our research and development programme for increasing cane productivity in the sugarcane districts with high and very high spread index as, such districts contribute more to acreage and cane production.

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Indian Journal of Sugarcane Technology **31(02)**: 46-49, December 2016

Growth pattern and sugar yield of sugarcane varieties as influenced by different fertility levels under upland rainfed condition

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ABSTRACT

A field experiment was conducted during spring season of 2015-16 at Sugarcane Research Institute, DRPCAU, Pusa, Bihar to study the effect of NPK levels on growth, quality and sugar yield of sugarcane varieties under upland rainfed conditions. Varieties had significant variation in growth attributes of sugarcane. Higher germination count was recorded with 'BO 153' which was followed by 'CoLk 94184' at both the stages. Experimental data indicated that variety 'BO 153' produced significantly higher plant population at all the stages of growth. Variety 'BO 153' recorded significantly higher LAI at both the stages. 'BO 139' gave taller plants at all the stages of growth. Similarly, thicker canes (2.44 cm) with maximum single cane weight (812 g) and number of nodes/cane (28.5) were also obtained with 'BO 139'. The maximum brix (21.60%), pol (18.34%), juice recovery (64.2%) and minimum fibre (11.28%) per cent were computed in variety 'CoP 9301'. 'BO 153' recorded the maximum sugar yield (8.10 t/ha) and it was superior over 'BO 130' and 'CoP 9301' with 8.0 and 26.6% more sugar yield, respectively. Similarly, 'BO 153' recorded significantly higher cane yield when compared with 'BO 139' and 'CoP 9301'. Among NPK levels, 100% recommended dose of NPK being at par with 75% recommended dose of NPK gave higher plant population, LAI and plant height at all the stages of growth except plant height at 210 DAP where with each successive increase in NPK level plant height increased significantly. The highest tiller mortality (26.9%) was noticed at 50% NPK level and minimum (23.9%) at 100% recommended dose of NPK. Application of 75% recommended dose of NPK significantly improved the length of internodes (8.82 cm), brix (20.54%), pol (17.98%) and CCS percentage (12.38%) of sugarcane. The fibre per cent cane responded significantly up to 100% recommended dose of NPK. The maximum sugar (8.01 t/ha) and cane yield (64.1 t/ha) were also obtained with application of 100% recommended dose of NPK. However, the differences between 75 and 100 % recommended dose of NPK were not significant.

Key words: Early variety, NPK levels, Quality, Sugar yield, Upland rainfed sugarcane.

Productivity of sugarcane is governed by soil type, planting season, agronomic practices, variety and its proper nutrition. Sugarcane grown under rainfed conditions are prone to water stress during pre-monsoon period that leads to reduced tiller formation, due to rapid loss of soil moisture and development of mechanical resistance in soil to root penetration. The lack of soil moisture during formative phase results in lower fertilizer use efficiency, thus reducing its growth and development. In such a situation stress tolerant variety provides better options to harvest good crop, although, its actual productivity under stress condition is low compared to potential productivity. Identification of suitable variety for upland rainfed conditions plays an important role in enhancing sugarcane productivity under such areas. Besides variety, other important factor for stepping up the productivity of upland rainfed sugarcane is nutrient management especially NPK (Singh *et al.* 2008). Higher sugarcane productivity can be maintained by judicious use of nutrients. However, lower input use efficiency due to lack of appropriate moisture regime in root zone of sugarcane is fate of upland rainfed conditions. Earlier studies showed variable response of the varieties to level of nutrients due to differential genetic potentiality of the particular varieties (Sinha *et al.* 2005; Kumar *et al.* 2012). Therefore, the study was undertaken to assess the performance of different sugarcane varieties to different level of NPK in calcareous soil of Bihar.

MATERIALS AND METHODS

A field experiment was conducted during spring season of 2015-16 at Sugarcane Research Institute, DRPCAU, Pusa, Bihar. The experiment was laid out in factorial randomized block design keeping combinations of 5 early varieties ('BO 130', 'BO 139', 'BO 153', 'CoP 9301', and 'CoLk 94184') and 3 NPK levels (50, 75 and 100% of recommended dose) replicated thrice. The soil of the experimental site was sandy loam with pH 8.3, organic carbon 0.43%, available NP and K 215.3, 10.3 and 118.9 kg/ha, respectively. Planting of sugarcane was done during third week of February at 90 cm row distance. Farmyard manure @ 20 tonnes/ha was evenly spread and mixed thoroughly in soil at the time of field preparation. Fertilizers were applied in furrows at 15 cm depth and mixed with indigenous plough. Half of N and full dose of P and K as per treatments were applied as basal and remaining half N was top-dressed at the time of earthling-up. Urea, diammonium phosphate and muriate

1. Based on a part of M.Sc. Thesis of the first author submitted to DRPCAU, Pusa, Samastipur, Bihar during 2016 (Unpublished)

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of potash were used as sources of nitrogen, phosphorus and potassium, respectively. The recommended dose of NPK (100%) for normal condition was 150, 37.1 and 49.8 kg N-P-K/ ha. Total rainfall received during the crop growth period was 932.6 mm. All the recommended plant protection measures were adopted during the course of investigation. Crop was harvested on 28 January 2016. Observations for plant population, leaf area index, number of nodes/cane, length of internode, plant height and cane yield were recorded as per standard procedure. Cane juice was extracted with power crusher and juice quality was estimated as per method given by Spencer and Meade (1964).

RESULTS AND DISCUSSION

Germination

Germination counts were recorded at 30 and 45 days after planting (Table 1). Significant variation in germination was observed with the variety during both the stages. At 30 DAP, higher germination per cent was recorded in the variety 'BO 153' (27.8%) which was comparable to 'CoLk 94184' (25.9%). However, at 45 DAP higher germination percentage was recorded with 'BO 153' (35.7%) which was almost similar to 'CoLk 94184' (33.4%), 'CoP 9301' (32.8%) and 'BO 130' (32.7%). The significant improvement in germination percentage among the varieties was mainly due to variation in glucose concentration of setts at cellular level and temperature requirement of particular varieties. Similar results were reported by Singh *et al.* (2008) and Kumar *et al.* (2014). Germination percentage did not undergo significant changes due to NPK levels. However, the germination ranged between 22.7 and 24.6% at 30 DAP and, 30.6 and 32.3% at 45 DAP. The non-significant variation in germination percentage of sugarcane due to NPK level might be due to absence of absorbing as well as assimilatory organs of sett at germinating stage. Wains *et al.* (2012) also obtained non-significant effect of nutrients on germination percentage.

Plant population and mortality percentage of tillers

Observations on plant population were recorded at 60, 90 and 120 days after planting. The results showed remarkable variation in plant population among the varieties (Table 1). Significantly higher plant population was recorded with the variety 'BO 153' followed by 'CoLk 94184' and 'BO 130' at all the stages of growth. The varietal difference in plant population might be due to inherent capacity of the varieties to contribute differently on tiller production. The results are in conformity with the findings of Vasantha *et al.* (2005).

The period of initial profuse tillering phase in sugarcane is followed by a wave of tiller mortality. It can be attributed to inter-tiller and inter-clump competition for micro-climate within crop canopy and tiller mortality is just reverse of emergence *i.e.*, the last emerged tiller dies first. In the present study, mortality of tillers tended to increase with increase in plant population among the varieties (Table 1). The significantly higher tillers mortality (30.8%) was observed with the variety 'BO 153'. However, the lowest tillers mortality (17.9%) of 'BO 139' was mainly due to formation of least tillers among the varieties and, availability of more nutrients, space and sunlight per tillers in unit area of land.

The plant population exhibited variable response to applied NPK (Table 1). The plant population of sugarcane at all the stages increased significantly up to 75% recommended dose of NPK indicating that crop required only 75% recommended dose of NPK under upland rainfed situations. The similar plant population at 75 and 100% recommended dose of NPK

Table 1 Effect of varieties and NPK levels on germination, plant population, tiller mortality, LAI, number of nodes/cane and length of internode in sugarcane

Treatment	Germination (%)		Plant population ($x10^3$/ha)			Tiller mortality (%)	LAI		Number of nodes /cane	Length of internode (cm)
	30 DAP	45 DAP	60 DAP	90 DAP	120 DAP		180 DAP	240 DAP		
Variety										
'BO 130'	24.7	32.7	76.8	116.3	124.5	25.9	3.11	2.97	28.3	7.85
'BO 139'	16.5	23.2	39.3	74.7	82.6	17.9	3.04	2.65	28.5	9.27
'BO 153'	27.8	35.7	91.2	129.4	139.7	30.8	3.55	3.46	25.8	9.97
'CoP 9301'	23.6	32.8	65.1	103.2	112.4	24.8	2.86	2.44	26.0	6.90
'CoLk 94184'	25.9	33.4	77.6	116.4	125.8	26.5	3.08	2.92	27.1	9.35
SEm (±)	0.86	1.23	2.64	3.90	3.87	0.91	0.114	0.110	0.69	0.242
CD (P=0.05)	2.5	3.6	7.6	11.3	11.2	2.63	0.33	0.32	2.0	0.70
NPK level (% recommended dose)										
50	22.7	31.8	61.8	100.5	108.8	26.9	2.90	2.61	27.7	8.24
75	24.6	32.3	71.3	109.6	118.3	24.7	3.21	2.98	26.9	8.82
100	23.8	30.6	76.9	113.9	123.9	23.9	3.28	3.08	26.9	8.93
SEm (±)	0.66	0.95	2.04	3.02	3.00	0.70	0.088	0.086	0.54	0.187
CD (P=0.05)	NS	NS	5.9	8.8	8.7	2.04	0.26	0.25	NS	0.54

probably be due to that lower moisture availability under upland rainfed conditions at formative stage might affect the nutrient supply as well as its adequacy in soil at higher level of NPK. The results are in accordance to the findings of Shankar (2015).

Leaf area index

Among the varieties, 'BO 153' recorded significantly higher values of LAI (3.55 and 3.46) over rest of the varieties at 180 and 240 DAP, respectively. The higher plant population in this variety at both the stages of growth might be responsible for greater LAI. Similar findings were also reported by Singh *et al.* (2008) and Islam *et al.* (2009).

NPK levels significantly augmented the LAI of sugarcane at both the stages of leaf growth (Table 1). Application of 100% recommended dose of NPK gave the highest LAI which was on par with that at 75% recommended dose of NPK but both of these were significantly superior to 50% recommended dose of NPK. The increase in LAI at higher level of NPK may be attributed to enhanced tillers production and growth of cane under these treatments.

Plant height, number of nodes/cane and length of internode

In the present investigation, plant height was recorded at 150, 180, 210 and 240 DAP. The increase in per day plant height from 150 to 180, 180 to 210 and 210 to 240 DAP were 1.96, 1.35 and 0.78 cm respectively, indicating lower proportionate increase in plant height with the advancement of crop age (Table 2). Among tested varieties, 'BO 139' gave the highest plant height followed by 'BO 153' and 'CoLk 94184' at all the stages of growth. The minimum plant height at all the stages of growth was recorded due to the variety 'CoP 9301'. The variations in plant height among the varieties might be attributed to variation in partitioning of photosynthates by different varieties. Similar variation was also reported by Meena *et al.* (2013). A perusal of the data presented in Table 1 revealed that the variety 'BO 139' recorded significantly higher number of nodes (28.5 nodes/cane) than the varieties 'CoP 9301' (26.0 nodes/cane) and 'BO 153' (25.8 nodes/cane) but was at par to rest of the varieties. However, the variety 'BO 153' produced significantly higher length of internodes (9.97 cm) than the variety 'CoP 9301' (6.90 cm) and 'BO 130' (7.85 cm).

Increasing NPK levels from 50 to 75% recommended dose of NPK significantly increased periodic plant height and length of internodes. However, further increase in NPK level to 100% of recommended dose did not increase plant height and length of internodes. This may be due to optimal supply of nutrients to the sugarcane crop upon use of 75% recommended dose of NPK under upland rainfed situations, thereby resulting in better crop growth and development of crop.

Quality

Quality constraints of sugarcane such as brix, pol, purity, fibre and juice recovery per cent (Table 2) were significantly influenced by different varieties. Among the varieties, 'CoP 9301' gave significantly higher brix percentage (21.60%) over rest of the varieties, followed by 'BO 139' (20.67%), and 'CoLk 94184' (20.62%). Similarly, significantly higher pol percentage (18.34%) was obtained with the variety 'CoP 9301'. However, the difference between 'CoP 9301' and 'BO 139' were not significant. Improvement in brix and pol percentage in 'CoP 9301' may be due to its genetic potential compared to other varieties. Chakrawal and Kumar (2014) also reported significant improvement in brix and pol percent juice due to different varieties.

Table 2 Effect of different varieties and NPK levels on plant height, quality and sugar yield of sugarcane

Treatment	Plant height (cm)				Quality						Sugar yield (t/ha)	Cane yield (t/ha)
	150 DAP	180 DAP	210 DAP	240 DAP	Brix (%)	Pol (%)	Purity (%)	Fibre (%)	CCS (%)	Juice recovery (%)		
Variety												
'BO 130'	124.7	179.9	225.6	244.1	20.11	17.79	88.46	12.59	12.31	60.4	7.50	60.8
'BO 139'	157.9	218.9	262.9	291.3	20.67	18.00	87.10	14.58	12.36	61.6	6.71	54.3
'BO 153'	130.6	197.4	236.4	261.2	19.24	17.45	90.69	13.71	12.22	60.1	8.10	66.1
'CoP 9301'	115.8	161.2	195.3	217.9	21.60	18.34	84.94	11.28	12.44	64.2	6.40	51.4
'CoLk 94184'	126.9	192.4	232.3	255.6	20.62	17.87	86.66	15.82	12.24	60.5	7.37	60.1
SEm (±)	4.37	6.00	8.02	8.83	0.142	0.130	0.305	0.098	0.099	1.13	0.281	2.24
CD (P=0.05)	12.6	17.4	23.2	25.6	0.41	0.38	0.88	0.28	NS	3.3	0.81	6.5
NPK level (% recommended dose)												
50	121.7	177.6	212.7	233.2	20.06	17.54	87.50	14.20	12.07	59.3	6.20	51.5
75	133.6	192.6	233.6	257.3	20.54	17.98	87.62	13.48	12.38	61.7	7.43	60.1
100	138.2	199.7	245.2	271.6	20.74	18.15	87.59	13.11	12.49	63.0	8.01	64.1
SEm (±)	3.38	4.65	6.21	6.84	0.110	0.101	0.236	0.076	0.076	0.87	0.215	1.74
CD (P=0.05)	9.8	13.5	18.0	19.8	0.32	0.29	NS	0.22	0.22	2.5	0.63	5.0

The variety 'BO 153' recorded significantly higher purity percentage (90.69%), followed by 'BO 130' (88.46%) and 'BO 139' (87.10%). Fibre per cent cane, which is related to quality of sugarcane, was found to be significantly affected by varieties. The lowest fibre content of 11.28% was present in the variety 'CoP 9301', which was significantly lower than other varieties. Since the brix and pol per cent was higher in the variety 'CoP 9301', the significant reduction in fibre per cent of cane was obvious. Almost similar trend as of brix and pol per cent was observed in juice recovery percentage too (Table 2). The highest juice recovery (64.2%) was recorded with 'CoP 9301' which was statistically comparable to 'BO 139' and significantly superior over other varieties. This may be due to lowest fibre content of this variety. The results corroborate the findings of Chakrawal and Kumar (2014).

Appreciable improvement in quality parameters of sugarcane was noted due to varying NPK level (Table 2). Significant increase in brix, pol and CCS per cent was observed with increase in level of NPK upto 75% recommended dose. However, there was no significant difference in brix, pol and CCS per cent between 75 and 100% recommended dose of NPK. The fibre per cent of sugarcane decreased significantly with each successive rise in NPK level from 50 to 100% of recommended dose. Kumar *et al.* (2014) also reported significant reduction in fibre content of sugarcane with increasing level of NPK.

Significant improvement in juice recovery was observed up to 75% recommended dose of NPK. However, at higher level *i.e.,* 100% recommended dose of NPK, the difference in juice recovery per cent was not significant compared to that at 75% recommended dose of NPK. The observations of present study are in line with the findings of Shankar (2015).

Sugar and cane yield

Among the varieties, 'BO 153' gave significantly higher sugar (8.10 t/ha) and cane yield (66.1 t/ha). However, differences in sugar and cane yield between 'BO 153', 'BO 130' and 'CoLk 94184' were non-significant. This was because of the fact that sugar yield is a function of cane yield and CCS per cent, thus the increase in all the related quality traits and cane yield brought significant variation in sugar yield. Similar results were also reported by Kumar *et al.* (2012). NPK levels caused significant impact on sugar and cane yield (Table 2). A significant increase in sugar and cane yield due to NPK level was recorded up to 75% of recommended dose. However, further increase in NPK level from 75 to 100% recommended dose did not show significant variation. No marked response of NPK beyond 75% of recommended dose might be attributed to nutrient imbalance and consequent metabolic disturbances under stress situations. The results are in close conformity with that of Raskar *et al.* (2011).

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Indian Journal of Sugarcane Technology **31(02)**: 50-54, December 2016

'CoP 09437'- A high yielding mid-late maturing sugarcane variety identified for commercial cultivation in North Central and North Eastern Zones of India

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ABSTRACT

A high yielding mid-late maturing sugarcane clone 'CoP 09437' was developed from 'BO91' GC at Sugarcane Research Institute, DRPCAU, Pusa. The genotype was initially selected from seedling population and evaluated for yield and quality parameters in different clonal generations. The clone was accepted for multi-location testing under AICRP(S) trials of North Central and North Eastern Zones of India. It was first evaluated under Initial Varietal Trial for one year and then under Advance Varietal Trial for two plant and one ratoon crops as per the technical programme during 2012-2015. Observations were recorded for cane yield, and its component traits, quality traits and resistance/tolerance to diseases and insect-pests. The clone 'CoP 09437' exhibited an average cane yield of 77.68 t/ha which was 15.37%, 17.66% and 18.13% higher than the standard varieties 'CoP 9301', 'BO 91' and 'CoSe 01034', respectively, while it was at par with 'BO 154' and 'CoP 2061'.This clone recorded 9.41 t/ha of CCS yield which was 12.69%, 22.85%, 17.48%, 5.97% and 5.49% higher than the standards 'CoP 9301', 'BO 91', 'CoSe 01034', 'BO 154' and 'CoP 2061', respectively. The clone CoP 09437 showed resistant reaction against red rot, smut and wilt under artificial inoculation and, low insect pest incidence was observed during the crop period. Based on its superiority over standard varieties in two plant and one ratoon crops for cane yield and juice quality traits evaluated in Advance Varietal Trials under AICRP(S), the clone 'CoP 09437' has been identified as a new variety of sugarcane by the Varietal Identification Committee for its release in North Central and North Eastern Zones of India. This sugarcane variety will play a pivotal role in improving the sugarcane productivity as well as sugar recovery in this particular zone in near future.

Key words: CoP 09437, Mid-late variety, North Central Zone, North Eastern Zone, Sugarcane.

Productivity of sugarcane in Bihar has been low since last fifty years (approximately 30-50 t/ha) due to lack of stable and high yielding varieties. Sugarcane varietal improvement programme involves crossing among the desirable parents and selection and evaluation of clones for desirable traits. A large number of seedlings are raised from fluff obtained from the desired crosses. Initially, the clones are selected on the basis of HR brix and growth performance of individual plant. Further, these clones are evaluated for yield and quality parameters and also screened for resistance/tolerance to major diseases and insect pests. Sreenivasan and Bhagyalakshmi (1993) reported varietal improvement in sugarcane for increasing sugar production.

Variety is of cardinal importance in sugarcane cultivation. It should fulfill not only the requirements of cane in the early and mid late seasons but also ensure high cane and sugar yield under varied climatic situations. It should be free from major diseases and insect pests which adversely affect cane yield as well as sugar recovery. India is the major sugarcane growing country with production of about 346 million tons from 5.34 million hectares. Sugarcane is an important cash crop of sub-tropical India including Bihar, Eastern Uttar Pradesh, Assam and West Bengal. Presently in Bihar, sugarcane is being grown on about 2.98 lakh hectares area with total production of 149 lakh tons (2013-14) with an average cane productivity of 50 tons per hectare. Sugarcane productivity and sugar recovery both are lower in North Central and North Eastern Zones when compared with the national average. The major cause of the poor performance in the zone is the non availability of high yielding and high sugar varieties recommended for this particular zone. For the development of suitable and stable cane varieties for North Central and North Eastern Zones, the varietal improvement programme is being carried out through All India Coordinated Research Project on Sugarcane at its different testing centres. The research efforts were made to identify high yielding sugarcane varieties coupled with high sugar and resistance/ tolerance to major diseases and insect pests prevalent under varying ecological situations of the zone. Concerted efforts by the sugarcane breeders led to the development of high yielding and high sugar variety 'CoP 09437' that may address the above mentioned problems of the zone to a great extent by improving the cane productivity and sugar recovery along with desired level of resistance to the diseases and pests. The result of carefully planned hybridization programme followed by rigorous clonal selection for high yield and sucrose percent in juice was reflected in the form of improved varieties released for cultivation in the area. As per the performance for yield

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attributes and juice quality 'CoP 09437' also showed superiority across the centres and over the years in AICRP(S) zonal trials. Thus, the variety 'CoP 09437' has been identified for cultivation in Bihar, Eastern Uttar Pradesh, Assam and West Bengal. This paper aims to discuss this newly released and identified variety 'CoP 09437', and its salient features (Table 1, Figs 1 and 2).

Table1 Distinguishing morphological features of identified sugarcane variety 'CoP 09437' as per DUS characteristics

S. No.	Character	State
1.	Plant growth habit	Erect
2.	Leaf sheath: Hairiness	Present
3.	Leaf sheath: Shape of ligule	Crescent
4.	Leaf sheath: Shape of inner auricle	Incipient
5.	Leaf sheath: Colour of dewlap	Dirty green
6.	Leaf blade: Curvature	Arched
7.	Leaf blade: Width	Medium
8.	Plant: Adherence of leaf sheath	Semi clasping
9.	Internode: Colour (not exposed to sun)	Light green
10.	Internode: Colour (exposed to sun)	Green
11.	Internode: Diameter	Medium
12.	Internode: Shape	Cylindrical
13.	Internode: Zigzag alignment	Absent
14.	Internode: Growth crack (split)	Absent
15.	Internode : Rind surface appearance	Smooth
16.	Internode: Waxiness	Low
17.	Node: Shape of bud	Oval
18.	Node: Size of bud (measured from base of bud to the tip)	Medium
19.	Node: Bud groove	Absent
20.	Node: Bud cushion (space between bud base and leaf scar)	Absent
21.	Node: Bud tip in relation to growth ring	Touch growth ring
22.	Node: Prominence of growth ring	Weak (not Swollen)
23.	Node: Width of root band (opposite to bud)	Medium
24.	Internode Cross section	Oval
25.	Internode: Pithiness	Present
26.	Plant: Number of millable canes (NMC) per stool	High
27.	Plant: Cane height	Medium

Fig 1. Internodes, bud shape and leaf carriage of 'CoP 09437'

Fig 2. Field view of 'CoP 09437'

MATERIALS AND METHODS

The fluff of 'BO 91' GC was collected from National Hybridization Garden, Sugarcane Breeding Institute, Coimbatore. The seedlings from the fluff of this general cross were raised at Sugarcane Research Institute, DRPCAU, Pusa, Bihar and evaluated under field condition. On the basis of HR brix and growth performance of individual plants, number of promising clones were selected in the seedling populations. Further, these clones were evaluated under different clonal generations for yield and quality parameters as well as for resistance to disease and insect pests. The clone 'CoX 01357' was selected and identified as mid-late maturing genotype and proposed for multi-location testing. The said clone was accepted for the evaluation in multi-location trials of North Central and North Eastern zone of AICRP(S) during 2009 and renamed as 'CoP 09437'. Testing of this clone was started during 2012-13 in Initial Varietal Trial under NC & NE zone at all the centres. On the basis of performance in IVT, the clone was promoted to Advanced Varietal Trial and evaluated for yield and quality parameters during 2013-2015. These trials were planted in Randomized Block Design with four replications and all the package and practices for raising good crops were followed at all the locations as per the technical programme (Patel and Patel 2014). Observations were recorded on five randomly selected plants for cane yield and yield attributing characters and the red rot score (0-9 scale) was also given after splitting of five randomly selected plants of each genotype under artificially inoculated condition. The reaction to red rot, wilt, smut and insect pests were also observed in natural field condition. Juice quality analysis was carried out at10 and 12 months stage in plant crop and at 9 and 11 months stage in ratoon crop as per standard procedures (Meade and Chen 1971). The observations on yield and its component traits were observed as per standard procedure suggested by Dutt *et al.* (1947) at 12 months crop stage. The number of millable canes, cane weight and cane height were reported to be yield contributing components (Mariotti 1987).

RESULTS AND DISCUSSION

Cane and sugar yield

'CoP 09437' showed consistence performance for cane and sugar yield in plant and ratoon crops across all the testing centres over the years. It recorded 9.41 t/ha commercial cane sugar yield which was 12.69%, 22.85%,17.48%, 5.97% and 5.49% higher than the checks 'CoP 9301' , 'BO 91', 'CoSe 01034', 'BO 154' and 'CoP 2061', respectively (Table 2).

The average cane yield of 'CoP 09437' was 77.68 t/ha and showed an improvement of 15.37.1%, 17.66% and 18.13% over the checks 'CoP 9301' (69.13 t/ha), 'BO 91' (65.02 t/ha) and 'CoSe 01034' (62.58 t/ha), respectively. 'CoSe 96436', 'BO 146', 'CoP 2061' and 'CoPb 08212' had also shown similar patterns of cane and sugar yield for their identification and release as sugarcane varieties, (Singh *et al.* 2001; Pandey *et al.* 2009; Kumar *et al.* 2015 and Sanghera *et al.* 2016).

Performance of yield components

'CoP 09437' showed very good germination and higher number of tillers. Perusal of Table 3 indicates that it had higher average number of millable canes (1, 20,080/ha) than the standard varieties. It recorded mean single cane weight of 0.89 kg which was higher than 'BO 91'(0.73 kg.) and 'CoP 9301'(0.73 kg.). Higher cane thickness was also recorded for 'CoP 09437' (2.33 cm) followed by 'CoP 9301' (2.25cm) and 'BO 91' (2.06 cm). Mean cane length of 'CoP 09437' was about 238.77 which was higher than 'BO 91'(234.10cm) and 'CoP 9301' (229.50cm). Similar results were also reported by Singh *et al.* (2001) for 'CoSe 96436', Pandey *et al.* (2009) for 'BO 146', Kumar *et al.* (2015) for 'CoP 2061' and Sanghera *et al.* (2016) for 'CoPb 08212'.

Performance of juice quality traits

Perusal of Table 3 indicates that 'CoP 09437' recorded higher sucrose percent in juice at harvest (17.60%) when compared with all the checks except 'CoP 9301' (18.22%). Similarly, 'CoP 09437' showed higher purity % in juice (88.41%) than all the checks. The pol in cane of 'CoP 09437' was about 13.13 %

Table 2 Performance of 'CoP 09437' in zonal varietal trials of North Central and North Eastern Zones under AICRP(S)

S. No.	Yield and juice quality traits	Checks					
		'CoP 09437'	'CoP 9301'	'BO 91'	'CoSe 01434'	'BO 154'	'CoP 2061'
1.	Commercial cane sugar yield(t/ha)	**9.41**	**8.35**	**7.66**	**8.01**	**8.88**	**8.92**
	Plant-I (2013-14)	9.76	8.56	8.12	8.53	9.40	8.75
	Plant –II (2014-15)	9.60	8.40	7.62	8.24	9.11	9.48
	Ratoon (2014-15)	8.86	8.09	7.25	7.26	8.20	8.54
2.	Cane yield (t/ha)	**77.68**	**69.13**	**66.02**	**65.76**	**75.74**	**74.45**
	Plant-I (2013-14)	81.38	72.07	69.53	66.75	80.00	73.55
	Plant –II (2014-15)	79.22	69.63	65.05	68.43	78.06	78.01
	Ratoon (2014-15)	72.44	65.69	63.49	62.10	69.17	71.79
3.	Sucrose percent in juice at harvest	**17.60**	**18.22**	**17.02**	**17.52**	**17.51**	**17.35**
	Plant-I (2013-14)	17.71	18.62	17.41	18.24	17.25	17.33
	Plant –II (2014-15)	17.58	17.76	17.03	17.22	17.32	17.74
	Ratoon (2014-15)	17.51	18.23	16.61	17.10	16.91	16.97
4.	Pol in cane at harvest (%)	**13.13**	**14.21**	**12.50**	**-**	**12.86**	**13.85**
	Plant-I (2013-14)	13.19	15.02	13.33	-	13.57	-
	Plant –II (2014-15)	12.93	13.54	12.23	-	12.66	13.89
	Ratoon (2014-15)	13.22	14.11	12.12	-	12.52	13.81

Table 3 Performance of 'CoP 09437' in zonal varietal trials of North Central and North Eastern Zones under AICRP(S) and percentage improvement over checks

'CoP 09437' and its percentage improvement over checks.	NMC (000'/ha)	Purity % in juice at 12th month	Extraction % at harvest	Cane diameter (cm) at harvest	Cane length (cm) at harvest	Single cane weight (kg) at harvest
'CoP 09437'	120.08	88.41	57.24	**2.33**	**238.77**	**0.89**
Checks						
'BO 91'	115.76	87.64	57.16	**2.06**	**234.10**	0.73
'CoP 9301'	112.03	87.44	58.32	**2.25**	**229.50**	0.73
% improvement over 'BO 91'	3.73	0.88	0.14	**13.11**	1.99	21.92
% improvement over 'CoP 9301'	7.19	1.11	-1.85	**3.56**	4.04	21.92

which was lower than the best check 'CoP 9301' (14.21%). In, 'CoP 09437', juice extraction percentage at harvest was about 57.24% which was at par with all the checks indicating its excellent crushing quality. The same results for juice quality parameters were also reported by other workers. (Singh *et al.* 2001; Pandey *et al.* 2009, Kumar *et al.* 2015 and Sanghera *et al.* 2016)

Performance of ratoon crop

The data presented in Table 2 indicates that cane and sugar yields of 'CoP 09437' were higher than all the checks in ratoon crop. 'CoP 09437' recorded 72.44 t/ha of cane yield in ratoon crop which was 10.27 %, 14.10% and 16.65% higher than 'BO 91', 'CoP 9301' and 'CoSe 01034', respectively. The CCS yield of 'CoP 09437' was also higher than 'BO 91', 'CoP 9301', 'CoSe 01034', 'BO 154' and 'CoP 2016' in ratoon crop. 'CoP 09437' recorded 17.51% sucrose percent in juice at harvest in ratoon crop which was higher than all the checks except 'CoP 9301' (18.23%). Better performance of other yield component traits *viz.*, higher number of tillers, higher NMCs, higher single cane weight, greater cane thickness and more cane height in ratoon crop indicated very good ratooning ability of 'CoP 09437' when compared to all the checks.

Distinguishing morphological features

As per the DUS testing characters, the clone 'CoP 09437' can be identified by its erect stool habit, medium thick, straight alignment, cylindrical green (exposed) and light green (unexposed) internodes without ivory marks while weather marks present and pith negligible, slightly swollen node, small ovate bud, medium broad leaves, green leaf sheath with purple blotch, loose clasping, incipient auricles, medium width of leaves with arched curvature (Fig 1). Table 1 showed the information about distinguishing morphological features of identified sugarcane variety 'CoP 09437'.

Reaction to diseases

A perusal of Table 4, indicates that 'CoP 09437' showed resistant reaction for red rot and smut diseases during the course of testing over the years. However, it showed moderately resistant reaction for wilt only in AVT I plant otherwise it showed resistant reaction in IVT and AVT II plant. It indicated that disease resistance ability might have come from its parent 'BO 91' which is a well known source of resistance genes for important sugarcane diseases.

Reaction to insect pests

An overview given in Table 5 indicates that low incidences of shoot borer, stalk borer and top borer appeared in 'CoP 09437' during the evaluation under natural condition. Percentage incidence based on dead hart was recorded in post germination phase at 30 days interval up to 120 days after planting and was found least susceptible. Incidence of *Pyrilla*, black bug and whitefly was also in traces. It shows that 'CoP 09437' has the ability to tolerate the major insect pests of sugarcane.

Table 4 Disease reaction of 'CoP 09437' and checks evaluated during 2012-2015

Disease	Trial-Year wise	'CoP 09437'	'CoP 9301'	'BO 91'	'CoSe 01434'	'BO 154'	'CoP 2061'
Red rot	IVT (2012-13)	R	MR	R	MR	R	R
	AVT-I (2013-14)	R	R	MR	MR	R	R
	AVT-II (2014-15)	R	MR	R	MR	R	R
Smut	IVT (2012-13)	R	R	R	R	MR	R
	AVT-I (2013-14)	R	R	R	R	MR	R
	AVT-II (2014-15)	R	R	R	R	R	R
Wilt	IVT (2012-13)	R	MR	R	R	R	R
	AVT-I (2013-14)	MR	MR	R	R	R	R
	AVT-II (2014-15)	R	MR	R	R	R	R

Table 5 Resistance/tolerance reaction to insect pests for the 'CoP 09437' and checks evaluated during 2012-2015

Insect-pests	Trial-Year wise	'CoP 09437'	'CoP 9301'	'BO 91'	'CoSe 01434'	'BO 154'	'CoP 2061'
Shoot borer	IVT (2012-13)	LS	LS	LS	LS	LS	LS
	AVT-I (2013-14)	LS	LS	LS	LS	LS	LS
	AVT-II (2014-15)	LS	LS	LS	LS	LS	LS
Stalk borer	IVT (2012-13)	LS	LS	LS	LS	LS	LS
	AVT-I (2013-14)	LS	LS	LS	LS	LS	LS
	AVT-II (2014-15)	LS	LS	LS	LS	LS	LS
Top borer	IVT (2012-13)	LS	LS	LS	LS	LS	LS
	AVT-I (2013-14)	LS	LS	LS	LS	LS	LS
	AVT-II (2014-15)	LS	LS	LS	LS	LS	LS

LS –Less susceptible (low incidences)

CONCLUSION

'CoP 09437' recorded better cane height, moderate single cane weight, thicker cane diameter, higher number of shoots and millable canes surpassing most of the checks with high tonnage and sugar yield. The variety was found resistant to red rot disease, wilt and smut under field conditions. The ability of red rot resistance was contributed by the parent 'BO 91'. This variety will play a great role in boosting the productivity of sugarcane of this area and also enhance the recovery of sugarcane in different sugar factories by crushing it for a long period *i.e.* from January to April. It remains green till harvest which is another advantage to use its top as a fodder. The variety 'CoP 09437' was identified by the Varietal Identification Committee of AICRP(S) for its notification and release in North Central and North Eastern Zones comprising Eastern Uttar Pradesh, Bihar, Jharkhand, West Bengal and Assam. It is expected that the variety 'CoP 09437' will be a better option for high tonnage under North Central and North Eastern Zones of India in coming years. The outcome will be helpful to sugarcane growers as well as sugar industry in improving the cane productivity and sugar recovery, respectively. It can also be utilized as a parents in the future crossing programmes for the development of improved sugarcane varieties.

ACKNOWLEDGEMENT

The authors are thankful to the Project Coordinator, AICRP(S) and Director Research, DRPCAU, Pusa for providing grant and facilities for research work. We also wish to acknowledge the help rendered by the Director, Sugarcane Breeding Institute, Coimbatore for hybridization programme and scientists of NHG, SBI, Coimbatore for proper fluff supply. Help by all the associated scientists of other centres of North Central & North Eastern Zones for evaluating the clone is gratefully acknowledged. The help and support in the development of this variety by all the scientists of S.R.I., Pusa are also duly acknowledged.

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Indian Journal of Sugarcane Technology **31(02)**: 55-60, December 2016

Effect of planting methods on growth, yield and quality of sugarcane in subtropical India

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ABSTRACT

A field experiment was conducted to study the effects of modified planting techniques. The investigation aimed at modulation of physicochemical rhizospheric environment for better soil-water-air relations, root proliferation, growth, yield and quality of sugarcane (*Saccharum* spp. hybrid complex) in *Udic Ustochrept* soils of Lucknow located in subtropical India. Results revealed that the total porosity, infiltration rate and size of stable soil aggregates were improved significantly in ring-pit planting method and trench planting as compared to conventional planting methods while bulk density decreased. The higher root volume (55.7 cm^3), number of root hairs (812.7 $stool^{-1}$ cm^{-1}) and root biomass (5.81 t ha^{-1}) were found in ring pit method of planting. The 'feeding zone' of roots in ring pit planting was greater (0.18 m^3 $stool^{-1}$) and the 'root intensity' (2587 g m^{-3}) and 'root efficiency' (shoot: root ratio 5.42) was greater in trench planting. Significantly higher germination (49.57%), cane length (252.85 cm), diameter (2.93 cm), cane weight (1.30 kg), cane yield (87.18 t ha^{-1}) and sugar yield (9.59 t ha^{-1}) were recorded in ring pit method followed by trench planting. Thus, ring-pit and trench planting methods apart from modulating sugarcane rhizosphere favourable in terms of improved physicochemical properties and root proliferation also boosted the cane productivity and its quality.

Keywords: Cane yield, Juice quality, Nutrient uptake, Planting methods, Root volume.

Sugarcane is a high biomass producing crop, requires huge root volume to sustain above ground biomass. Root development however, depends on the field management (Wu *et al*. 2005). Under conventional method of planting, sugarcane is planted by three bud cane setts in 10 cm deep furrows (Fig 1a). At the time of planting, fertilizers and manures are applied in the furrows beneath cane setts followed by covering of setts by soil. The sugarcane roots reach up to the 45 cm depth and supply nutrients to the plant. In this method of planting, on an average 60 t/ha yield is harvested (Yadav 1991). Population driven demand of sweeteners coupled with the expansion of sugar industries in India necessitated higher production of sugarcane in future. Considering low productivity of conventional methods, there was a need to develop a suitable method of planting by which higher yield can be obtained. Indian Institute of Sugarcane Research has developed ring-pit method for yield maximization (Singh *et al.* 1984). After ring- pit, trench method is also being used for increasing yield (Yadav 1991).

In rig-pit planting method, sugarcane is planted in a 45 cm deep circular pit having 75 cm diameter (O-shaped). Fifteen two bud setts are placed at bottom after applying manure in the pits. The setts are covered with 2.5 cm soil layer. The setts germinate and are allowed to grow in the pits. The pits are filled gradually by dug-up soil as the plant grows. In trench method of planting, setts are placed in 45 cm deep U-shaped furrows at a distance of 120 cm between two furrows (Figs 1b, c and d). The setts are placed after applying manures in the trenches up to 10 cm from the bottom by FYM mixed soil and covered with 2.5 cm soil layer. Trenches are filled by dug-up soil as the plant grows. As in latter two planting methods, soil is dug-up up to 45 cm depths and fertilizer is localized in pit-rings and trenches.

The objectives of the present study were to assess the effect of different planting methods on physicochemical properties, root proliferation, growth, yield and quality.

MATERIALS AND METHODS

The experimental site

A field experiment was conducted in three consecutive growing periods (2005-06, 2006-07 and 2007-08) at Research Farm of ICAR-Indian Institute of Sugarcane Research, Lucknow (26°50'N, 80°52'E and 111 m MSL) under sub-tropical India. The soil of the experimental site was categorized under group non-calcareous mixed hypothermic *Udic Ustochrept*, neutral in reaction (pH 7.5) with a bulk density (BD) of 1.42 Mg m^{-3}, soil aggregate (0.31 mm), an infiltration rate 3.65 mm h^{-1}, low in organic carbon (0.34 %) and available N (184.9 kg ha^{-1}), medium in available P (17.6 kg ha^{-1}) and K (195.5 kg ha^{-1}). Texture of experimental field was sandy loam (63% sand, 22% silt and 15 % clay) of Gangetic alluvial origin. The soil was about 2.0 meters deep, well drained and well leveled (slope < 1%). The climate location was semi-arid subtropical with dry hot summer (April to June) and cold winter (November to January). The average annual rainfall was 989 mm, of which and nearly 85% was received through south-west Monsoon from mid-June to September in 40-45 rainy days.

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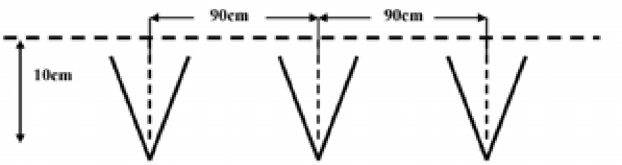

Fig 1a. 'V'shaped furrow

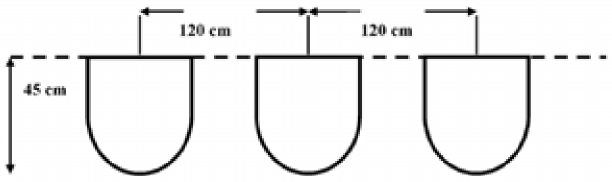

Fig 1b. 'U'shaped trenches

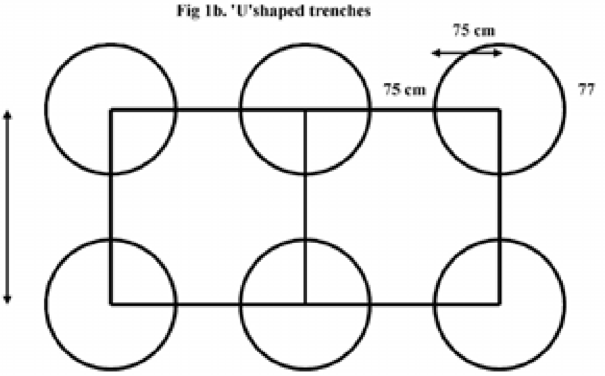

Fig 1c. 'O' shaped ring-pits

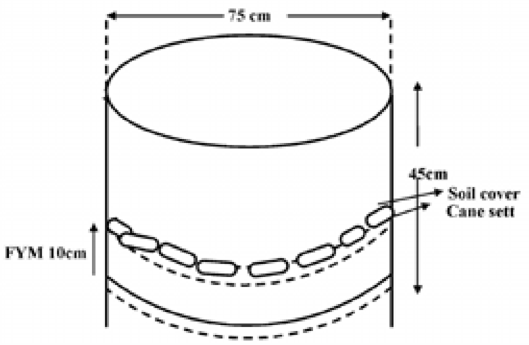

Fig 1 d. – Ring-pit planting

Treatment and crop culture

The experiment consisted of 4 sugarcane planting methods as treatments namely (i) conventional planting (CP) at 60 (CP-60) and 90 (CP-90) row spacing (ii) deep trenches planting (TP) at 120 cm apart, and (iii) ring-pit planting (RP). The experiment was conducted in a randomized block design with twelve replications. The plots were kept at 10 m x 10 m size and sugarcane variety 'CoSe 92423' was planted on 8th February 2005 and 10th February 2006 and 2007. For conventional flat planting, 10 cm deep furrows were opened at a distance of 60/ 90 cm by tractor drawn furrow opener and three bud cane setts were placed horizontally end to end in furrows. Under trench planting, trenches of 45 cm depth and 30 cm width were made by a tractor drawn trench maker developed by IISR, Lucknow. Two rows of sugarcane setts were planted on both sides of 30 cm bottom width trench at the same rate as the conventional planting. The trenches were covered with soil gradually. Planting in ring-pit was done by digging circular pits of 75 cm diameter and 45 cm depth, 120 cm apart from center to center of the pits, by a tractor drawn pit digger developed by IISR, Lucknow. The pits were refilled with mixture of loose soil and farm yard manure (FYM) to a depth of 10 cm. While planting, 24 two bud setts were placed in a hexagonal fashion and covered with soil to a thickness of 2.5 cm. The recommended rates of N: P: K for sugarcane was 150:60:60 kg ha-^{1}. The sources of nutrients applied were urea (46.6% N), diammonium phosphate (18% N and 46% P) and muriate of potash (60% K). Full amount of P and K fertilizers and one-third N were applied as basal dose beneath cane setts at the time of planting. Chlorpyriphos 20 EC @ 5 L ha^{-1} was sprinkled over setts before covering them with soil to safeguard against insect–pests. Remaining amount of the N was applied in two equal splits at 60 and 120 days after planting.

Six pre-monsoon irrigations were given to sugarcane in addition to a pre-planting. One post monsoon irrigation in September in first year and two irrigations in September and October in the second and third year were given. The crops were harvested manually in the last week of January in each year.

Soil and plant sampling and analyses

Initial soil samples were collected before commencement of the experiment in February 2005 for first crop cycle and in 2006 and 2007 for second and third crop cycles. Soil samples were collected from three depths (0-20, 20-40 and 40-60 cm) at four sites in the experimental field with the help of a core sampler. These samples were analyzed for physical properties (Singh 2001), organic carbon (Walkley and Black 1934), available N (alkaline $KMNO_4$ method), available P (0.5 M $NaHCO_3$, pH 8.5 extractable) as described by Olsen and Sommers (1982) and extractable K using NH_4OAC (1:6 soil: solution) following Page *et al*. (1982). The bulk density (BD) of the soil at different depths in the initial and final stages (post sugarcane 2006, 2007 and 2008) after crop harvest were measured. Texture analysis was done by international pipette method (Piper, 1966) and aggregate size distribution (wet sieving) as described by Yodor (1936). The pH was measured in 1:2 soil water suspensions. Infiltration was measured *in situ* using double ring in filtrometer (Bertrand 1965).

Three healthy clumps (stools) per treatments 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 root spread (vertical/horizontal) led to derivation of a cone shaped 'feeding zone' and was calculated by the volume of a cone represented as

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

(Where h = one way (halt 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:

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

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' was computed as:

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

Five millable canes (ripen canes ready to send to sugar mills) were randomly sampled for observations on cane yield attributes (length, girth and average cane weight) and juice quality parameters (^{0}brix, pol and purity). Juice purity and commercial cane sugar were calculated by the formulae as described by Gupta (1977):

Juice purity (%) = Sucrose (%) in juice/corrected brix x 100 (Eq. 4)

CCS (%) = {S-(B-5) x 0.4} x 0.73 (Eq. 5)

Where S is sucrose % in juice, and B is corrected brix (%) determined as per the method of Meade and Chen (1977). Results were statistically analyzed following the procedures of Cochran and Cox, (1957).

RESULTS AND DISCUSSION

Soil physical and chemical properties

Soil working for making pits/trenches brought a significant improvement in soil physical properties. Significant decrease in soil bulk density (BD) was recorded in ring-pit planting which was statistically at par with trench planting at 0-20 cm soil depth (Table 1). Soil bulk density was decreased in all the planting methods as compared to initial values at both the soil depths. Soil physical properties were not significantly improved in conventional planting.

The mean weight diameter (MWD) of the soil aggregates under ring pit planting and trench planting significantly increased compared to the conventional planting (Table 1). There was no change in total porosity of 0-20 cm soil layer; however, it was significantly increased in ring-pit planting at 20-40 cm soil layer.

The infiltration rate was increased significantly under trench planting method to the tune of 9.0% as compared to initial value 4.25 mm hr^{-1} and 6.6% to the conventional planting system. This treatment was however, statistically at par with ring–pit planting with corresponding increases of 6.4% and 4%. Soil organic carbon content remained unaffected from different planting methods (Table 1). However, significant increase in SOC was observed in ring-pit at 20-40 cm layer which was closely followed by trench planting. Post-harvest soil nutrients and pH values did not show any significant variation due to different treatments.

Maclean (1975) and Wood (1985) also reported significant differences in bulk density of surface and subsurface soils. The lower bulk density of soil in ring-pit planting system was due to greater biomass of the roots produced by sugarcane and their partial decomposition after harvest of the crop. Additional organic matter through root mass decreased the bulk density of soil directly by diluting the soil with less dense high volume material and also decreased the proportion of water stable aggregates. Moreover, deep tilling created pits with loose soil that also resulted in a decreased bulk density. Continuous cropping of sugarcane with mechanized operations causes soil compaction which is a major structural disorder in sugarcane fields. As soil is compacted, BD is increased resulting in reduction of proliferation and volume of roots. This leads to the decreased feeding zone for the roots. Root proliferation and extension of roots is restricted in compacted soils. Thus, compaction results in reduced aeration and restricted availability of water and nutrients.

Deep ploughing and localized application of FYM at the time of field preparation/digging in ring and trench planting

Table 1. Effect of planting methods on soil physical and chemical properties after harvest of sugarcane

Planting method	Bulk density (Mg m^{-3}) Soil depth (cm)		Total porosity (%) Soil depth (cm)		Infiltration rate (mm hr^{-1})	Soil aggregate (mwd) (mm)		Soil nutrient status (kg ha^{-1}) Soil depth 0-20 cm			Soil organic carbon (%) Soil depth (cm)		pH values	
	0-20	20-40	0-20	20-40		0-20	20-40	N	P	K	0-20	20-40	0-20	20-40
CP (60)	1.35	1.41	0.49	0.47	3.99	0.428	0.307	196.2	18.2	227.2	0.40	0.37	7.6	7.4
CP (90)	1.35	1.41	0.49	0.47	3.99	0.443	0.312	196.3	18.4	228.0	0.40	0.31	7.5	7.5
TP	1.32	1.37	0.50	0.48	4.25	0.457	0.332	197.1	19.1	230.9	0.43	0.39	7.4	7.5
RP	1.33	1.36	0.50	0.49	4.15	0.463	0.345	197.8	19.2	235.9	0.45	0.40	7.4	7.5
CD ($P<0.05$)	0.01	0.02	NS	0.01	0.18	0.026	0.022	NS	NS	NS	NS	0.06	-	-
Initial	1.38	1.46	0.48	0.45	3.90	0.362	0.251	193.6	19.2	209.7	0.37	0.29	7.6	7.5

helped in decreasing compaction and improving physical conditions of soil. Singh *et al.* (2007a) also reported improvement in porosity by incorporation of organic residues in the soil. The localized placement of FYM in ring and trench planting increased stable soil aggregates. Deep tilling along with application of FYM and decomposition of root biomass increased soil porosity (MacRae and Mehuys 1985). Further, this also increased organic matter content in 20-40 cm soil layer. FYM and root biomass together increased soil organic carbon content (Singh *et al.* 2007b). An increase in infiltration rate of soil was due to decreased bulk density and increased porosity in RP compared to CP. The maximum root spread in the RP might be due to greater nutrient availability in the ring-pits as a result of localized application of nutrients (Yadav 2004). Moreover, by digging the pits, the large volume of rhizospheric soil becomes porous and easily penetrable to roots. The vertical spread (root length) was positively correlated with air filled porosity indicating the importance of below ground air supply for crop production (Nixon and Simmonds 2004). The purpose of tillage is to prepare the soil with adequate physical conditions for plant growth (Martin-Rueda *et al.* 2007).

Rooting parameters

Ring-pit planting method recorded a higher root volume at all the crop growth stages (Table 2). At tillering and maturity stages, it produced significantly higher root volume than trench-planting and conventional planting methods. The increase in root volume under ring pit planting was by 32.8% as compared to conventinal planting and 10.0% over trench planting. The vertical and horizontal spreads of roots were found higher in ring-pit planting system, whereas data were statistically at par with trench planting as all the crop growth stages (Table 2). Vertical spread was 50.9% more in ring-pit as compared to the conventional planting and was statistically significant. Irrespective of the planting methods, larger vertical spread occurred at grand growth stage and remained constant up to the maturity stage. The highest root vertical spread was found at grand growth stage whereas the highest horizontal spread was found at maturity stage.

The root hair count per cm per stool indicated the root proliferation in the upper half of the root length at every growth stage (Table 3).The root hair count were recorded significantly higher in ring-pit planting at all the growth stages of crop. The root biomass at maximum tillering stage varied from 0.48 to 0.67 t ha^{-1}. The ring-pit planting method recorded significantly higher biomass accumulation by roots. The highest root biomass was recorded at grand growth stage and further declined slightly at maturity. The reduction in biomass at maturity might be due to partial decomposition of the dead root parts. The root biomass was statistically similar in ring-pit and trench planting at tillering, grand growth and at maturity stages.

The 'feeding zone' represents the volume of rhizosphere potentially available to a sugarcane plant to draw its nourishment. The 'feeding zone' (0.01 to 0.02 m^3 $stool^{-1}$) was found small at tillering stage in all the planting methods and the differences remained statistically not significant (Table 3). However, at grand growth and maturity stages, the 'feeding zone' of the roots expanded. Ring-pit planting method recorded a significantly larger 'feeding zone' (0.18 and 0.19 m^3 $stool^{-1}$) among the treatments at these stages. The conventional planting at 60 cm spacing with 0.05 m^3 $stool^{-1}$ feeding zone recorded 6313 g m^{-3} root intensity against merely 223 g m^{-3} from feeding zone of 0.18 m^3 $stool^{-1}$ in ring-pit planting system. Root intensity was significantly more in conventional planting compared to RP and TP.

Table 2 Effect of planting methods on volume and spread of roots at different growth stages of sugarcane

Planting method	Root volume (cm^3)			Root length (cm)					
				Vertical			Horizontal		
	Tillering	Grand growth	Maturity	Tillering	Grand growth	Maturity	Tillering	Grand growth	Maturity
CP (60)	5.41	46.4	36.8	11.80	49.1	48.0	24.07	31.0	32.0
CP (90)	4.99	46.7	35.8	10.92	50.0	46.2	28.14	37.8	41.5
TP	5.96	55.7	50.5	14.25	70.7	68.9	33.74	44.6	44.6
RP	6.73	61.6	56.1	16.01	74.1	72.9	37.99	48.0	50.2
CD (P<0.05)	0.74	7.69	3.68	3.76	12.64	5.48	4.36	5.67	8.21

Table 3 Effect of planting methods on root characteristics at different growth stages of sugarcane

Planting method	Root hairs (count $stool^{-1}$ cm^{-1} of root length)						Root biomass (t ha^{-1})			Feeding zone (m^3 $stool^{-1}$)			Root Intensity (g m^{-3})			Root efficiency (Shoot: root ratio)		
	Tillering		Grand growth		maturity													
	Upper half	Lower half	Upper half	Lower half	Upper half	Lower half	Tillering	Grand growth	Maturity	Tillering	Grand growth	Maturity	Tillering	Grand growth	Maturity	Tillering	Grand growth	Maturity
CP (60)	426.9	263.6	419.9	187.3	542.8	299.1	0.48	3.85	2.78	0.01	0.05	0.05	10877	6313	5952	11.91	5.51	10.70
CP (90)	468.6	311.4	427.7	194.4	586.6	351.9	0.44	3.62	2.69	0.01	0.08	0.08	8832	4007	3951	11.59	5.67	10.22
TP	657.6	482.8	531.6	297.2	654.1	373.6	0.55	5.00	3.86	0.02	0.15	0.14	5207	2587	2597	9.17	5.42	8.14
RP	812.7	613.4	663.4	421.9	764.5	565.5	0.67	5.81	4.21	0.02	0.18	0.19	3709	2239	2066	9.16	5.13	8.04
CD (P<0.05)	26.83	31.28	35.48	53.4	56.29	34.67	0.13	1.07	0.86	NS	0.12	0.03	108.6	115.6	176.4	1.24	NS	1.38

A direct relationship between shoot biomass to its root biomass was observed through 'root efficiency'. The treatments having higher shoot biomass to its roots recorded higher root efficiency. Root efficiency was significantly higher in the treatment of CP-60 (11.91) at tillering stage (Table 3). However, different treatments did not show significant variation in root efficiency. Increase in root biomass in RP is due to greater flux and availability of nutrients in close vicinity of absorption sites of roots. Moreover, loosening of soil provided congenial rhizospheric environments for profused growth of the roots in deep tillage planting methods as in ring pit & trench planting methods.

Growth and yield of sugarcane

Significantly higher germination (49.6%) was recorded in RP followed by TP. Significantly higher numbers of tillers were produced in CP at 60 cm row spacing in flat planting system, which was similar to TP. However, cane length (253.2 cm), cane girth (3.09 cm), individual cane weight (1.30 kg) and cane yield (87.6 t ha^{-1}) were significantly higher in RP. Though significantly larger numbers of millable canes were recorded with planting at 60 cm row spacing (Table 4), it could not contribute to yield due to less individual cane weight. The higher number of millable canes at high planting density with closer row spacing was also reported by Singh *et al*. (2005).

greater the soil cover over the sett, the greater the distance, which young shoot, has to travel in order to emerge out of the soil surface. As long as shoot has not reached the soil surface, it thrives at the expense of sett reserves owing to transience.

CONCLUSIONS

Sugarcane monoculture with mechanized field operations causes soil compaction and adversely affects soil-water relations, soil aeration, soil bulk density and root penetration. The research at Lucknow has developed modified planting techniques to overcome such problems and obtain optimum millable cane population with improved quality traits per unit area. Ring-pit planting is one semi-mechanized system in which the growth of the mother shoot is encouraged and that of tillers is suppressed. The planting systems involving soil working technique, modulated the rhizospheric environments e.g., chemical (221.7 kg N, 37.3 kg P and 188.3 kg K ha^{-1}), physical porosity of soil (BD: 1.33 Mg m^3 and IR: 4.15 mm/hr) root proliferation (Root volume 55.7 cc and root biomass 5.81 t/ha) and cane yield (87.18 t/ha). Similarly the deep trench planting (TP) also improved the productivity of sugarcane by improving the soil porosity, root intensity and root efficiency. Deep tillage along with a localized application of manure/fertilizer decreased the bulk density, increased infiltration rate and improved soil porosity. These in turn resulted in greater root proliferation, nutrient uptake and yield of cane and sugar in *Udic Ustochrept* soils of subtropical India. Trench planting, a fully mechanized method of planting sugarcane is the next best to ring-pit system.

Table 4. Effect of planting methods on sugarcane yield attributes, yield and juice quality

Planting method	*NMC (000 ha^{-1})	Cane Length (cm)	Cane Girth (cm)	Single Cane Weight (kg)	Cane Yield (tha^{-1})	^{0}Brix	Pol (%)	Purity (%)	CCS (%)	CCS (tha^{-1})
CP (60)	142.98	228.66	2.32	0.83	75.02	18.19	15.50	85.23	10.56	7.96
CP (90)	122.67	232.83	2.37	0.94	69.28	18.24	15.59	85.54	10.64	7.41
TP	135.53	237.92	2.43	1.13	79.28	18.24	15.63	85.66	10.64	8.47
RP	132.10	252.85	2.93	1.30	87.18	18.49	15.96	86.38	10.92	9.59
CD (P<0.05)	14.67	9.35	0.28	0.34	5.63	0.32	0.47	NS	0.28	0.73

*NMC= Number of Millable Canes

Juice quality and sugar yield

The juice quality parameters of cane *viz.* ^{0}brix, pol, purity and CCS% clearly indicate that quality parameters were significantly influenced by planting methods (Table 4). Ring-pit method recorded significantly higher ^{o}brix (18.49), pol% (15.96) and CCS% (10.92) over conventional planting. The sugar yield, a function of quantity and quality of cane produced was significantly higher (9.59 t ha^{-1}) in this planting method. Juice from sugarcane raised through RP was of better quality because only mother shoots were converted into millable canes.

Sugarcane is propagated by stalk setts having three buds. Bud germination is a key factor, as good germination means a good start of the crop which ensures adequate plant population. Lower germination percentage in flat planting both at 60 and 90 cm row spacings might be due to thick soil cover over the setts resulting into skimpy emergence. More so, the

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Indian Journal of Sugarcane Technology **31(02)**: 61-64, December 2016

Drought tolerance potential of promising sugarcane cultivars in western Uttar Pradesh

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ABSTRACT

Water requirement varies throughout the developing stages of sugarcane crop. For higher tillering and development of millable canes, there is a higher water requirement than during the maturation stage. Drought is one of the most frequent abiotic stresses limiting the productivity and geographical distribution of sugarcane. Drought tolerance is a very important factor considering the actual climate change scenario throughout the world. In subtropical region, water requirement of sugarcane ranges from 1500-1700 mm in a crop season. The use of drought tolerant genotypes is one of the important approaches for overcoming the effects of water stress. In order to identify drought tolerant genotypes for cultivation under drought prone areas in western U.P., ten elite sugarcane genotypes were evaluated for yield attributes and sucrose content at Sugarcane Research Centre, Muzaffarnagar (UP), during three consecutive years (2012-13 to 2014-15) in spring planting season under normal and drought conditions. Based on the pooled data of three years, effect of moisture stress on different attributes *viz.* shoot population, number of millable canes, yield (t/ha) and sucrose % in juice was found to be statistically significant. Varieties 'CoS 07250' and 'CoSe 01434' showed higher shoots and NMC under both normal and deficient irrigation levels (below 10% reduction) as compared to other varieties tested. These varieties also produced higher cane yield along with the minimum yield reduction. The sucrose % in juice at 10 month crop age was marginally reduced. Conclusively, varieties 'CoS 07250' and 'CoSe 01434' could be useful for cultivation under water stress areas of western Uttar Pradesh.

Key words: Drought tolerance, Water stress, Sugarcane, Cane yield

Sugarcane occupies a significant position as an agro-industrial crop of country and world's 2nd largest sugar production next to Brazil, and contributes about 7.5% to the gross value of the agricultural production in the country. Its impact can be understood with the fact that in India about 50 million farmers and equal number of agricultural labourers depend on sugarcane for their livelihood. Half a million skilled workers are engaged in the sugar industry. India occupies about 5.0 million ha area under sugarcane and produces approximately 350 million tonnes of sugarcane with average sugarcane productivity of 700 q/ha. Similarly, the total sugarcane area in Uttar Pradesh is about 20.52 lakh ha and produces around 136.4 million tonnes of cane with average sugarcane productivity of 665 q/ha.

Sugarcane is cultivated in India under a wide range of agro-climatic conditions, distributed both in tropical and subtropical regions between 10-30N^{o} latitudes. In tropical climate, the cultivation of sugarcane is more successful in terms of cane yield and sugar recovery throughout the year. However, the productivity of sugarcane is adversely influenced due to several abiotic and biotic stresses in sub-tropics. Availability of moisture throughout the growing period is important for ascertaining maximum yield. Depending upon climate, water requirement (ETm) of sugarcane varies from 1500 to 1700 mm distributed evenly over the growing season. Sugarcane being a long duration crop, requires considerable quantity of water to the extent of 1400-1500 mm in the sub-tropics (Solomon 2012). It is a long duration crop and has a high water requirement for production of 1 kg of cane for which the amount of water required is about 100 litres, subject to climatic conditions, soil type and nature of sugarcane varieties and for producing 1 kg sugar, it requires 1000 lit of water. However, a vast area in northern part of India faces scarcity of water especially in summer season due to insufficient irrigation facilities.

Deficiency of water is the most common abiotic stress during the summer season that limits yield in much part of sub-tropical regions. The severity of yield losses depends on factors such as time and length of the stress period (Zia *et al.* 2013). The changes induced by it are reported to be reversible, at the cellular level in sugarcane (Abbas *et al.* 2014).

The establishment of genotypes with higher tolerance characteristics towards water stress is desirable for the successful breeding programme. However, breeding for drought tolerance in sugarcane is complex task because of the lack of precise screening method (Araus *et al.* 2008). The commonly used practices for phenotyping the genotypic performance to drought are laborious and destructive (Roy *et al.* 2011). Keeping the above points in view, present study was conducted to screen promising sugarcane genotypes/varieties from the germplasm to find out their suitability for cultivation in drought prone areas of Uttar Pradesh.

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MATERIALS AND METHODS

An experiment employing ten elite sugarcane varieties, namely 'CoS 07250', 'CoS 07240', 'CoS 06241', 'CoS 06246', 'CoS 06280', 'CoS 07282', 'CoSe 01434', 'CoSe 06455', 'CoSe 06456' and 'UP 05125' was conducted for the evaluation of yield contributing parameters as well as sucrose content under normal and drought conditions during spring season for three consecutive years (2012-13 to 2014-15) at Sugarcane Research Centre, Muzaffarnagar (UP). Three budded setts were planted in strip plot design in three replications with a row spacing of 90 cm with 5 x 3.6 m of plot size each. Nitrogen was given @ 150 kg /ha in 2 equal split, half at the time of planting (basal dressing) and rest half before the onset of monsoon apart from the recommended dose of fertilizers. Two moisture levels *i.e.* normal (5 irrigation) and deficient (2 irrigation) were maintained during the formative stage of crop to ascertain the stress. All the cultural practices were followed as per recommendations.

Two common irrigations were given to both normal and deficient plots up to 60 days of crop by maintaining 50% available soil moisture. In normal plots, 40-50 % available soil moisture was kept by giving 3 more irrigation, whereas deficient plots did not receive any more irrigation till the onset of monsoon. Observations were carefully made on number of tillers/ha, NMC/ha, sucrose% in juice and cane yield (t/ha) and reduction % for all the parameters were calculated. Data were statistically analyzed as per the standard procedure. Juice quality in terms of sucrose% was analyzed according to Meade and Chen (1977).

RESULTS AND DISCUSSION

Results depicted in Table 1 revealed the significant influence of water stress on tillers/ha, millable canes/ha, sucrose% in juice and cane yield in almost all the varieties under study. The reduction in tillers ranged from 5.39% ('CoS 07250') to 11.73% ('CoSe 06455') due to water stress indicating a large variation among the test varieties for water stress tolerance (Fig 1). Similarly, less number of millable canes were recorded under water deficient condition than normal condition in most of the varieties under study, however, varieties 'CoSe 01434' (4.38%), 'CoS 06280' (6.09%) and 'CoS 07250' (6.29%)

Table 1 Performance of sugarcane genotypes/varieties under normal and water deficit conditions

Sl. No.	Varieties	Germination. %	Tillers (000/ha)		Tillers reduction %	NMC (000/ha)		NMC reduction %	Sucrose %		Sucrose reduction%	Yield (t/ha)		Yield reduction%
			N	D		N	D		N	D		N	D	
1	'CoS 07250'	43.02	204	193	5.39	159	149	6.29	17.17	16.96	1.22	79.16	72.22	8.77
2	'CoSe 01434'	47.29	208	196	5.77	160	153	4.38	16.83	16.45	2.26	80.51	75.00	6.84
3	'CoSe 06455'	34.58	179	158	11.73	143	127	11.19	16.87	16.35	3.08	70.83	62.50	11.76
4	'UP 05125'	44.06	202	180	10.89	157	142	9.55	17.84	17.64	1.12	75.00	65.28	12.96
5	'CoS 07240'	41.4	195	178	8.72	155	144	7.10	16.86	16.4	2.73	76.39	66.67	12.72
6	CoSe 06456	37.91	189	171	9.52	150	135	10.00	16.59	16.44	0.90	72.22	63.89	11.53
7	'CoS 07282'	34.47	156	145	7.05	126	114	9.52	16.3	15.98	1.96	62.50	55.56	11.10
8	'CoS 06241'	36.35	174	162	6.90	139	127	8.63	16.14	15.79	2.17	69.45	58.23	16.16
9	'CoS 06246'	39.79	185	169	8.65	149	112	24.83	16.39	15.99	2.44	68.06	56.17	17.47
10	'CoS 06280'	31.04	149	134	10.07	115	108	6.09	16.06	15.74	1.99	56.94	50.00	12.19
SE#/CD Varieties			5577.66/11712.36			4976.63/10455/89			0.322/NS			41.1923/8.8080		-
SE#/CD Treatments			5715.75/2868.67			1777.78/5498.28			0.0481/0.100			0.8333/3.5858		-
SE#/CD VXT			5915.72/NS			7151/NS			0.7210/0.155			4.3499/NS		-
SE#/CD TXV			5573.05/NS			84000/NS			0.701//0.142			4.3078/NS		-

N = Normal; D = Deficient

V XT= Variety X Treatments

showed minimum reduction % in number of millable canes (Fig 2) under water deficient condition. Among the varieties under evaluation, 'CoS 07250' and 'CoSe 01434' resulted in higher number of millable canes at both normal as well as deficient irrigated levels as compared to other varieties. The maximum number of millable canes could be counted in varieties 'CoS 07250' and 'CoSe 01434' (159,000 and 160000/ ha under normal irrigation and 149000 and 153000/ha under deficient irrigation level, respectively). Thus results indicated that availability of moisture throughout the growing period is an important factor for obtaining maximum number of canes and is in accordance to earlier observations of Dillewijn (1952).

Reduction% in cane yield was observed ranging from 6.84% to 17.47% under deficient soil moisture condition. Varieties 'CoS 07250' and 'CoSe 01434' showed lower reduction of 8.77 and 6.84% respectively in cane yield under water stress condition as compared to other tested varieties (Fig 3). The cane formation and grand growth period is the most critical period for moisture supply in sugarcane. This is because the critical cane yield builds up or stalk growth takes place during this period (Reddy 2007). As far as juice quality is concerned, it was not influenced significantly due to moisture deficiency in varieties under evaluation. The reduction in sucrose content

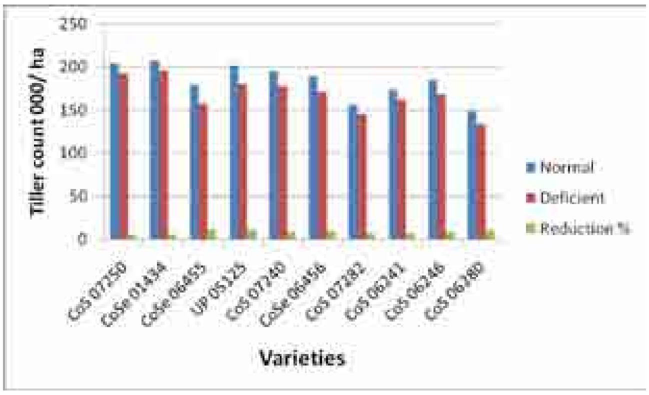

Fig 1. Number of tillers in sugarcane genotypes under normal and water deficit conditions

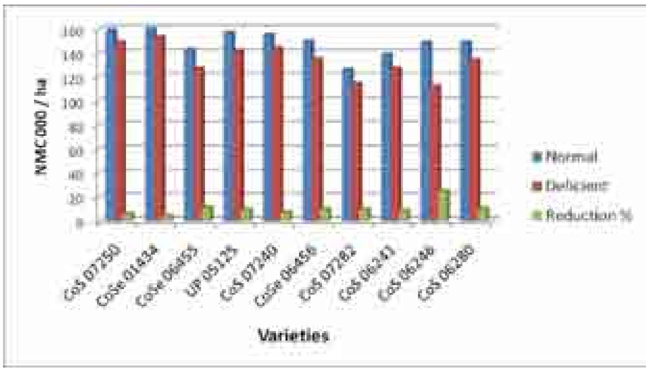

Fig 2. Number of millable canes in sugarcane genotypes under normal and water deficit conditions

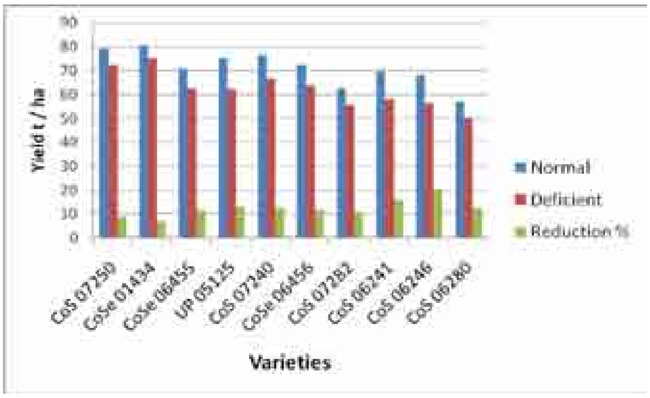

Fig 3. Cane yield of sugarcane genotypes under normal and water deficit conditions

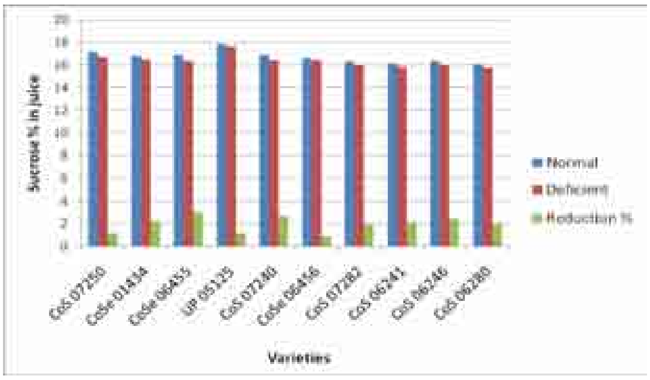

Fig 4. Sucrose% of sugarcane genotypes under normal and water deficit conditions

ranged from 0.90% to 3.08% in different varieties. The minimum reduction % in sucrose in juice (Fig 4) was observed in varieties 'CoSe 06456' (0.9%), 'UP 05125' (1.12%) and 'CoS 07250' (1.22%).

Results of the present study also revealed that the effect of moisture stress on different sugarcane attributes (tillers/ha (000), number of millable canes, cane yield (t/ha) and sucrose% in juice) was statistically significant. Two varieties namely 'CoS 07250' and 'CoSe 01434' produced maximum numbers of tillers (Fig 1) and NMC (Fig 2) at both normal and deficient irrigation levels than the other varieties and also produced higher cane yield (72.22 and 75 t/ha) with minimum yield reduction percent (8.77, and 6.84 respectively). On the basis of results obtained on tillers, number of millable canes, cane yield and yield reduction percent, these two varieties 'CoS 07250' and 'CoSe 01434' revealed the highest tolerance against deficient soil moisture conditions. Hence these genotypes are suitable for cultivation under drought prone areas of western Uttar Pradesh and might be beneficial to the cane growers and millers both.

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Indian Journal of Sugarcane Technology **31(02)**: 65-67, December 2016

Effect of *ethrel* and gibberellic acid on growth and yield of sugarcane (cv 'CoS 03251') with recommended agronomic practices

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ABSTRACT

Low sugarcane yield in north India is a matter of concern for the farmers as well sugar industry. In about 75 percent area of subtropical India, planting is delayed upto April-May after wheat harvest.There is ample scope of using growth regulating substances for increasing the germination and cane height, especially in the late planted sugarcane, where yields are low due to production of short millable canes. However, the technology of application of these substances needs to be evaluated. Keeping this in view, an experiment was conducted for two years (2015-16 and 2016-17) in spring season at the research farm of U.P. Council of Sugarcane Research, Shahjahanpur (U.P.), India. The experimental soil was sandy loam in texture, low in organic carbon content (0.36%), low in available phosphorus (11.35 kg/ha) and medium in potassium content (122 kg/ha), with pH of 6.8. An early maturing variety 'CoS 03251' was used and the experiment was laid out in a randomized block design in the month of March and it was harvested after 12 months. The growth and yield parameters at various stages were significantly influenced by the use of growth substances like *ethrel* and gibberellic acid. The treatment with planting of two budded setts after overnight soaking in *ethrel* solution (100 ppm) + spraying of gibberellic acid (35 ppm) at 90, 120 and 150 DAP (days after planting) recorded significantly higher germination of setts, higher number of tillers (179744/ ha), millable canes (139698/ha), greater cane height (2.18 m), leaf area index (5.42) and cane yield (115.79 t/ha) as compared to conventional planting. CCS% in cane was not significantly affected due to various treatments.

Key words: Agronomic practices, *Ethrel*, Gibberellic acid, Growth regulators, Sugarcane, Yield.

Average productivity of sugarcane in India has reached upto 70 t/ha through various improved agro-techniques. Still there is wide scope to enhance the productivity by using growth regulators. The plant growth regulators are organic substances which are needed in small quantities at low concentrations to modify plant growth and development and generally their site of action and biosynthesis are different. In general, four groups of growth substances are recognized, *viz.* Gibberellins, Indole derivatives, Abscisic acid and Cytokinins. Recently to these groups, ethylene has been added. Beneficial effects of various growth substances on growth and yield of sugarcane have been reported by Rao *et al.* (1960), Kanwar and Kanwar (1986) and Bendigeri *et al.* (1986). Gibberellic acid stimulated stem elongation in sugarcane under green house conditions and under commercial field conditions has been reported from different sugarcane growing countries of the world (Nickell 1984). Although the effect of *ethrel* on cane flowering has been studied by earlier workers but there are not much studies on effect of *ethrel* on germination.The present work was taken up with an idea that germination% of sugarcane is generally low whereas its contribution for cane yield is about 30%. An attempt has been made in the present study to find out the effect of growth regulating substances *viz.* gibberellic acid and *ethrel* on germination, growth and yield of sugarcane under field conditions.

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MATERIALS AND METHODS

A field experiment was conducted during 2015-16 and 2016-17 in spring season at research farm of U.P. Council of Sugarcane Research, Shahjahanpur, (U.P.). The experimental soil was sandy loam in texture, low in organic carbon content (0.36%), low in available phosphorous (11.35 kg/ha) and medium in potassium (122 kg/ha) with 6.8 pH value. Experiment was laid out in a randomized block design with three replications. An early maturing variety 'CoS 03251' was used as experimental material. Experiments were planted in March and harvested after 12 months. Mean data of two years was analysed. Full dose of P and K as per recommendation were applied at the time of planting through SSP and MOP, and nitrogen was given through urea, one third as basal and two third as top dressing in two equal splits upto onset of monsoon. The observations on germination, shoots, millable canes, cane weight, leaf area index (LAI) and cane yield were recorded. Juice quality was also determined at the time of harvesting (Meade and Chen 1977). CCS percent in cane was calculated according to the formula given by Parthasarathy (1977). Treatment details are given as under:

T_1 – Conventional planting/ farmers practice (3 budded setts)

T_2 – Planting of setts after overnight soaking in water.

T_3 – Planting of setts after overnight soaking in 50 ppm *ethrel* solution.

T_4 – Planting of setts after overnight soaking in 100 ppm *ethrel* solution.

T_5 – T_1 + Gibberellic acid (GA_3) spray (35 ppm) at 90, 120 and 150 DAP.

T_6 – T_2 + GA_3 spray (35 ppm) at 90, 120 and 150 DAP.

T_7 – T_3 + GA_3 spray (35 ppm) at 90, 120 and 150 DAP.

T_8 – T_4 + GA_3 spray (35 ppm) at 90, 120 and 150 DAP.

RESULTS AND DISCUSSION

The mean data of two years on growth and yield attributes of cane is presented in Table 1 and, Figs 1, 2 and 3. Germination % recorded at different stages under overnight soaking in 100 ppm *ethrel* solution was significantly superior to conventional and overnight soaking in water. The treatment T_8 (planting of two budded setts after overnight soaking in *ethrel* solution (100 ppm) + spraying of gibberllic acid (35 ppm) at 90, 120 and 150 DAP recorded significantly higher germination, higher number of tillers (157.65 thousands/ha), number of millable canes (129.26 thousands/ha), more cane height (3.18 m) and leaf area index as compared to conventional planting. Kanwar and Kanwar (1986) also reported promising performance of gibberellic acid and *ethrel* on cane yield parameters confirming our results. Many workers have reported that *ethrel* checks the flowering in sugarcane.

Favourable effects of GA_3 application on growth of sugarcane have also been observed by several workers of other sugarcane growing countries of the world. McDavid and Babiker (1981) reported that GA_3 increased stem elongation and fresh weight of stem and leaf. Gonzales *et al.* (1978) reported the possibility of obtaining desirable response of sugarcane to foliar spray of GA_3 when applied at proper time. Yamaguchi *et al.* (1986) found that split application of proper amount of GA_3 after completion of tillering phase had a promotional effect on internodal elongation for a longer period

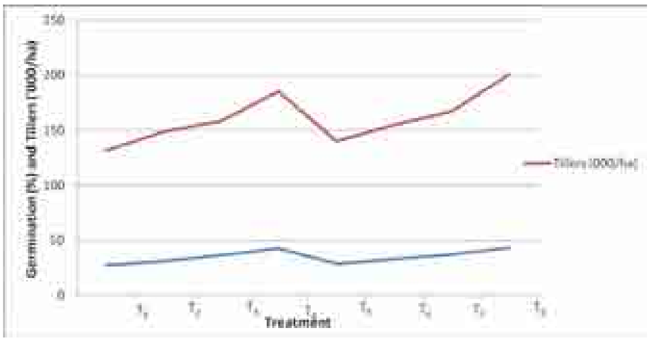

Fig 1. Germination (%) and tillers ('000/ha) as influence by various treatments

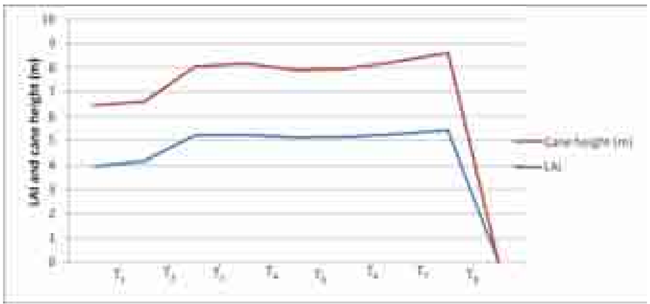

Fig 2. Leaf Area Index (LAI) and cane height (m) as influenced by various treatments

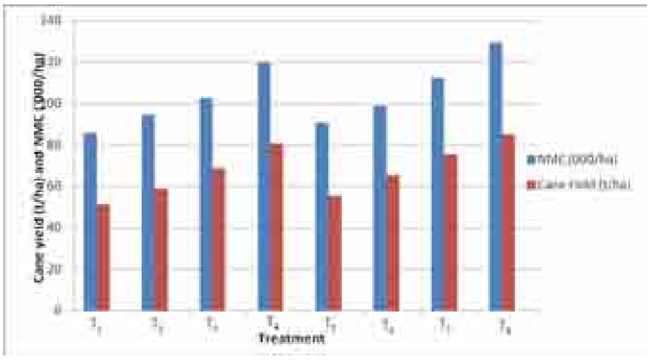

Fig 3.Effect of various treatments on cane yield and number of millable canes (NMC)

Table1 Growth, yield and juice quality of sugarcane as influenced by various treatments

Treatment	Germination (%)	Number of tillers (000/ha)	Number of millable cane (000/ha)	Cane height (m)	LAI (Leaf Area Index)	Cane yield (t/ha)	CCS (%)
T_1	27.41	103.99	85.76	2.49	3.95	51.25	12.71
T_2	31.34	117.67	94.68	2.43	4.18	58.95	12.60
T_3	36.80	121.76	102.55	2.85	5.20	68.90	12.63
T_4	42.85	142.76	119.86	2.95	5.23	80.70	12.86
T_5	28.70	111.60	90.74	2.79	5.13	55.55	12.65
T_6	32.92	121.93	98.84	2.81	5.15	65.45	12.73
T_7	37.00	130.31	112.39	3.01	5.25	75.50	12.76
T_8	43.16	157.65	129.26	3.18	5.42	85.35	12.70
SE±	4.03	2.28	1.76	0.21	0.31	1.19	0.22
CD (5%)	8.88	4.94	3.89	0.65	0.93	2.48	NS

(mean data of two years)

than its single application. Besides, early application caused decrease in tiller numbers.

Effect of various treatments on CCS% in cane was not significant. Verma and Ali (1963) also recorded significant increase in cane yield due to GA_3 application in pot experiment but no significant change in sucrose% and purity % of sugarcane juice was observed. Based on the results obtained, it can be concluded that planting of setts after overnight soaking in 100 ppm *ethrel* solution + GA_3 (35 ppm) spray at 90, 120 and 150 DAP resulted in significantly higher germination, tillers, millable canes and cane yield than that of conventional planting. In our country there appears ample scope of using GA for increasing cane length in late planted sugarcane where yields are low due to production of shorter millable canes.

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Indian Journal of Sugarcane Technology **31(02)**: 68-72, December 2016

Molecular diversity assessment in a general cross population of sugarcane using SSR markers

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ABSTRACT

Fourteen selected genotypes from a population derived from a general cross of the sugarcane variety 'CoLk 8102' were subjected to genetic diversity analysis using simple sequence repeat markers. Thirty nine SSR primers used for amplification yielded 997 amplicons. Pair-wise genetic similarity coefficients of these fourteen genotypes ranged from 0.39 to 0.89. UPGMA analysis of similarity coefficients separated the genotypes into different clusters and helped in the identification of most distant progenies. Two highly polymorphic SSR primers were identified that would be useful for rapid genotyping and molecular diversity studies in sugarcane.

Keywords: Cluster analysis, Genetic Diversity, Genetic similarity, microsatellites, PIC.

Sugarcane is an important crop of almost 100 countries of the world for producing sugar and fuel, as well as for molasses and paper as by products and supplies an estimated 75% of the world's sugar (Dillon *et al*. 2007; Waclawovsky *et al*. 2010). India is the second largest producer of sugarcane in the world and sugarcane occupies a commanding position as an agro-industrial crop of the country, covering around 5.0 million hectare area.Sugarcane belongs to the genus *Saccharum* which is the complex of six species: *S. officinarum*, *S. barberi*, *S. sinense*, *S. edule*, *S. spontaneum* and *S. robustum*. Out of these *S. spontaneum* and *S. robustum* are wild in nature while other four are cultivated species. Sugarcane varieties are man-made hybrid clones involving *S. officinarum* and *S. spontaneum* with a few genes incorporated from, *S. sinense, S. barberi* and to a limited extent from *S. robustum* (Daniels *et al.* 1987). Crossing is done to improve the economically important traits for development of commercial sugarcane varieties, and superior progenies are selected from segregating populations. The genetic base of cultivated sugarcane being quite narrow, it becomes difficult sometimes to distinguish the progeny on the basis of morphological attributes (Srivastava and Gupta 2006). Molecular markers are powerful tools to estimate genetic variability *in vivo* and *in vitro,* as they are accurate, abundant and are not affected by the environment. A number of PCR based markers such as Random Amplified Polymorphic DNA (RAPD), Inter Simple Sequence Repeats (ISSR), Amplified Fragment Length Polymorphism (AFLP) and Simple Sequence Repeats (SSR), also known as microsatellites have become available for molecular characterization of sugarcane (Srivastava *et al.* 2005; Srivastava and Gupta 2008; Swapna and Srivastava 2012; Srivastava and Pathak 2017). Screening and evaluating the available genetic variability with molecular markers will help understand the molecular-based genetic relationship of sugarcane genotypes for exploitation of new gene resources of sugarcane, to help broaden the genetic base of sugarcane. Therefore, the objective of the present study was to evaluate the molecular diversity of subset of progeny clones of a general cross using SSR markers.

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MATERIALS AND METHODS

Plant material

The experimental material comprised of progeny clones from a population of a general cross (GC) of the sugarcane variety 'CoLk 8102'. The cross was effected at National Hybridization Garden, Sugarcane Breeding Institute, Coimbatore, India. Fluff was collected and sown in mist chamber, and seedlings obtained were transplanted in field. The progeny genotypes were later evaluated for various economic traits in ratoon crop (data not presented here) and fourteen genotypes showing good performance with respect to economic attributes were selected for molecular diversity analysis using SSR markers.

DNA isolation, PCR amplification and electrophoresis

Genomic DNA was extracted from young fresh leaf tissues of the selected genotypes of sugarcane using modified CTAB method (Srivastava and Gupta 2001), purified, quantified and stored at -20^{o}C. A set of 39 SSR primers was used to amplify the DNA from all the samples. PCR amplification was performed on thermal cycler PTC 200 (Peltier thermal cycler, MJ research Pvt. Ltd., USA). The reactions were carried out in 20µl final volume of the reaction mix, containing 20 ng template DNA, 0.5 Unit Taq polymerase, 2 µl 10 X PCR buffer, 2 µl 25 mM $MgCl_2$, 1.6 µl 10 mM dNTPs and 4.0 pmoles each of the forward and reverse primers. The PCR conditions were as follows: An initial step of denaturation at 94°C for 3 minutes, thirty five cycles of denaturation for 45 sec at 94°C, annealing for 30 seconds at 48-55°C (depending upon annealing temperature of the primers) followed by 30 sec at 72°C and a final elongation step at 72°C for 10 minutes. The PCR products were stored at 4°C before loading.

The PCR products were separated on 3% agarose gels in 1X TAE buffer containing 0.5 µg/ml of ethidium bromide (EtBr) at 3 V/cm in SubCell GT electrophoresis unit of BioRad. A 50 bp DNA ladder (Fermentas, Gene Ruler) was used as molecular weight marker. The gels were photographed under UV light, using an AlphaImager™ 1220 Gel Documentation System.

Scoring of gels and data analysis

The size of the amplified fragments was calculated by comparison with a 50 bp ladder (Fermentas, Gene Ruler) using the software Alpha Imager EC. The reproducible SSR bands from the agarose gels were scored as present (1) or absent (0) in each sample. The bands were arranged in decreasing order of molecular weight for each primer. Each DNA fragment generated was treated as a separate character and scored as a discrete variable. Accordingly, rectangular binary data matrix was obtained which was used for further analysis.

The polymorphism information content (PIC) was calculated for each locus according to Anderson *et al.* (1993) as PIC = $1-\Sigma xi^2$, where, xi is the relative frequency of the i^{th} allele of the SSR loci. PIC provides an estimate of the discriminating power of a locus by taking into account the number of alleles generated by each reaction unit and their frequency distribution in the population. Markers were classified as informative when PIC was e ≥ 0.5.

Effective Multiplex Ratio (EMR) for an individual primer was obtained by the formula; EMR = $n\beta$ where β = percent of polymorphic markers and n = number of bands per reaction unit. The marker index (MI) to characterize the ability of each primer to detect polymorphic loci among the genotypes was calculated for all the primers as the product of two functions that is PIC and EMR, as described by Prevost and Wilkinson (1999).

Pair-wise similarity coefficient matrix was computed for all the markers by simple matching similarity algorithm using NTSYS-pc version 2.1 (Rohlf 2000). Mean similarity coefficients of individual progeny were calculated by taking average of SM coefficients of one genotype with respect to rest of the genotypes. Phylogenetic dendrogram was constructed using the UPGMA (Unweighted Pair Group Method with Arithmetic Mean clustering) method (Sneath and Sokal 1973) following the SAHN (Sequential Agglomerative Hierarchical Nested) cluster analysis module of software NTSYS-pc.

RESULTS AND DISCUSSION

Molecular variation in progeny genotypes

Among the various molecular markers, SSRs have evolved as a useful marker system for breeders due to their suitability for assessment of genetic diversity (Hoxha *et al*. 2004; Yepuri *et al*. 2013). Their use in sugarcane is a potential cost effective method for molecular diversity analysis. SSR markers have provided significant information about genetic diversity of sugarcane genotypes which is essential to establish breeding strategies. In the present study, molecular diversity was analyzed in 14 selected progeny genotypes of sugarcane derived from 'CoLk 8102' GC using 39 microsatellite (SSR) primer pairs. Electrophoretic analyses of amplicons using these SSR primers on 3% agarose gel provided reliable distinct multiple band profiles for these sugarcane genotypes (Fig 1). Eleven

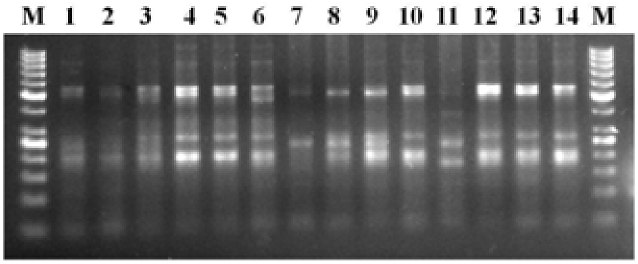

Fig 1. SSR amplification profile of sugarcane population 'CoLk 8102' GC using primer SS08-17. M= 50bp Gene Ruler ladder, 1-14= progeny genotypes of 'CoLk 8102' GC

out of these thirty-nine primers showing complete parsimony were very useful for diversity analysis and the rest twenty eight primers showed monomorphism. A total of 997 bands were produced across all genotypes, of which, approximately 26.98 % bands were polymorphic. An average number of 71.21 fragments/ genotype were amplified. Total number of bands amplified for each primer ranged from 13-70, with an average of 25.56 fragments/primer. Only the polymorphic primers were considered for diversity analysis (Table 1). Thus, a total of 255 amplicons from these eleven polymorphic primers with an average of 23.18 amplicons/ primer were taken into consideration. The molecular weight of these 255 amplicons ranged from 85 to 750bp, based on which they were grouped into 41alleles of distinct molecular weight, ranging from 2 to 9 alleles with an average of 3.72 alleles/ primer.

Primer efficiency based on PIC, EMR and MI values

The average number of polymorphic bands/genotype produced by 11 polymorphic primers ranged from 0.92-3.28, with a mean value of 1.65 (Table 1). The Polymorphic Information Content (PIC) index indicating the extent of polymorphic bands generated by a primer ranged from 0.26-0.86, with a mean value of 0.53. Five out of eleven primers (SS-53, SS-64, SS-65, SS-67 and SS-08-17) showed PIC value of 0.5 or more (Table 1). Effective Multiplex Ratio (EMR) of the primers ranged from 0.71-2.33 with a mean value of 1.33 (Table 1). Marker Index (MI) ranged from 0.24 to 2.02 with a mean value of 0.78.

Overall, in the 'CoLk 8102' GC progeny, the highest values of average number of polymorphic bands/genotype (3.28), PIC index (0.86) EMR (2.33) and MI (2.02) were obtained for primer

Table 1 SSR markers used in the study and their parameters in sugarcane progeny population of 'CoLk 8102' GC

S. No	Name of primer	Total number of bands	Number of alleles	Range of product size (bp)	PIC*	EMR*	MI*	N*
1	SS-43	20	2	152-244	0.42	**0.71**	0.29	1.42
2	SS-44	23	2	150-230	0.47	0.82	0.39	1.64
3	SS-45	**13**	**2**	145-161	**0.26**	0.92	**0.24**	**0.92**
4	SS-53	18	4	200-600	0.54	1.02	0.56	1.28
5	SS-58	21	4	295-556	0.49	0.75	0.37	1.50
6	SS-62	20	3	195-290	0.45	1.42	0.65	1.42
7	SS-64	23	3	280-457	0.52	1.64	0.86	1.64
8	SS-65	35	5	155-750	0.68	2.50	1.70	2.50
9	SS-67	22	5	85-275	0.72	1.57	1.14	1.57
10	SS-70	14	2	236-258	0.40	1.00	0.40	1.00
11	SS08-17	**46**	**9**	**189-529**	**0.86**	**2.33**	**2.02**	**3.28**

*PIC = Polymorphic Information Content, EMR = Effective Multiplex Ratio, MI = Marker Index and n = Average number of bands/genotype

SS-08-17 (Table 1). High PIC index was also obtained for the primer SS-67 (0.72), along with EMR of 1.57, MI of 1.14 and n of 1.57, thus proving the suitability of these two primers for the study of molecular polymorphism and genetic diversity. The other three primers with PIC indices more than 0.50 exhibited EMR values ranging from 1.02–2.50, MI from 0.56-1.70 and n from 1.28-2.50. Earlier sugarcane researchers (Pinto *et al.* 2006; Cordeiro *et al.* 2003) have also suggested the suitability of SSR markers for diversity analysis in sugarcane, on the basis of their high PIC values. Using EST-SSRs markers in sugarcane, Liu *et al.* (2011) obtained PIC value as high as 0.90. In another study using SSR markers in commercial sugarcane cultivars, the PIC values ranged from 0.34 to 0.78 (Duarte Filho *et al.* 2010). Similarly, the features MI and EMR have been used to evaluate the discriminatory power of molecular marker systems in some plant species like wheat (ISSR, EMR = 12, MI = 3.36) and apricot (ISSR, EMR = 4.8, MI = 3.74), (Abdollah *et al.* 2015).

Although, the average number of polymorphic bands/primer is only 1.65 in the present study, the level of polymorphisms among the genotypes tested indicates that distinction between any two genotypes should be possible with appropriate primers. Comparative values in some other plants range from 3.8 polymorphic bands/primer in rapeseed (Mailer *et al.* 1994), and 3.9 in rice (Song *et al.* 1992).

Genetic similarity and Cluster analysis

The data of SSR markers scored in each genotype was analyzed using simple matching similarity algorithm (Sneath and Sokal 1973) of the software NTSYS-pc version 2.1 (Rohlf 2000). The pair-wise SM similarity coefficients (Table 2) ranged from 0.39 (between the progeny 7 and 14) to 0.89 (between the progeny 3 and 4; 8 and 9) with the mean value of 0.64. This genetic similarity matrix was used to obtain dendrogram through UPGMA based cluster analysis (Fig 2). The dendrogram showed two clusters; the Cluster A contained the genotypes 5, 7, 8 and 9, and the Cluster B contained the genotypes 1, 2, 3, 4, 6, 10, 11, 12, 13 and 14. The Cluster B consisted of two sub-clusters *viz.* BI and BII with 6 (1, 2, 3, 4, 6 and 13) and 4 genotypes each (10, 11, 12 1nd 14).

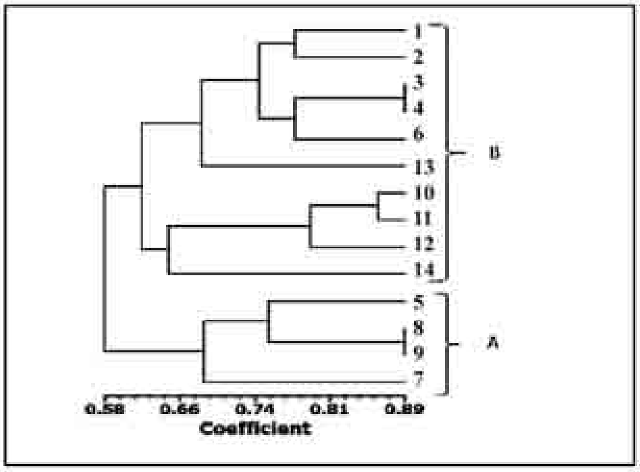

Fig 2. UPGMA based clustering of progeny population of 'CoLk 8102' GC using genetic similarity matrix for SSR markers

In general the genetic similarity estimated for the selected genotypes from 'CoLk 8102' GC population is quite high (0.39 to 0.89) which indicates that genetic distance amongst the alleles using SSR markers in this sub-set of the population is not much. It also indicates that the genetic diversity among the genotypes studied is very less. The narrow genetic base of cultivated sugarcane and the low genetic diversity documented among the cultivated genotypes has been supported by Pan (2010); Srivastava and Gupta (2006, 2008); Srivastava *et al.* (2005, 2011); Zhang *et al.* (2008), and there is a need to identify diverse genotypes for future breeding programmes of sugarcane.

Identification of diverse progenies in the cross population

The result of cluster analysis of cross population may be

Table 2 Genetic Similarity Matrix of 'CoLk 8102' GC population of sugarcane using SSR markers

Progeny genotype	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.00													
2	0.78	1.00												
3	0.72	0.78	1.00											
4	0.78	0.78	0.89	1.00										
5	0.69	0.64	0.75	0.69	1.00									
6	0.72	0.67	0.72	0.83	0.64	1.00								
7	0.47	0.53	0.47	0.53	0.61	0.58	1.00							
8	0.61	0.61	0.61	0.61	0.75	0.67	0.75	1.00						
9	0.56	0.50	0.56	0.56	0.75	0.67	0.69	0.89	1.00					
10	0.58	0.53	0.58	0.69	0.50	0.69	0.50	0.64	0.69	1.00				
11	0.61	0.61	0.67	0.72	0.58	0.72	0.47	0.72	0.72	0.86	1.00			
12	0.44	0.56	0.50	0.61	0.53	0.61	0.53	0.61	0.61	0.81	0.78	1.00		
13	0.69	0.64	0.69	0.69	0.61	0.69	0.50	0.58	0.58	0.67	0.69	0.58	1.00	
14	0.64	0.64	0.69	0.64	0.56	0.64	0.39	0.53	0.58	0.72	0.69	0.53	0.61	1.00

used to design a strategy for developing more genetic variability in order to obtain improved sugarcane variety by using distant genotypes in crossing programmes. On the basis of SSR marker-based similarity coefficient analysis, the lowest genetic similarity coefficient of 0.39 was found between progenies 7 and 14 which indicated that these two progenies were genetically more distant from each other. Mean similarity coefficients of individual progeny genotypes of 'CoLk 8102' GC, with respect to rest of the genotypes are given in Fig 3. The highest mean similarities coefficients (MSC) were observed for progenies 4 and 6 (0.694 and 0.681 respectively), whereas, the lowest mean similarities coefficients (MSC) were observed for progeny 7 followed by 12 (0.54 and 0.592 respectively). Thus, the progeny 7 of 'CoLk 8102' GC (MSC=0.54) was genetically least similar to rest of the 13 progenies of the cross sub-population studied. Interestingly, when seen in context with pairwise similarity coefficients, progeny 7 was the most dissimilar one showing SM similarity coefficients of 0.50 or less with 6 other progeny genotypes, followed by progeny 12 showing SM similarity coefficients of 0.53 or less with 5 other progeny genotypes (Table 2).

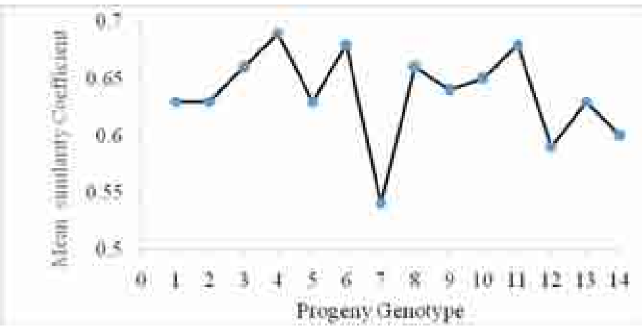

Fig 3. Mean Similarity Coefficients (MSC) of progeny genotypes in population 'CoLk 8102' GC

Overall, at least two progeny genotypes could be identified among the 14 selected progenies of 'CoLk 8102' GC population, which were quite distant from rest of the genotypes. The usefulness of SSRs was once again ascertained as a tool for molecular diversity analysis in general and identification of genetically diverse genotypes from the progeny of a cross population in particular. Moreover, two highly efficient SSR primers were also identified which could be utilized to facilitate molecular diversity and polymorphism analysis of other cultivars and wild species of sugarcane. The genetic diversity assessed in the cross population in this study can be used to select the better progenies taking into account their qualitative and quantitative attributes.

ACKNOWLEDGEMENTS

The authors are grateful to the Director, ICAR-IISR, Lucknow for providing the facilities to carry out this research work. The first author (P.S. Kharate) gratefully acknowledges the DBT, Govt. of India for fellowship during the period of research for Master's degree thesis work.

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Indian Journal of Sugarcane Technology **31(02)**: 73-76, December 2016

Estimating the sources of growth and instability of sugarcane production in India: Special reference to southern States

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ABSTRACT

The present study was an attempt to estimate the sources of growth and instability in sugarcane production in India, with special reference to southern states. The time series data for the period from 1995-1996 to 2014-2015 on area, production and yield were collected from website of Directorate of Economics and Statistics, Government of India. Analytical tools like Compound growth rate (CGR), Coppock's Instability Index (CII) and decomposition of change in average production were employed.The results revealed that effect of growth in the area, on growth in production was much higher than the growth in yield, in both period I and II in India and in the southern states as well. However, it was accompanied with moderate degree of instability. The main source of mean production differential was mean area than the mean yield in India, and in all southern states except in Telangana, where the turn around phenomenon was noticed.

Keywords: Sugarcane, CGR, Instability index, Decomposition of change, Southern states, India,

INTRODUCTION

India ranked 2nd in sugarcane area, with 5.01 million hectares (mha) and with a production of 352.14 million tonnes (mt) but, ranked 37th in yield with 70.26 tonnes/hectare (t/ha) in the world during 2014 (FAOSTAT 2016). In India, sugarcane occupies 2.6 per cent of the total cropped area that contributes 22 per cent in world's production (Directorate of Economics and Statistics).

Studies by Hazell (1984) and Jayadevan (1991) revealed that the growth in crop production during the post-green revolution period has been accompanied with increased instability and the yield fluctuation has turned out to be the major source of production instability. Rao *et al.* (2011) revealed that mean yield effect (55.92%) was higher than the mean area effect (25.70%) on the production differential between the Pre-WTO (1985-1986 to1994-1995) and Post WTO period (2000-2001 to 2009-2010) in north coastal districts of Andhra Pradesh.

In India, in the recent times, the sugarcane area has decreased from 5.15 m ha in 2006-2007 to 4.92 m ha in 2015-2016. Also, during the same period in southern states, the sugarcane area has decreased from 9.87 l ha to 8.91 l ha (Sugar Statistics 2016). In order to indentify the factors causing growth and instability of sugarcane in India and southern states, the present study was conducted with the following specific objectives:

1) To estimate the magnitude of growth in area, production and yield
2) To calculate the extent of instability in area, production and yield
3) To assess the factors causing change in average production between periods

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MATERIALS AND METHODS

The study pertains to India (Country as a whole) and five southern states *viz*., Andhra Pradesh, Telangana, Karnataka, Tamil Nadu and Kerala. The time series data for the period of last 20 years *i.e.* from 1995-1996 to 2014-2015, was collected on area, production and yield from the website of Directorate of Economics and Statistics, Government of India (http://eands.dacnet.nic.in). For the states of Andhra Pradesh and Telangana, district wise data for the corresponding period was taken and summed-up. The overall period (1995-96 to 2014-15) was divided into two equal parts *viz*., Period-I (1995-96 to 2004-05) and Period-II (2005-06 to 2014-15) and the analysis was conducted separately for each period.

Analytical tools

1) Estimation of growth rates: Compound growth rates were employed to estimate the growth, by fitting an exponential function of the following form.

$$Y = A.b^t$$

$$\text{Log } Y = \text{Log } A + t.\ \log b$$

Where,

Y = Area/Production/Yield **A**= Constant **b**= (1+r)

r = Compound Growth Rate **t** = Time variable in years (1,2,3…n)

The value of antilog of '**b**' was estimated by using **LOGEST** function in MS-Excel. Then the percent Compound Growth Rate was calculated as below;

$$\textbf{CGR (\%) = [LOGEST } (Y_1\textbf{:Yn) - 1] x 100}$$

2) Estimation of extent of instability: For the calculation of extent of instability, Coppock's Instability Index (CII) was employed. CII is a close approximation of the average year-to-year percentage variation adjusted for trend. In algebraic form:

$$C.I.I = [\text{Antilog} \sqrt{\log V} - 1] \times 100$$

$$\text{Log } V = \frac{\left[\text{Log } (X_{t+1}/X_t) - m\right]^2}{N-1}$$

Where, X_t = Area/ production/ Yield in the year 't' **N**= Number of years

log V = Logarithmic variance **m**=Arithmetic mean of difference between the logs of X_{t+1} *etc.*

3) Decomposition of Change in average production: Change in average production between the periods arises from changes in mean area and mean yield, interaction between changes in mean yield and mean area and change in yield-area covariance (Hazell 1984).

The change in average production ΔE (P) between the periods can be obtained as follows:

$$\Delta E(P) = \overline{A_1}.\Delta Y + \overline{Y_1}.\Delta A + \overline{\Delta A}.\overline{\Delta Y} + \Delta Cov(A,Y)$$

Where,

$\overline{A_1}.\Delta Y$, $\overline{Y_1}.\Delta A$, $\overline{\Delta A}.\overline{\Delta Y}$ and $\Delta Cov(A,Y)$ are change in mean yield, change in mean area, changes in mean area & mean yield and changes in covariance of area & yield respectively

RESULTS AND DISCUSSION

I. Magnitude of growth

During the overall period, among the states, ranges of growth rates in area varied between – 6.60 per cent (Kerala) to 1.38 per cent (Karnataka); in production, they were from – 5.16 per cent (Kerala) to 1.39 per cent (Karnataka) and in yield, varied they were between – 0.12 per cent (Tamil Nadu) and 1.54 per cent (Kerala) (Table1). Taking the country as a whole, the impact of growth in area (1.24%) had higher impact on the growth in production (1.37%) than the growth in yield (0.13%). Similarly, in the southern states, the growth in area (0.74%) had higher effect than the growth in yield (0.10%) on the growth in production (0.84%). Thus, in the 25 years time period since 1995-1996, the sugarcane production growth in India and the southern states was also led by area expansion rather than yield hike, though highest yielding states like Tamil Nadu and Karnataka were also in the group,

During the period-I, in the country as a whole, the impact of decline in yield (-1.18%) had more impact than decline in area (-0.34%) on decline in production (-1.51%). However, turn around trend was recorded in southern states *in toto*, where the effect of decline in area (-1.80%) was more than the decline in yield (-1.12%) on decline in production (-2.90%). Among the states, ranges of growth rates in area varied between – 8.40 per cent (Kerala) and 1.50 per cent (Telangana), in production from – 8.61 per cent (Kerala) to 1.24 per cent (Telangana) and in yield from – 1.56 per cent (Karnataka) to – 0.12 per cent (Andhra Pradesh).

During the period-II, in country as a whole, growth in area (1.28%) had higher influence on growth in production (1.78%) than growth in yield (0.49%), which is dissimilar with the period - I trend. Similar trend was noticed in southern states; growth in area (0.81%) countervailed the decline in yield (- 0.26%) to contribute towards increase in production (0.55%). Among the states, growth rates in area varied between – 12.72 per cent (Kerala) and 7.15 per cent (Karnataka), in production varied from – 12.80 per cent (Kerala) to 8.01 per cent (Karnataka) and in yield varied between - 0.89 per cent (Tamil Nadu) and 0.80 per cent (Karnataka). Individually in all the five states, growth in area contributed more towards growth in production than growth in yield. Magnitude of area impact on production was higher during period - II than period - I, in all the southern states and country as a whole.

II. Extent of Instability

Taking southern states *in toto*, during overall period, area variability (5.84%) had higher influence than yield fluctuations (2.74%) on production variation (7.96%) (Table 2). Highest instability in area (23.52%), production (21.05%) and yield (8.72%) were recorded in Kerala. Lowest instability in area (5.19%) and production (7.3%) were noticed in Andhra Pradesh, whereas, in yield (2.42%), it was observed in Tamil Nadu. During the period - I, the lowest instability in area (2.16%) and production (3.82%) were recorded in Andhra Pradesh, whereas, in yield (2.71%) was recorded in Tamil Nadu. Highest instability in area (12.79%) it was recorded in Kerala,

Table 1 Compound Growth Rate (%) of area, production and yield of sugarcane in India and southern states during Period-I, Period-II and Overall Period

States and Country	Period - I (1995-96 to 2004-05)			Period - II (2005-06 to 2014-15)			Overall Period (1995-96 to 2014-15)		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
Andhra Pradesh	0.57	0.45	-0.12	-4.13	-4.79	-0.68	-0.07	0.25	0.32
Telangana	1.50	1.24	-0.25	-4.84	-5.40	-0.60	-0.63	0.54	1.18
Karnataka	-2.63	-4.15	-1.56	7.15	8.01	0.80	1.38	1.39	0.01
Tamil Nadu	-3.24	-4.16	-0.96	-2.03	-2.90	-0.89	0.57	0.45	-0.12
Kerala	-8.40	-8.61	-0.24	-12.72	-12.80	-0.10	-6.60	-5.16	1.54
Southern States	-1.80	-2.90	-1.12	0.81	0.55	-0.26	0.74	0.84	0.10
India	-0.34	-1.51	-1.18	1.28	1.78	0.49	1.24	1.37	0.13

Table 2 Coppock's Instability Index (%) of area, production and yield of sugarcane in India and southern states during Period-I, Period-II and Overall Period

States and Country	Period - I (1995-96 to 2004-05)			Period - II (2005-06 to 2014-15)			Overall Period (1995-96 to 2014-15)		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
Andhra Pradesh	2.16	3.82	2.98	7.06	9.36	2.48	5.19	7.31	3.02
Telangana	6.64	6.44	4.20	8.55	10.34	2.80	7.49	8.90	5.10
Karnataka	12.09	16.88	6.18	7.49	8.60	1.56	11.45	14.55	4.39
Tamil Nadu	7.31	9.66	2.70	4.93	6.57	2.20	7.33	9.21	2.42
Kerala	12.79	14.47	4.12	19.98	13.87	9.09	23.52	21.05	8.72
Southern States	6.93	9.89	3.69	2.00	2.52	1.12	5.84	7.96	2.74
India	2.71	3.94	2.52	3.06	3.71	1.22	4.58	5.75	2.05

whereas, in production (16.88%) and yields (6.18%) were recorded in Karnataka. Effect of variability in area was more on variability in production was observed in all states except Andhra Pradesh. During the period - II, the lowest instability in area (4.93%), and production (6.17%) were recorded in Tamil Nadu and in yield (1.56%) in Karnataka. Highest instability in area (19.98%), production (13.87%) and yield (9.09%) were noticed in Kerala. In all variables, magnitude was higher in period – II than in period – I in all states which shows the higher fluctuation in sugarcane production in recent periods.

In the country as a whole, during the period - I, impact of area variability (4.58%) was higher than yield variability (2.05%) on production fluctuations (5.75%). Similar trend was noticed during the period I and II as well. However, the only variation is magnitude which was higher during period-II than period-I.

III. Sources of change in production between period-I and Period-II

Sources of change in production were estimated and are presented in Table 3. A perusal of table revealed that in the country as a whole, effect of change in mean area (83.11%) was higher than mean yield (-14.12%), mean area and yield (2.29%) and covariance of area and yield (0.48%). Thus, change in mean area has higher destabilizing effect on average production differential between period I and II.

Similar trend was noticed in all states from period – I to period – II, where change in mean area had higher effect on production differential than other components of change in all states except Telangana. When compared with magnitude, it was highest in Kerala (170.98%) followed by Karnataka (103.42%), Tamil Nadu (92.21%) and Andhra Pradesh (48.74%). However, yield had higher effect on sugarcane production in Telangana (108.68%). Rao *et al.* (2013) reported that during the period 1990-91 to 2011-12, technological (yield attributing) factors had higher effect on sugarcane production in Karnataka (116.3%) and, in rest of the states, policy (area attributing), factors had higher influence on change in production in southern states. Present results are in conformity with this report, where the only difference is magnitude and reversal of trend in Karnataka state.

CONCLUSIONS AND POLICY IMPLICATIONS

1. Since area contributes more towards area expansion efforts like assured supply of farm in-puts, providing the remunerative prices should be given prime importance.
2. However, area expansion under a particular crop is elastic and after a certain limit area under cultivation is inelastic. Hence, growth in production should come from yield attributing factors like development of high yielding farming system specific varieties and improvement in input use efficiency through technology transfer and frequent trainings.

Table 3 Components of change in average production (%) in sugarcane in India and southern states between period I and II

States and Country	Sources of Change			
	Change in mean Area	Change in mean Yield	Changes in mean Area and mean Yield	Changes in covariance of Area and Yield
Andhra Pradesh	48.74	43.27	2.75	5.25
Telangana	-12.60	108.68	-2.31	6.24
Karnataka	103.42	5.49	0.63	-9.53
Tamil Nadu	92.21	7.99	1.35	-1.55
Kerala	170.98	-120.91	43.42	6.51
Southern States	78.12	23.57	2.63	-4.32
India	83.11	14.12	2.29	0.48

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Indian Journal of Sugarcane Technology **31(02)**: 77, December 2016 **Short Communication**

'CoLk 07201' (*Ikshu-1*) - An early maturing sugarcane variety for North West Zone

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'CoLk 07201' (Fig 1) is the outcome of directed breeding efforts for top borer tolerance under the subtropical agro-climate of India. It has been developed by the Indian Institute of Sugarcane Research, Lucknow through biparental mating of 'CoLk 8102' x 'CoS 96260' (performed in the year 2000, at the National Hybridization Garden, Sugarcane Breeding Institute, Coimbatore). 'CoLk 07201' is an early maturing genotype with excellent ratooning ability, a rare combination of the two desirable attributes *viz*. high sugar yield and red rot resistance. It is tolerant to top borer.

This genotype was proposed for AICRP(S) testing in 2007 for the North western Zone and was tested in the Initial Evaluation Trial (IVT) in 2010-11, where it showed the highest cane yield along with red rot resistance. Based on its performance in the IVT, it was promoted to the Advance Varietal Trial (AVT). The first plant crop of AVT was raised in 2011-12 and the second plant and ratoon crops were grown in 2012-13.

The salient features of this clone observed during testing are as follows:

- Its CCS content (8.72 t/ha) was higher in comparison to checks 'CoJ 64' and 'CoPant 84211' (7.94 to 7.98 t/ha) over two plant crops and one ratoon across the test locations.
- 'CoLk 07201' was superior in CCS in different locations ranging from 6.25 percent at Sriganganagar to 30.99 percent higher at Lucknow over best check.
- It was the high yielder and gave 70-93.6 t/ha yield in first plant, 87.17-97.77 t/ha in second plant and 56-77.5 t/ha in ratoon at different locations.
- 'CoLk 07201' was 18.96 percent higher over best check in cane yield of two plant crops and one ratoon performance.
- It is 18 percent higher over 'CoJ 64' and 6 percent higher over 'CoPant 84211' in single cane weight.
- It possessed 3.2 % more stalk diameter over best check.
- It is resistant to moderately resistant, to red rot by both plug and nodal methods at all test locations. Red rot resistance is an important trait in the North western Zone.
- No incidence of smut, wilt, leaf scald, grassy shoot disease (GSD) or ratoon stunting disease (RSD) has been recorded under field conditions.
- It is one of the promising varieties recently identified by ISMA (Indian Sugar Manufacturers' Association) for trials in several factory zones in North Central and North Western Zones.
- It is one of the promising varieties in UP state varietal trial also.
- It is under evaluation in Bihar state as a promising genotype.

Fig 1. Field view of 'CoLk 07201'

It is evident that 'CoLk 07201' is an early maturing high sugar yielding genotype with very good ratooning ability. It has an erect bearing and is non-lodging, hence it is especially suited to the growing conditions of North western Zone. It has been a consistent performer and has recorded better performance in terms of cane productivity and juice quality over checks. It possesses resistance to red rot and smut and is tolerant to top borer and other pests (AICRP, PI's reports for Plant Pathology and Entomology for 2011-12and 2012-13). Its top remains green even in later stages of the crop, which extends its utility as green feed to animals.

'CoLk 07201' is a stable genotypes across the location of North Western Zone of sub-tropical India.

INDIAN JOURNAL OF SUGARCANE TECHNOLOGY

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INDIAN JOURNAL OF SUGARCANE TECHNOLOGY

Statements about Ownership and Other Particulars

Place of Publication	:	Lucknow
Periodicity of Publication	:	Half Yearly (June and December)
Publisher's Name	:	Dr. Sanjeev Kumar
Nationality and Address		Indian Hony. Secretary, The Association of Sugarcane Technologists of India, ICAR-Indian Institute of Sugarcane Research, Dilkusha P.O., Lucknow – 226002 India
Chief Editor's Name	:	Dr. Sangeeta Srivastava
Nationality and Address	:	Indian ICAR-Indian Institute of Sugarcane Research, Dilkusha P.O., Lucknow – 226002 India
Printer's Name and Address	:	Stuti Enterprises 326, Subhash Mohal, Sadar Lucknow - 226 002 India
Owner's Name and Address	:	The Association of Sugarcane Technologists of India, ICAR-Indian Institute of Sugarcane Research, Dilkusha P.O., Lucknow – 226002 India

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INDIAN JOURNAL OF SUGARCANE TECHNOLOGY

ISSN 0970-3233 Issue: Volume 31 No.2 December 2016

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