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Early generation selection for resistance to red rot (*Colletotrichum falcatum*) and sucrose content in sugarcane (*Saccharum* spp. Hybrids)

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ABSTRACT

Bi-parental, self and general crosses of *Saccharum* hybrid complex were attempted to evaluate the progenies of them for resistance to red rot caused *by Colletotricum falcatum* Went and its relationship with sugar content in juice during 2004-07. Seedlings of these families were transplanted in field during 2005-06. All the progenies were further advanced as ratoon crop in 2006-07. Each progeny in ratoon crop was inoculated by prevailing races and scored for disease reaction to red rot. Hand refractometer (HR) brix (%) was also recorded on the individual clump (plant) of each cross. A number of individual clones 'LG 05817' ('CoLk 8102' x 'ISH176') and 'LG 05823' ('CoLk 8102' x 'CoSe 95423') with high pol % (> 17.5%) exhibited moderately resistant reaction and clones with low pol % (< 15%) showed susceptible reaction and vice versa to red rot indicating no significant associations between HR brix % and red rot resistance (r=0.234) as well as pol % in juice and red rot resistance (r=0.315). Clone 'LG 05817' exhibited moderately resistant (MR) reaction to red rot pathotypes *Cf* 01, *Cf* 08, *Cf* 09 and resistant reaction to *Cf* 11. While, 'LG 05823' showed MR reaction to *Cf* 01, *Cf* 08, *Cf* 11 and moderately susceptible (MS) reaction to *Cf* 09, indicating durable resistance to this pathogen. Progenies of cross 'CoLk 8102' x 'ISH 176' also showed higher average brix % than the progenies of other families. Progenies of 'CoLk 8102' x 'ISH 176' also exhibited maximum variability for brix % (15.4 -21.1) and sucrose % (13.4 -18.34).

Key words: Resistance, Red rot, Early generation selection, Sugarcane

Sugarcane is an important cash crop in India. It occupies over 5.05 million hectare area in the country with a production of 348.19 million tonnes, out of which more than 66% is concentrated in the sub-tropical states. The production and productivity of sugarcane is severely affected by the various diseases. It is estimated that loss caused by diseases ranges from 10 to 25 per cent (Alexander and Viswanathan, 1996). In India, red rot (*Colletotrichum falcatum)* is considered as very serious disease in most of the states. This disease was responsible for the elimination of many commercial ruling varieties. At present, development of red rot resistant sugarcane varieties is the most important aspect of commercial breeding programme to manage the menace of this dreaded disease. Red rot has been effectively managed by growing resistant varieties of sugarcane in endemic areas. Identification of resistant varieties for multiple red rot pathotypes is the most important strategy to manage this disease among all other methods like seed selection, phytosanitary practices, crop rotation and seed treatment with fungicide. Screening of re**sistant** clones depends upon the different methods namely plug method of inoculation (Srinivasan and Bhat 1961), nodal method of inoculation (Singh and Budharaja 1964), seedling blast technique (Srinivasan 1962), nodal inoculation with cotton swab and controlled condition testing for red rot reaction (Mohanraj *et al*. 1997). A large number of sugarcane seedlings derived from true seeds of different bi-parental crosses were evaluated in sugarcane breeding programme. Progeny selection based on individual clump of a family has not been much effective in seedling as well as first clonal generation due to confounding effect of environment. This information can be utilized to retain or drop the parents from the crossing programme and other effective cross combinations could be planned for expected results.

MATERIALS AND METHODS

The material for the study consisted of progenies of seven bi-parental crosses, 01 general cross and 01 self of sugarcane (*Saccharum spp*. Hybrid complex). The crosses were attempted using resistant and susceptible genotypes at National Hybridization Garden, Coimbatore to study the resistance to red rot disease caused *by Colletotricum falcatum* Went in the progenies. Seedling progenies of these crosses were transplanted in field during 2005-06 at the main farm of the ICAR-Indian Institute of Sugarcane Research, Lucknow. Phenotypically poor (shy tillering, thin stem with narrow leaves and stunted growth) clumps were discarded. Selected clones from the seedling generation were inoculated by red rot pathotypes *Cf* 08 and *Cf* 09 using plug method of inoculation (Srinivasan and Bhat 1961) in the month of August 2006 and 2007. Further, eight selected clones namely 'LG 05806', 'LG 05809', 'LG 05810', 'LG 05817', 'LG 05821', 'LG 05823', 'LG 05828' and 'LG 05890' along with 'CoJ 64' and 'CoS 767' were inoculated using three pathotypes *Cf* 08, *Cf* 09 and *Cf* 11 during 2008-09. Clones 'LG 05817' and 'LG 05823' were again inoculated by *Cf* 01 during 2010-11 to validate its durability to resistance. Every year after 60 days of incubation period, canes were split open longitudinally and scored on a 0- 9 scale based on condition of top, progress of red rot lesion, width of lesion and presence of white spots. Progenies with resistant (R) and moderately resistant (MR) were categorized as resistant while moderately susceptible (MS), susceptible (S) and highly susceptible (HS) progenies were kept under susceptible category for disease reaction to red rot.

Brix (%) was also recorded on the individual clump of each cross. Individual progeny as well as family as a whole were used for selection mainly based on reaction to red rot symptoms, brix % and visual appraisal for cane yield attributes. Mean value of each family were computed to evaluate the performance of progenies within and between families. Cane yield and juice quality traits were recorded in selected clones. Standard analysis procedure was adopted to compute different statistical parameters.

Table 1 Disease rating scale (0 -9) for red rot resistance

Score	Red rot reaction
0.0 to 2.0	Resistant
2.1 to 4.0	Moderately resistant
4.1 to 6.0	Moderately susceptible
6.1 to 8.0	susceptible
8.1 to 9.0	Highly susceptible

RESULTS AND DISCUSSION

Family selection was effective in identifying them with a high proportion of elite clones. It was more efficient when red rot resistance combined with visual selection for plant growth, NMCs and plant height. The efficiency improved further when clones with good visual grade were subjected to hand refractometer brix. A number of individual clones with high pol % (> 17.5%) exhibited moderately resistant reaction and clones with low pol % (< 15%) showed susceptible reaction and vice versa. It indicates that no significant associations between HR brix % and red rot resistance (r=0.234) as well as pol % in juice and red rot resistance (r=0.315). Three families namely, 'CoLk 8102' x 'ISH 176', 'CoLk 8002' GC and 'CoLk 8102' x 'CoSe 95423' having resistant parents gave higher number of resistant progenies 7, 3 and 2, respectively (Table 2). Analysis of progenies of individual family showed

Table 2 Performance of families for red rot resistance and juice quality

Family	Seedling generation				First clonal generation		
	Red rot reaction		Selection	Brix %	Red rot reaction		Brix %
	R	S	**(%)**	(range**)**	R	S	(range)
'Co 7201' (S) x 'CoLk 94194' (R)	0	27	7.5	18.0-22.8	-	-	-
'Co7201' (S) x 'Co1148' (S)	1	14	10.7	16.0-21.2	1	0	20.2
'CoLk 8102'(R) x 'ISH 176' (R)	7	53	18.0	15.4-21.2	5	2	18.6-22.2
'CoLk 8102' (R) x 'CoSe 95423' (R)	2	24	3.5	16.6-20.0	2	0	19.4-20.2
'Co 7201'(S) x 'BO 91' (R)	1	26	15.4	15.6-19.0	0	1	20.0
'BO 91'(R) x 'ISH 100' (R)	2	17	11.1	19.4-20.0	1	1	20.0
'BO 91'(R) x 'ISH 107'(R)	1	21	9.2	18.4-20.2	1	0	20.4
'CoLk 8002' (R) GC	3	29	14.0	16.4-22.8	3	0	15.8-18.4
'CoLk 8102' (R) self	1	24	2.5	15.6-19.4	1	0	19.8

Table 3 Screening of selected clones in ratoon of seedling generation & first clonal generation (C1) for resistance to red rot

Clone	Parentage	Seedling ratoon			C_1 generation		
		HR brix	Red rot reaction		HR brix	Red rot reaction	
		%	*Cf* 08	*Cf* 09	%	*Cf* 08	*Cf* 09
'LG 05802'	'CoLk 8002' GC	20.5	MR	MR	19.0	MR	R
'LG 05803'	'CoLk 8002' GC	21.0	MR	MR	-	-	-
'LG 05805'	'CoLk 8002' GC	19.0	MR	MR	19.0	MS	MS
'LG 05806'	'CoLk 8002' GC	19.0	-	-	18.5	MR	MR
'LG 05807'	'CoLk 8002' GC	20.2	MS	MR	20.0	S	MS
'LG 05810'	'CoLk 8102' x 'ISH 176'	19.0	MR	MR	19.5	MS	MS
'LG 05821'	'CoLk 8102' x 'ISH 176'	18.6	MR	MR	-	-	-
'LG 05817'	'CoLk 8102' x 'ISH 176'	20.0	MR	MS	20.5	MR	MR
'LG 05818'	'CoLk 8102' x 'ISH 176'	21.5	MR	MR	20.5	MS	MS
'LG 05823'	'CoLk 8102' x 'CoSe 95423'	20.1	MR	MR	21.2	MR	MR
'LG 05826'	'CoLk 8102' x 'CoSe 95423'	21.5	MR	MS	20.2	MR	MR
'LG 05827'	'CoLk 8102' 'x 'CoSe 95423'	20.5	MS	MS	20.0	MR	MR
'LG 05828'	'BO 91' x 'ISH 100'	20.0	MS	MR	20.0	MS	MR
'LG 05830'	'Co 7201' x 'BO 91'	19.0	MR	MR	20.0	-	-

that ‘CoLk 8102’ x ‘ISH 176’ produced progenies with higher mean value for hand refractometer brix % in juice followed by ‘CoLk 8102’ x ‘CoSe 95423’ and ‘CoLk 8002’ GC in both seedling as well as second clonal generations. These families also gave clones with moderately resistant (MR) reaction to three pathotypes *Cf* 08, *Cf* 09 and *Cf* 11 of red rot indicating horizontal resistance to this pathogen. Shanthi *el al.* (2008) reported that performance of families could be judged on the basis of mean performance of progenies of individual family. It was noticed that early selection in cross ‘CoLk 8102’ x ‘ISH 176’ gave maximum number of promising progenies having higher brix % and resistance to red rot (Table 2 & 3). When eight selected advance clones of different families were evaluated for their performance with two standards ‘CoS 767’ and ‘CoJ 64’, marked variability was observed for the traits under study. Clones differed significantly for the traits such as sucrose %, CCS %, single cane weight (kg), cane yield (t/ha) and commercial sugar yield (t/ha). Magnitude of variance and coefficient for phenotype variance were higher than corresponding genotypic variance and coefficient of variation (Table 5). A perusal of Table 4 indicated that clone ‘LG 05817’ (‘CoLk 8102’ x ‘ISH 176’) exhibited moderately resistant (MR) reaction to three pathotpyes *Cf* 01, *Cf* 08 , *Cf* 09 and resistant reaction to *Cf* 11, while ‘LG 05823’ (‘CoLk 8102’ x ‘CoSe 95423’) showed MR reaction to three pathotpyes *Cf* 01, *Cf* 08 , *Cf* 11 and moderately susceptible (MS) reaction to *Cf* 09 confirming field resistance/ durable resistance to red rot pathogen.

CONCLUSION

Family and individual clonal selection could be a practical and cost-efficient method for Red rot resistance in early stage of selection in sugarcane breeding. Early generation selection based on the performance of progenies of individual family was effective in isolating desirable clones having good agronomic attributes. Two clones ‘LG 05817’ and ‘LG 05823’ having durable resistance to red rot pathotypes *Cf* 01 , *Cf* 08 , *Cf* 09 and *Cf* 11 could be used as donor parents to produce resistant genotypes.

Table 4 Performance of clones with durable resistance to red rot pathotypes

Clone	Parentage	*Cf* 01	*Cf* 08	*Cf* 09	*Cf* 11	Sucrose % 10 M	Sucrose % 12M	Cane yield (t/ha)
'LG 05810'	'CoLk 8102' x 'ISH 176'	-	MR	MR	MR	16.2	18.6	83.6
'LG 05817'	'CoLk 8102' x 'ISH 176'	MR	MR	MR	R	17.3	18.8	88.3
'LG 05823'	'CoLk 8102' x 'CoSe 95423'	MR	MR	MS	MR	15.5	19.0	92.0

Table 5 Yield and quality attributes of promising red rot resistant clones

Genotype	Red rot reaction			Cane yield (t/ha)	Pol % juice at 10 M	CCS %	Single cane weight (kg)	CCS (t/ha)
	Cf 08	*Cf* 09	*Cf* 11					
'LG 05823'	MR	MS	MR	92.0	19.0	13.05	0.85	12.00
'LG 05817'	MR	MR	R	88.3	18.8	13.11	0.65	11.58
'LG 05806'	MR	MR	MR	74.9	18.4	12.91	0.56	9.67
'LG 05821'	MR	MR	MS	76.2	16.5	11.08	0.62	8.44
'LG 05890'	MS	MS	R	71.4	18.1	12.13	0.64	8.66
'LG05809'	MS	MR	MR	79.5	18.6	12.73	0.84	10.12
'LG 05828'	MR	MR	MR	81.2	19.2	13.08	0.71	10.62
'LG 05810'	MR	MR	MR	80.4	18.4	12.94	0.58	10.40
'CoS 767'	S	S	S	56.4	18.2	12.47	0.69	7.03
'CoJ 64'	S	S	S	52.8	19.4	13.52	0.56	7.14
GM				75.31	18.46	12.70	0.67	9.57
SE m				1.90	0.20	0.04	0.01	0.25
SED				2.69	0.28	0.06	0.02	0.35
CD (0.05)				5.65	0.59	0.13	0.04	0.74
CV %				4.37	1.58	0.60	3.24	4.45
PV				156.23	0.66	0.47	0.01	2.94
GV				152.62	0.62	0.46	0.01	2.88
PCV				16.60	4.39	5.38	15.66	17.92
GCV				2.52	1.07	0.35	1.87	2.57

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'CoP 2061' – A released and notified mid-late maturing sugarcane variety for Bihar, Eastern Uttar Pradesh, Assam and West Bengal

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Variety is a cardinal importance in sugarcane cultivation. It should fulfil not only the requirements of cane in the early and mid late seasons but should also ensure high cane and sugar yield under varied climatic situation, free from diseases with low insect incidences of various kind which affect yield or recovery. The trial network of AICRP on Sugarcane are being conducted to enhance the productivity and sugar yield of the country. Presently in Bihar sugarcane is being grown on 2.98 lakh hectares with total production of 149 lakh tons of cane (2013-14) at an average cane yield of 50 tons per hectare. Cane and sugar yield of North Central and North Eastern Zone are lower in comparison to other Zones of India due to many factors which adversely affect yield. Among them, cultivation of low yielding sugarcane varieties is a major factor while another important factor is spreading of sugarcane varieties which are not recommended or released for this zone, which restricts optimum cane yield and sugar recovery in this zone. For proper availability of suitable and stable cane varieties in North Central and North Eastern Zone, the varietal improvement programme is being carried through All India Coordinated Research Project on Sugarcane at Pusa (Bihar), Motipur (Bihar), Gorakhpur (UP), Searohi (UP), Buralikson (Assam) and Bethuadahri (WB). The research efforts were made to identify high yielding and high sugar varieties tolerant to red rot and low incidence of insect pests under all the six varying ecological situation prevailing in this area. The result of carefully planned hybridization programme followed by rigorous selection for high yield and sucrose percent in juice reflected in the form of improved varieties released for cultivation in the area. This paper is aimed to discuss one of the end products of such concentrated effort and salient features of the newly released and notified variety 'CoP 2061'.

A Bi-parental cross was attempted between the high yielding variety 'CoLk 8102' as female parent and red rot resistant clone HR 83/65 as male at National Hybridization Garden, Sugarcane Breeding Institute Coimbatore (T.N.). The fluff of this cross was raised at Sugarcane Research Institute Pusa, Bihar. Clonal selection procedure was followed from the seedling nursery and the clone no. CoX 99110 was selected as mid-late maturing clone further named as 'CoP 2061' which was included in AICRP(S) crop improvement trial as per provided slot no. 'CoP 06436'. The testing of this variety was started during 2009-10 in initial varietal trial under NC & NE zone at all the centres. From 2010 to 2012, two plant crops were planted and one ratoon crop with all the package and practices for raising good crops at all the locations. Due to its good performances at Pusa (Bihar) this variety has already been released for commercial cultivation in Bihar during 2011 under the name 'CoP 2061'. While the performance of 'CoP 2061' for yield attributes and juice quality also showed superior one across the centres and over years in AICRP zonal trials. The Juice quality test at10 month and 12 month stage in plant crop and 11 month in ratoon crops, were conducted as per standard procedure (Meade and Chen, 1971). The morphological traits were observed as per standards suggested by Dutt *et al* (1974) at 10 to 12 months crop stage. The reaction to red rot, wilt and smut was observed in field condition and rated under artificial condition also. The number of millable cane, cane weight and cane height were reported to be yield contributing components (Mariotti 1987) The variety had produced higher number of millable cane, longer plant height, thicker cane diameter, moderate single cane weight and high CCS yield compared to other entries. The proposed name of this variety CoP 2061 was all ready mentioned in Proposal for Identification as well as in Proposal of Release and Notification of 'CoP 06436'. The variety has been registered and notified in the Gazette of India S.O. 268(E) dated

Fig 1. Field view of CoP 2061

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28 January, 2015. The seed of 'CoP 2061' shall be sold for Bihar, Uttar Pradesh, Assam and West Bengal.The mean performance of 'CoP 2061' over the locations across the years is discussed here under.

Cane and sugar yield: 'CoP 2061' showed consistence performance for cane and sugar yield in plant and ratoon crops across the all zonal centres over the years and trials. This variety recorded 9.18 t/ha commercial cane sugar yield which was 24.1%, 28.3% and 24.4% higher than the checks 'BO 91'(7.40 t/ha), 'CoP 9301' (7.12 t/ha) and 'CoSe 92423' (7.38 t/ha), respectively (Table 2).

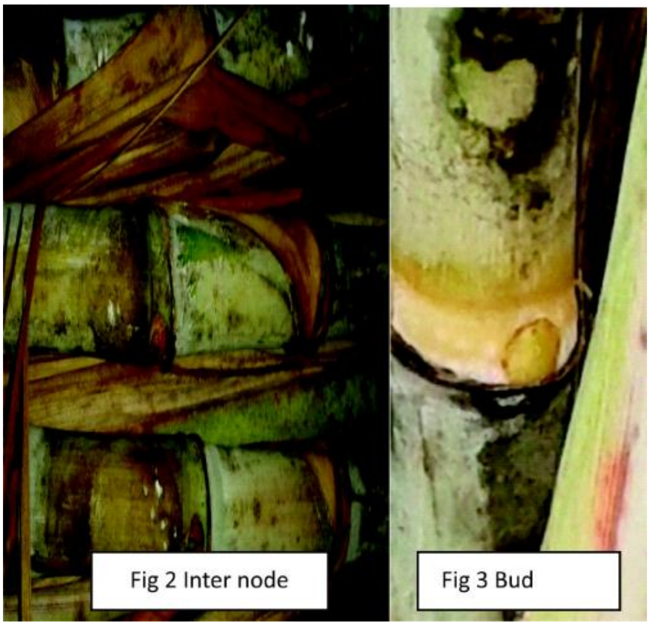

Fig 2 & 3. Inter node and Bud shape of 'CoP 2061'

The pooled mean for cane yield of 'CoP 2061' was recorded to be 77.61 t/ha which was 25.1%, 34.4% and 24.0% higher than the checks 'BO 91'(62.04 t/ha), 'CoP 9301' (57.75 t/ha) and 'CoSe 92423'(62.58 t/ha), respectively (Table 2). Table 2 further revealed that 'CoP 2061' surpassed all checks in multi-location trials conducted at Pusa (Bihar), Motipur (Bihar), Seorahi (U.P.), Gorakhpur (U.P.), Buralikson (Assam) and Bethuadahari (W.B.) under North Central and North Eastern zone by a margin of more than 10% for cane and sugar yield.

Performance of yield component: 'CoP 2061' recorded (Table 2) good germination percent (48.12%), high number of tillers (141830/ha) as compared to all the three checks in different trials over the years across the centres. 'CoP 2061' recorded 18.03% and 12.5% higher single cane weight than 'BO 91' (0.61 Kg) and 'CoP 9301' (0.64 Kg). The check 'CoSe 92423' (0.73 Kg) was best for single cane weight. The cane diameter of 2.33 cm was recorded maximum for 'CoP 2061' followed by the checks 'CoSe 92423' (2.30 cm), 'CoP 9301' (2.19 cm) and 'BO 91' (2.10 cm) over the years. The recorded cane length was 237.2cm for 'CoP 2061' which was higher than 'CoSe 92423' (225.60 cm), 'BO 91'(219.20cm) and 'CoP 9301'(215.67 cm) over the year across locations.

Performance of Juice Quality traits: An overview given in table 2 indicated that 'CoP 2061' recorded 11.77% commercial cane sugar (percent) in juice at harvest which is *at par* with 'BO 91'(11.77%), 'CoP 9301'(12.20%) and 'CoSe 92423'(11.66%). The sucrose percent in juice at harvest (17.13%) and purity percent in juice at harvest (88.46%) of variety 'CoP 2061'was also found *at par* with checks. The pol percent in cane at harvest of 'CoP 2061'was 13.85% while the best check 'CoP 9301' had 14.43%. In 'CoP 2061' extraction percent of juice at harvest was 53.67% which was at par with all the checks. Lowest fibre percent in cane at harvest was recorded in 'CoP 9301' (13.30%) and CoP 2061(13.33%) indicating suitable for crushing with good juice quality.

Performance of ratoon crop: Cane and sugar yield of 'CoP 2061'were higher than the checks in ratoon crop. 'CoP 2061' recorded 71.79 t/ha cane yield in ratoon crop which was 25.75 %, 28.01% and 21.16% higher yield than 'BO 91', 'CoP 9301' and 'CoSe 92423' respectively. The commercial cane sugar t/ha at harvest in ratoon crop was also 24.49 %, 23.03% and 21.86% higher than 'BO 91', 'CoP 9301' and 'CoSe 92423' respectively. In respect to sucrose percent in juice at harvest in ratoon crop 'CoP 2061' recorded 17.26% which was *at par* with 'BO 91'(17.07%), 'CoP 9301'(17.57%) and 'CoSe 92423'(16.97%). Other parameters *viz*, higher number of tillers, number of millable cane, higher single cane weight, thicker cane diameter and longer cane height in ratoon crop indicated very good ratooning ability of 'CoP 2061'.

Reaction to diseases: Year wise data given in table 3 indicated that no disease was observed in 'CoP 2061' during 2009 to 2012 after artificial inoculation of isolates of red rot. For Wilt, this variety showed moderately resistant reaction while for Smut disease it shoed resistant reaction. It means male parent 'HR 83/65' of this variety 'CoP 2061' is responsible for disease resistance.

Distinguishing morphological features: 'CoP 2061' could be identified by its erect stool habit, the cylindrical internode and straight alignment without ivory marks, weather marks, splits and bud groove. The swollen node bears small round ovate bud (Plate 3). Medium width green leaves without spines on leaf sheath with purple blotches, Semi clasping and drooping carriage. The distinguishing bud character can be seen in Plate1, 2 & 3.

CONCLUSION

This variety recorded taller cane (237.20 cm), moderate single cane weight (0.72 kg), thicker cane diameter (2.33cm), large number of shoots (141.83 thousand/ha.) and millable canes (116.49 thousand/ha) surpassing most of the checks with high cane and sugar yield. The variety was found resistant to

Table 1 Distinguishing morphological features of newly released sugarcane variety CoP 2061

Morphological traits as per Descriptor		Descriptor status of 'CoP 2061'
Clone number		CoX 99110
Stool habit (erect/semi crept)	:	Erect.
*Stem colour (exposed)	:	Dirty green
Stem colour (unexposed)	:	Light Green
Ivory marks (Present/absent)	:	Absent
Weather marks (corky potches, Present/absent)	:	Absent
Inter node shape (as per Artschwager, 1940)	:	Cylindrical
Inter node alignment(straight/zig-zag)	:	Straight
Pithiness (Absent/medium/high)	:	Absent
Splits on the internodes (Absent/medium/heavy)	:	Absent
Wax on the internodes (Low/medium/heavy)	:	Medium
Node swelling (Swollen/not swollen)	:	Swollen
Root zone colour (exposed)	:	Light green to purple
Root zone colour (unexposed)	:	Pale yellow
No. of root eyes rows	:	1 to 2
Arrangement of root eyes	:	Irregular
Bud size(Big/medium/small)	:	Small
Bud shape (as per Artschwager, 1940)	:	Round ovate
Bud cushion(Present/Absent)	:	Absent
Bud germpore position (Apical/medium/sub-medium)	:	Medium (Below growth ring)
Bud groove (Present/Absent)	:	Absent
Growth ring colour	:	Greenish yellow
Leaf length (1st transverse leaf of 180th days).	:	146.0 cm
Leaf width (1st transverse leaf of 180th days)	:	4.75 cm
Lamina colour	:	Dark green
Leaf carriage shape	:	Drooping
Leaf sheath colour	:	Green with purple tinge.
Leaf sheath waxiness	:	Medium
Leaf sheath spines	:	Absent
Leaf sheath clasping (self detrashing/semi clasping/strong clasping)	:	Semi clasping
Dewlap colour (at 10 months)	:	Dirty green
Presence or absence of ligular process	:	Present
Shape of the auricles	:	Presence of hairs in place of the auricles
Percentage of flowering	:	Non flowering.

* Colour of stem recorded at IV inter node from the base, two months after detrashing.

Table 2 Summary of performance of 'CoP 2061' in zonal varietal trial of North Central and North Eastern Zone AICRP(S).

Yield and Juice Quality traits		Checks		
Yield Attributes	**'CoP 2061'**	'BO 91'	'CoP 9301'	'CoSe 92423'
Commercial Cane Sugar Yield(t/ha)	**9.18**	7.40	7.12	7.38
Cane Yield(t/ha)	**77.61**	62.04	57.75	62.68
No. of Millable Cane (000/ha)	**116.49**	104.37	107.01	96.66
Single Cane Weight (Kg.)	**0.72**	0.61	0.64	0.73
Cane Length (cm)	**237.20**	219.20	215.67	225.60
Cane Diameter(cm)	**2.33**	2.10	2.19	2.30
No. of tillers (000/ha)	**141.83**	134.67	136.87	128.83
Germination Percent	**48.12**	44.00	40.18	39.97
Juice Quality traits				
Sucrose percent in juice at harvest	17.35	17.19	**17.95**	16.99
Purity percent in juice at harvest	**88.46**	86.7	86.52	87.10
CCS percent in juice at harvest	**11.77**	11.77	12.20	11.66
Pol percent in Cane at harvest	13.85	13.88	**14.43**	13.79
Extraction percent of juice at harvest	**53.67**	51.31	53.88	51.09
Fibre percent in cane at harvest	13.33	13.50	**13.30**	15.18

Table 3 Summary of Disease reaction such as red rot, wilt and smut for the 'CoP 2061' and checks during 2009-2012.

Diseases	Year	'CoP 2061'		Check varieties					
				'BO 91'		'CoP 9301'		'CoSe 92423'	
		Score	Rating	Score	Rating	Score	Rating	Score	Rating
Red rot	2009-10	1.2	R	1.1	R	1.3	R	5.2	MS
	2010-11	1.1	R	1.2	R	1.6	R	5.8	MS
	2011-12	1.0	R	1.1	R	1.4	R	3.8	MR
Smut	2009-10	0.0	R	0.0	R	0.0	R	8.8	MR
	2010-11	0.0	R	1.6	MR	1.9	MR	7.9	MR
	2011-12	0.0	R	2.5	MR	2.3	MR	4.5	MR
Wilt	2009-10	2.4	MR	1.7	MR	2.7	MR	5.3	MR
	2010-11	3.1	MR	2.6	MR	1.9	MR	3.7	MR
	2011-12	3.6	MR	1.9	MR	1.3	MR	7.8	MR

red rot disease, wilt and smut under field condition. The resistance ability against red rot contributed from male parent HR 83/65 and the contribution of high yielding coupled with high sugar ability from female parent i.e. 'CoLk 8102'. This variety will play a great role in enhancing 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 May, it does not flower and remain green till harvest which is another advantage to use its top as a fodder. This variety has already been released by Research Council of RAU, Pusa for its commercial cultivation in Bihar in 2011.The registration and notification by Central variety release committee in the Gazette of India has open an window for its wider cultivation in North Central and North Eastern Zone comprising Eastern Uttar Pradesh, West Bengal and Assam. It is expected that the variety 'CoP 2061' will replace 'BO 91' in coming years through its adaptability in subtropical as well as in tropical condition also.

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Effect of drip irrigation and fertigation on growth and yield of sugarcane

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ABSTRACT

A field experiment was conducted to find out optimum drip irrigation and fertigation schedule for sugarcane in sandy loam soil at Agricultural Research Station, Sriganganagar during 2005-06 to 2007-08. The treatments comprising of the combination of two levels of irrigation (drip irrigation at 50+70% PE & 70+100% PE on alternate day), three levels of fertigation (75, 100 & 125% RD of N & K) and two levels of time of fertigation (9 equal splits at an interval of 21 days & 12 equal splits at an interval of 15 days) along with one control (recommended practice of irrigation and fertilizer application). The pooled results of three years study revealed that irrigation levels significantly influenced plant height, length of inter node and cane yield. Drip irrigation scheduled at 50+70% PE & 70+100% PE increased cane yield by 15.5 and 34.1 percent, respectively over that of conventional flood method of irrigation. The saving of irrigation water in respective drip irrigation treatments was 44.1 & 22.2 % over that used in flood irrigation treatment. Fertigation levels as well as fertigation splits did not influence cane yield and yield attributes. Fertigation with 75% recommended dose of N and K_2O in 9 equal splits at an interval of 20 days was found optimum for sugarcane. Drip irrigation was found more economic than conventional flood irrigation.

Key words: Sugarcane, Fertigation, Drip irrigation, Growth and Yield

Sugarcane is an important and major cash crop in India. India's water demand will nearly double in 2030 from present 740 billion m^3 to trillion m^3. The demand of water for agriculture, industry and power generation is competing and increasing with progressive increase in the population and development of human societies. These two factors are inevitable and therefore, satisfying the increasing water needs for various sectors always remains a matter of concern. Hence, efficient water management for improving agriculture productivity is inevitable. Sugarcane being a long duration crop requires considerable quantity of water to the extent of 1400-1500 mm in the subtropics (Solomon 2012). Its peak water requirement coincides with the crucial deficit period. Providing optimum soil moisture conditions throughout the crop growing period however, is of paramount importance to realize higher yields (Sundara 1998). Drip fertigation, one of the potential technologies, offers the great scope to increase cane productivity up to 200-220 t/ha (Senthil Kumar 2009), saves 40-50% irrigation water and enhance nutrient efficiency by 40% (Solomon 2012). Fertigation with conjunctive use of fertilizer nutrients and irrigation water offers the possibility to optimize the water and nutrient distribution over time and space (Nanda 2010). The present study was therefore, conducted to find out optimum irrigation and fertigation schedule for sugarcane in irrigated north west plain zone of Rajasthan.

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MATERIALS AND METHODS

A field experiment was conducted to find out optimum irrigation and fertigation schedule for sugarcane at Agricultural Research Station, Sriganganagar, Rajasthan during cropping season of 2005-06 to 2007-08. The soil of the experimental field was sandy loam in texture with pH 8.2, organic carbon 0.20%, available P_2O_5 43 kg/ha and K_2O 320 kg/ha. The treatments comprising of the combination of two levels of drip irrigation (I_1-50% PE in April & May and 70% PE from June onward, I_2-70%PE in April & May and 100% PE from June onward), three levels of fertigation (F_1-75%, F_2-100%, F_3-125% recommended dose of N & K) and two timings of fertilizer application (S_1-9 Splits each at 20 days interval, S_2-12 Splits each at15 days interval) along with control treatment of surface irrigation (boarder strip) and recommended dose of fertilizer. The experiment was conducted in Randomized Block Design with three replications for evaluating thirteen treatments. Drip irrigation was applied on alternate day as per treatment and flood irrigation was scheduled at IW/CPE 1.0. The recommended dose of N, P_2O_5 & K_2O for sugarcane was 150, 40 and 40 kg/ha, respectively. Nitrogen and potash were applied in 9 and 12 equal splits as per treatment in fertigation treatments. In flood irrigation treatment N was applied in three splits, one third by drilling at planting in February, one third as top dressing in June and remaining one third as top dressing in August and full dose of potash was applied as basal at the time of planting. A basal dose of 40 kg P_2O_5/ha was applied at the time of planting in all the treatments. Nitrogen was applied through urea, potash through muriate of potash and phosphorus through single super phosphate. The sugarcane variety

'Co-6617' was planted on 26.02.2005, 21.02.2006 and 23.02.2007 and harvested on 31.01.2006, 22.01.2007 and 18.02.2008 in the respective seasons. In surface method 16, 14 and 13 post sowing irrigations and in drip system 127,114 and 96 irrigation events were applied in 2005-06, 06-07 and 07-08, respectively. The rainfall during respective season was 199.6, 240.5 and 421.7 mm. The observations on plant height, number of tillers, length and diameters of tillers and cane yield recorded at the respective growth and harvesting stages. Rrecommended package of practices were followed in the experiment. A pre-sowing irrigation of 100 mm was applied by surface method of irrigation in experimental area to ensure good germination. Ground water level in the experimental area was beyond ten meters.

RESULTS AND DISCUSSION

Water use and water use efficiency

Drip irrigation was applied to the crop on alternate day and average 112 irrigation events were given as against 14 post-sowing irrigations in surface method of irrigation. In surface irrigation 1395 mm irrigation water was applied as against 780 mm in drip irrigation at 50% +70% PE and 1086 mm in drip irrigation at 70% +100% PE treatments (Table 1). Drip irrigation at 50% +70% PE and 70% +100% PE saved 22 and 44 per cent irrigation water in comparison to surface irrigation. The water use efficiency in drip irrigation treatments was more than 1.5 times higher than that of surface irrigation. Mahadkar *et al.* (2005) reported 42.7 per cent water saving in drip irrigated sugarcane in comparison to surface method of irrigation in deep black soil of Rahuri in Maharastra.

Yield and yield attributies

The pooled data of three years revealed that irrigation schedule significantly influenced plant height, length of inter node and cane yield (Table 2). Within drip treatments irrigation scheduled at 70+100% PE gave significantly higher plant height, length of inter node and cane yield in comparison to its lower level at 50+70% PE. Flood irrigation treatment gave the minimum plant height, length of inter node and cane yield among the three treatments. Drip irrigation scheduled at 50+70 % PE and 70+100% PE gave 15.5 and 34.1 per cent higher

Table 1 Effect of irrigation schedules on water use and water use efficiency (pooled mean of 3 years)

Irrigation schedules	Irrigation water applied (mm)	Water use** (mm)	Water use efficiency (kg/ha mm)
50% PE April & May & 70 % PE June onward by drip system	780	1067.3	54.9
70% PE April & May & 100 % PE June onward by drip system	1086	1373.3	49.6
Surface irrigation (Boarder strip)	1395*	1682.3	30.2

*including 25 per cent conveyance losses, **including 287.3 mm effective rainfall

Table 2 Effect of different treatments on yield and yield attributes of sugarcane (pooled mean of 3 years)

Treatments	Plant height (m)	No. of tillers/ square m	Length of inter node (cm)	Diameter of inter node (cm)	Cane yield (q/ha)
Irrigation Levels					
I_1 - 50% PE in April & May & 70 % PE from June onward by drip system	1.75	26.67	12.17	2.41	586.42
I_2 70% PE in April & May & 100 % PE from June onward by drip system	1.91	28.42	13.59	2.46	680.95
Surface irrigation (Boarder strip)	1.70	26.89	11.95	2.35	507.82
S Em $\pm$	0.04	0.89	0.36	0.03	19.92
CD at 5%(Drip)	0.11	NS	1.03	NS	57.93
CD at 5%(Drip v/s Surface)	0.18	NS	1.34	NS	78.05
Fertilizer Dose (N & K)					
F_1 - 75% of RD	1.80	27.61	12.59	2.44	612.81
F_2 -100% of RD	1.83	27.14	12.77	2.42	620.21
F_3 - 125% of RD	1.86	27.89	13.28	2.46	668.03
S Em $\pm$	0.05	1.09	0.43	0.04	24.40
CD at 5%	NS	NS	NS	NS	NS
Time of fertilizer application (N&K)					
S_1 - 9 Splits at 20 days interval	1.79	28.06	12.76	2.43	636.51
S_2 - 12 Splits at 15 days interval	1.87	27.04	12.99	2.45	630.86
S Em $\pm$	0.04	0.89	0.36	0.03	19.92
CD at 5%	NS	NS	NS	NS	NS

Table 3 Benefit cost analysis of surface and drip system of irrigation in sugarcane

Particulars	Method of Irrigation	
	Surface	Drip
Fixed Cost (Rs.)	--	100000
Life (years)	--	12
Depreciation (Rs/year)	--	8333
Interest (12% yearly)	--	12000
Maintenance & running cost	--	2000
Cost of cultivation (per ha)	102460	100000
Total cost (Rs/ha)	102460	122333
Irrigation Water used (mm)	1395	1086
Cane yield (q/ha)	507.8	680.9
Selling price (Rs/q)	295	295
Return from produce (Rs)	149801	200865
Net income (Rs)	47341	78532
Additional area cultivated due to water saving (ha)	--	0.28
Additional expenditure due to additional area cultivated (Rs)	--	34253
Additional return due to additional area (Rs)	--	56242
Additional net income (Rs)	--	21989
Gross cost of cultivation (Rs)	102460	156586
Gross return (Rs)	149801	257107
Net total income (Rs)	47341	100521
Benefit cost ratio	0.46	0.64

cane yield in comparison to to surface irrigation treatment. The higher plant height and more length of inter node under drip system of irrigation may be ascribed to availability of moisture and nutrients at optimum level under drip irrigation which resulted higher cane yield of the crop. Dhindwal *et al.* (2005) reported 17 to 29 per cent higher sugarcane yield under drip irrigation in comparison to conventional flood irrigation in sandy loam soil of Hisar in Haryana. Different fertilizer dose treatments through drip system did not influence cane yield and yield attributes. Thus, fertigation at 75 per cent recommended dose of N and K was sufficient to meet the requirement of the crop. Time of fertilizer application also did not influence the yield and yield attributes of sugarcane. However, numerically higher cane yield was recorded with 9 splits of N and K at 20 days interval in comparison to 12 splits at 15 days interval.

Economics

The net return and benefit cost ratio was calculated under surface and drip method of irrigation assuming 12 years life of drip system and installation cost Rs 1,00,000 per hectare (Table 3). The net income under surface and drip was Rs. 47,341 and Rs. 78,532 per hectare respectively. At recommended drip irrigation schedule of 70 +100% PE, 28 per cent additional area may be cultivated with the saved irrigation water as land is not the constraint. When additional area is considered, the net income under drip raised to Rs. 1,00,521. The benefit cost ratio under drip was 0.64 as against 0.46 under surface irrigation. Thus, drip irrigation was found economically viable for sugarcane crop in irrigated north west Rajasthan.

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Growth, yield and quality of autumn sugarcane as influenced by phosphorus levels and P.S.B. inoculation in legume based inter- cropping systems

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ABSTRACT

Field trials were carried out to test the efficiency of phosphorus solubilizing bacteria (P.S.B.) in cane + pea inter-cropping systems on solubility of applied phosphorus during autumn seasons in soil. The treatment 80 kg P_20_5/ha produced more number of shoots, millable canes and recorded significantly higher cane yield (92.74 t/ha) than the 0 kg P_20_5/ha during both the years. Cane + pea (inoculated with *Rhizobium*) + P.S.B. @ 6 kg/ha gave significantly higher cane yield (92.61 t/ha) than the cane alone without P.S.B. during both the years. C.C.S. per cent were not affected significantly due to various P levels and inter-cropping systems.

Key words: Phosphorus, Legume, autumn, sugarcane, P.S.B., *Rhizobium*, inoculation.

Sugarcane is the main source of sugar in India and holds a prominent position as a cash crop. It is well known that sugarcane is a large duration crop and in early stages much wide spaces are there in between rows, hence inoculation of appropriate legumes as inter-crop reduces the cost of production per unit area and appreciably meets nitrogen requirement of sugarcane. Due to alkaline nature of soil substantial quantity of P unavailable to plant P.S.B. are used which could solubilize it into available form (Banger *et al*., 1993).

MATERIALS AND METHODS

Field trials were conducted in sandy loam soil (pH 7.4) at Sugarcane Research Farm, Shahjahanpur during two years in autumn seasons. The soil was low in organic carbon, available phosphorus and medium in potassium. The experiment was laid out in split-plot design with three replications allocating main plot to P levels and sub-plot to inter-cropping systems. P levels were 0, 40 and 80 kg/ha and P.S.B. culture @ 6 kg/ha was mixed with compost @ 50 kg/ha and applied on the side of cane rows after cane planting in between the cane rows. Sugarcane variety ‘CoS 94275’ (mid late maturing) was the test crop. 200 kg N, 60 kg K_2O and Phosphorus was applied as per treatment. The observations were recorded on number of shoots, millable canes, cane yield and quality parameters at harvest stage.

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RESULTS AND DISCUSSION

Cane yield is a function of growth, development attained and production of biomass and its partitioning into components which constitute yield. These attributes increased continuously up to harvest. Phosphorus levels had favorable effect on almost all the growth attributes like number of shoots and millable canes.The growth parameters such as number of shoots and millable canes were influenced significantly due to treatments during both the years. 80 kg P_20_5/ha gave significantly more number of shoots, millable canes and cane yield than the 0 kg P_20_5 h^{-1}. Among inter-cropping systems the treatments having P.S.B. @ 6 kg/ha increased the shoots, millabe canes and cane yield than the cane alone where no P.S.B. culture was applied during both the years because phosphorus application is known to improve the root growth and early vigour of plants and resulted in better growth being manifested through growth parameters like increase in number of shoots and millable canes. Kadam *et al.* (1993) clearly indicated significant increase in shoots and millable canes due to phosphors application. Malic *et al.* (1982) and Pannu *et al.* (1985) endorsed that application of phosphorus promotes root growth, stimulate tillering and lastly number of millable canes.

Application of P.S.B. which is known to produce vitamins (Baya *et.al.* 1981) and growth harmones (Sattar and Gaur 1987) which is likely to favour increased number of shoots and milable canes. Since phosphorus creates more favourable situation for symbiosis between plants in terms of supply of photosynthates to bacteria and *Rhizobia* which are known to feedback the host plants with fixed nitrogen. Use of bio fertilizers can serve as supplementry source and become economic for the use of nitrogen in sugarcane. Effect of P.S.B. culture was found more pronounced in the systems and these observations suggested that P.S.B. culture is more effective in solubilising the native soil phosphorus (Mohod *et al.*1989). The growth attributes like shoots, number of millable canes are primary requirements for development of immediate yield components, such as cane length, cane weight, number of internodes per cane, cane girth. However, it is not sufficient to say that these yield components are correlated with yield but its is more important to analysis different factors such as phosphorus levels, P.S.B. inoculation, which influence the yield components and ultimately the improvement in cane yield. The increase in yield components due to phosphorus application might be due to low initial phosphorus status in the soil, which is considered to be low for the pea legume and sugarcane yield also. Application of phosphorus also enhanced nodulation in the legumes probably because it activated the *Rhizobia* on one hand and enhanced plant growth on other hand as it is evidant from length and weight of canes, thus led to better development of yield attributes and this is also due to efficient translocation of photosynthates to the reproductive parts and retention of higher percentage of flowers of increase in yield.

Ramesh (2000) opined that cane and sugar yield were significantly and negatively correlated with decrease in phosphorus and positively correlated with K from tillering to grand growth (120 to 240 days) and from tillering to maturity (120-360 days) phases. Similar result was endorsed by Tiwari and Nema (1999).

Green pod yield of pea was also recorded significantly with 80 kg P_20_5/ha (61.34 q/ha). Inoculation of pea seed gave higher green pod yield than the systems where pea seeds were not inoculated. Increased cane yield due to P.S.B. culture was also confirmed with the results of Yadav and Prasad (1987) and Yadav and Singh (1990). These factors in combination with better nutritional condition due to increase in P availability in soil might have played role in increasing yield of pea and cane crop. The P.S.B. perhaps solubilize more native soil P.

Economics of the treatments

Data clearly showed that highest B:C ratio was obtained (2.53) from the 80 kg P_20_5/ha. In respect of P.S.B. application cane + Pea (inoculated with *Rhizobium*) + P.S.B. @ 6 kg/ha gave highest B:C ratio (2.64). These results also have conformity with results of Shankaraiah *et al.* (2000) and Kathiresan *et al.* (1993).

Juice quality parameters

All juice quality parameters like brix, sucrose and commercial cane sugar (CCS) in juice increased with increasing P levels during both the years. Germination and CCS per cent were not affected significantly due to P levels and inter-cropping systems. Numerically, CCS per cent increased due to increasing P levels but differences were not

Table 1 Growth, cane yield, CCS %, green pod yield and B:C ratio as influenced by application of P.S.B. and P levels (mean of two years)

Treatments	Germi. (%)	Green pod Yield (q/ha)	Shoots (000/ha)	Millable canes (000/ha)	Cane yield (t/ha)	C.C.S (%)	B:C ratio
P levels							
0 kg P_20_5/ha	40.84	46.29	127	95	82.12	10.27	2.20
40 kg P_20_5/ha	41.10	52.83	149	111	87.47	10.39	2.35
80 kg P_20_5/ha	41.53	61.34	153	120	92.74	10.46	2.53
S.E±	**0.21**	**0.28**	**5.64**	**4.53**	**0.82**	**0.11**	**-**
C.D 5%	**N.S.**	**0.78**	**11.29**	**8.26**	**2.28**	**N.S.**	**-**
Inter-cropping systems							
Autumn cane alone + no P.S.B.	40.74	-	131	97	84.89	10.85	2.07
Cane + P.S.B. @ 6 kg/ha	40.67	-	143	114	88.34	10.95	2.14
Cane + pea (un. Ino.) + no P.S.B.	40.65	49.69	139	100	84.02	11.10	2.35
Cane + pea (un. Ino.) + P.S.B. @ 6 kg/ha	41.15	52.00	146	111	87.67	11.14	2.44
Cane + pea (Ino. With *Rhiz.*) + no P.S.B.	41.50	54.38	148	118	87.11	11.07	2.49
Cane + pea (Ino. With Rhiz.) + P.S.B. @ 6 kg/ha	41.70	57.87	153	123	92.61	11.36	2.64
S.E±	**0.23**	**0.30**	**2.48**	**2.20**	**1.02**	**0.28**	**-**
C.D 5%	**N.S.**	**0.63**	**5.56**	**4.49**	**2.07**	**N.S.**	**-**

up to the level of significance. Interaction between phosphorus levels and application of P.S.B. in inter-cropping systems were found to be non-significant during both the years. Kadam *et al*. (1993) also reported that CCS% was unaffected by incorporation of pulses.

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Divergence analysis in sugarcane germplasm under alkaline conditions

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ABSTRACT

A study was conducted to estimate the nature and magnitude of genetic diversity in sugarcane germplasm at the farm of Sugarcane Research and Seed Multiplication Centre, Katya Sadat, Ghazipur. A total of 30 entries selected from germplasm were planted in Randomized Block Design with three replications during 2009-11 to 2011-13. The assessment of genetic diversity was based on eight quantitative and qualitative traits. The analysis of variance showed significant differences among the accessions for each character studied. D^2 values varied from 13.43 to 45.89 showing higher divergence among the traits. No relationship was observed between geographical and genetic diversity in sugarcane. All the entries under study were grouped into seven non over lapping clusters in such a way that the varieties within the cluster had smaller D^2 values among themselves than those belonging to two different clusters. On the basis of the clusters distance and performance of the varieties under alkaline condition, it may be concluded that the crosses between 'CoSe 98231', 'CoSe 92423', 'CoSe 01434' and 'BO 91' or 'UP 9530' would to be more beneficial in producing potential varieties for cultivation in alkaline condition area than others.

Key words: Divergence, Sugarcane, Germplasm, Alkaline condition

Sugarcane is one of the most important food crops of the tropics and subtropics which is cultivated in about 121 countries encompassing approximately half of the world. The present varieties of sugarcane are complex hybrids derived from the inter-specific crosses involving *Saccharum officinarum* (2n=80) and *S. spontaneum* L. (2n=128) species. Genetic divergence among the parents is a prerequisite to improve chances of selecting better segregants for various characters. Creation of variability and selection of superior recombinant among the variants are the major objectives of any plant breeding programme. According to Atkin *et al.* (2009) and Sanghera *et al.* (2014) the most important factors in sugarcane breeding and production is the choice of a variety. Different varieties have their different yield potential, insect pest and disease resistance behaviour and are bred for different ecological and economic conditions. Selection of diverse parents belonging to distant groups lead to a wide spectrum of gene combination for quantitative and qualitative inherited traits. Any genetic investigation carried out on the quantitative characters becomes complicated when more than one environment is considered because of the change in the gene expression that may occur with change in the environment. Varieties belonging to distinct geographic regions are usually selected for hybridization programme presuming presence of considerable genetic diversity among them. Genetically diverse genotypes are used as parents in hybrids breeding programme to generate a wide range of variability in the segregating population for enhancing the probability of new phenotype expression due to accumulation of maximum desirable genes. Highly diverse parentage are more useful in a hybridization programme than those having close affinities at genetic level. According to Arunachalam (1981), Mahalanobis D^2 statistics is one of the best methods of distance analysis and being used extensively in all crops. The agriculture land (under crop cultivation) is shrinking day to day due to increasing population and urbanization of the available land. A large area comes under alkaline stress condition in North India and left partially or uncultivated. Production of sugarcane in stress area is lower than normal one. The aim of breeders is to improve the yield and sugar by developing the suitable varieties for specific abiotic conditions.

Keeping these views in mind the present study was undertaken to estimate the nature and magnitude of genetic diversity in sugarcane germplasm under alkaline condition to identify contrasting parental candidates for future breeding programme to evolve suitable genotypes cultivation under alkaline soil condition.

MATERIALS AND METHODS

The study was carried out to estimate the nature and magnitude of genetic diversity in sugarcane germplasm at the farm of Sugarcane Research and Seed Multiplication Centre, Katya-Sadat (Ghazipur) (Latitude $54^0 41^1$ N, Longitude $84^0$38'E and 74 meter above the mean sea level). A total of 30 entries of different species as well as commercial hybrids were selected from the sugarcane germplasm maintained at the farm of Sugarcane Research Institute, Shahjahanpur (U.P.). The farm of research station is highly affected by alkaline condition. The status of the experimental field was on an average pH 8.56, EC 0.66 ds/m , organic carbon 3.84 g/kg available phosphorus 7.74kg/ha and available potash 1.94kg/ha. The experiment was planted in randomized block design with 3 replications in autumn planting season during three consecutive years 2009-11 to 2011-13. The entries were planted in single rows of 3 meter length spaced at 90 cm, in each replication. Twelve healthy buds were planted per running meter. The recommended agronomical cultural practices were followed and fertilizers were given as per recommendations to raise an ideal crop. Data on number of germinant per plot, number of shoot per plot, number of millable canes per plot, stalk height (m), stalk thickness (cm), single stalk weight (kg), yield per plot (kg) and HR brix % (November) were recorded timely. These observations were subjected to analyses of multivariate analysis D^2 statistics according to Mahalanobis (1936). The grouping of genotypes in different clusters was done as per Torcher's method (Rao, 1952).

RESULTS AND DISCUSSION

The analysis of variance showed significant differences among the accessions for each trait under the study indicating the genetic potentiality of the population capable of producing sufficient variability. The computed inter cluster D^2 values varied substantially from 13.43 to 45.89 showing the high divergence among different traits. On the basis of relative magnitude of D^2 values, all the 30 entries were grouped into seven clusters so that the varieties within the cluster have smaller D^2 values among themselves than those belonging to two different clusters. Six varieties were accommodated in cluster I, 2 in cluster II, 7 in cluster III, 4 in cluster IV, 3 in cluster V and VII and 5 in cluster VI. The seven non overlapping clusters consisted of entries of different origin clustered together as well as into different clusters. Conversely the hybrids of the same geographical origin were also found in different clusters. The data presented in Table 1 revealed that entries from different locations are accommodated in the same cluster and suggesting their clonal affinity. No relationship was observed between geographical and genetic diversity in sugarcane. These result confirmed that geographical diversity may not necessarily be related to genetic diversity has also opined earlier Rai and Singh, 1990; Singh and Singh, 1998; Srivastava *et al.*, 1999; Singh and Singh, 2002; Ahmad and Obeid, 2010; Singh *et al.* 2001; Sanghera *et al.* 2015). On the basis of magnitude of diversity obtained it may be concluded that the entries with same geographical origin might be of different genetic back ground with vast divergence in their feature.

Intra and inter-cluster distance are presented in Table 2. The values of intra cluster distance ranged from 8.29 (Cluster VII) to 15.13 (Cluster IV). Maximum inter cluster distance (45.89) was obtained between clusters 1 and IV followed by 41.72 between clusters IV and V and 33.67 among clusters IV and VII which indicated a wide genetic diversity between these groups. The use of the genotypes as parents belongs to these clusters for crossing could produce a good segregants for

Table 1 Composition of clusters based on D^2 statistics in sugarcane germplasm

Clusters	No. of entries	Name of the entries
I	6	'CoH 56', 'CoSe 98231', 'CoS 96275', 'CoS 99259', 'Co Pant 84212', 'CoS 8118'
II	2	'CoS 510', 'Co 1148'
III	7	'CoSe 96436', 'UP 0097', 'CoLk 8101', 'Malani', 'Sugar doctor', 'CoS 8432', 'CoJ 64'
IV	4	'CoSe 92423', 'ISH 59','Kheli', 'Co 1158'
V	3	'CoSe 01434', 'Uba white', 'CoS 07250'
VI	5	'CoSe 01424', 'Khadya', 'CoLk 8102', 'UP 39', 'CoH 72'
VII	3	'BO 91', 'UP 9530', 'CoSe 95422'

Table 2 Average intra and inter cluster D^2 values

Clusters	I	II	III	IV	V	VI	VII
I	(10.82)	(32.00)	(21.16)	(45.89)	(16.91)	(25.71)	(25.00)
	117.28	1024.49	448.14	2105.92	286.04	661.14	625.10
II		(9.75)	(17.30)	(24.55)	(24.13)	(13.43)	(26.83)
		95.16	299.41	603.18	282.40	180.49	720.16
III			(12.93)	(28.84)	(20.07)	(16.76)	(18.11)
			167.24	832.28	403.10	280.95	328.14
IV				(15.13)	(41.72)	(30.73)	(33.67)
				229.16	1741.28	944.44	1134.15
V					(13.32)	(16.32)	(29.45)
					177.64	266.51	867.43
VI						(09.17)	(27.74)
						84.15	769.59
VII							(8.29)
							68.68

Table 3 Clusters means for different traits in sugarcane germplasm

Clusters	Number of germinants/ plot	Number of shoots/plot	Number of millable cane/plot	Stalk height (m)	Stalk thickness (cm)	Stalk weigh (kg)	Yield/ plot (kg)	H.R. Brix (%)
I	21.28	49.96	34.28	1.86	2.11	0.414	17.83	19.83
II	20.00	40.15	26.50	1.70	2.05	0.360	14.50	18.05
III	19.43	45.70	30.04	1.63	1.94	0.382	16.60	19.20
IV	18.50	48.43	31.95	1.47	2.13	0.388	16.45	19.05
V	22.20	45.90	23.83	1.72	2.03	0.303	15.97	19.03
VI	21.06	48.17	32.76	1.78	2.09	0.403	16.22	18.62
VII	26.47	69.67	47.47	1.99	2.10	0.445	18.83	19.17

selection under alkaline condition.

Minimum inter cluster distance 13.43 was found between clusters II and VI, 16.32 between V and VI, 16.76 between III and VI and 16.91 between I and VI. Thus, it may be stated that clusters II and VI , V and VI, III and VI, I and V are in close relationship and cannot be used as parents in crossing programme. During the selection of the parentage, the inter cluster distance must be taken into consideration. The greater is the distance between two clusters, wider is the genetic diversity in the genotype but while considering their genetic diversity, their yield potential under the specific conditions (alkaline) should not be ignored. It is also suggested that the entries with higher index for specific traits that comes into different clusters may be inter crossed to generate the progenies having higher potentiality for desirable characteristics.

On the basis of three years mean data, varieties like 'CoSe 98231', 'CoSe 96436', 'BO 91', 'UP 9530', 'CoSe 92423', 'CoSe 01434' and 'CoLk 8102' performed better in yield contributing traits as well as in yield potential as compared to others. 'CoSe 98231' took position in cluster I, 'CoSe 96436' in cluster III, 'BO 91' and 'UP 9530' in cluster VII, 'CoSe 92423' in clusters IV, 'CoSe 01434' in cluster V and 'CoLk 8102' in cluster VI. The mean performance of each cluster for all the traits is presented in Table 3. Number of germinant shoots/plot and number of millable canes, height, single cane weight and cane yield was maximum in cluster VII followed by cluster I. It is due to inclusion of two varieties 'BO 91' and 'UP 9530' in the cluster VII. Stalk thickness was maximum in cluster IV and H.R. brix in cluster I; possibly due to inclusion of 'CoSe 92423' and 'CoSe 98231', respectively in these clusters. According to the results of cluster distance and performance of the varieties it may be concluded that the crosses between 'CoSe 98231', 'CoSe 92423', 'CoSe 01434' and 'BO 91' or 'UP 9530' would be more beneficial to produce the potential varieties for cultivation in alkaline condition area than others.

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Performance and ratoonability of promising genotypes of sugarcane at early clonal selection

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ABSTRACT

Sugarcane plays a crucial role in the economics of farmers and in the survival of the ever-expanding sugar industry in Egypt. Eighteen promising genotypes and two commercial varieties were evaluated at two locations in middle and southern Egypt during 2010 (plant cane) to 2012 (second ratoon). Significant differences among evaluated genotypes for all measured traits across all crop cycles were observed. Stalk diameter for twelve genotypes decreased with older crop cycles, meanwhile stalk length for ten tested genotypes increased with older crop cycles. Stalk weight of 15 genotypes decreased from plant cane to first ratoon. Cane yield of genotypes G99-103 and G2004-121 significantly exceeds the control variety GT54-9 across all crop cycles. Generally, cane yield was significantly decreased in the second ratoon by 4.36% compared to first ratoon. Genotype G2004-136 produced high cane and sugar yields in the second ratoon indicating superiority in ratoonability.

Key words: *Saccharum*, Sugarcane, Ratooning, Ratoonability, Crop cycle.

Sugarcane (*Saccharum officinarum* L.), one of the most important crops in tropical and sub-tropical countries, is the first major sugar crop worldwide. In Egypt, sugarcane is an important cash crop, plays a crucial role in the economics of farmers and provides main stay to sugar industry in southern Egypt and also raw material to many allied industries. Ratoonability in sugarcane is the ability to maintain yield as the number of ratoon crops increase and is a desirable character because it improves the economics of sugarcane production. Ratoonability is cane yield related trait and is defined as the ratio between cane yields of the second ratoon crop relative to the plant cane and is associated with stalk numbers, bud viability, vigorous root formation and biomass production (Chapman 1988, Milligan *et al*. 1996, Sundara, 1989). Ratooning of sugarcane is a common practice throughout the world and ratoon occupies almost 50 per cent of the total area under sugarcane cultivation (Sundara 2008). A variety may be considered to have good ratoonability if it can maintain yield and/or it has a high yield potential over the normal crop cycle. The plant characteristics of sugarcane associated with ratoonability were studied for possible use as selection criteria in breeding (Ferraris *et al*. 1993, Matsuoka and Stolf 2012). The major cane growing countries normally take two or more ratoons (Bashir *et al*. 2013, Singh and Dey 2002, Yadav 1991). Ratoon crop yields usually typically decreased with age and, hence, limit the economic production of sugarcane (Johnson *et al*. 1993, Mirzawan and Sugiyarta 1999, Ricaud and Arceneaux, 1986). The average yield gap between plant and ratoon crop is 20% - 25% (Gomathi *et al*. 2013). At early selection stage of sugarcane stalk diameter and stalk weight decreased with older crops, while stalk number, cane yield, juice quality traits and sugar yield increased with older crops (Milligan *et al*. 1990). Bissessur *et al*. (2000) evaluated the performance of four sugarcane families including 154 clones at two sites. They found significant differences among families and environments for stalk height, stalk diameter, recoverable sucrose% and cane yield. The family × environment interaction was significant for stalk height, stalk number, stalk diameter, sucrose content, cane and sugar yields per hectare, whereas it was not significant for Brix reading either in plant cane or ratoon crops.

Selection of the best families based on their mean performance and further selection of individual clones based on their sugar yield in early stages would improve the efficiency of selection and increase heritability (Shanthi *et al*. 2008). Furthermore, family selection has been shown to be superior to individual selection in terms of gains from selection, resource efficiency, and cost of operation. Family selection has also been shown to provide a superior method for estimating the breeding value of parent clones (Stringer *et al*. 2010).

Reports on genetic and selection study of ratoonability are quite a few. In the ratoon crop it is common that stalk weight is decreasing. Competition which occurs when high tiller density in the early growth of ratoon crop resulted in reduced weight of the cane (Chapman *et al*. 1992, Hunsigi 1982). Characters such as cane yield and its components, i.e., stalk length, stalk diameter, stalk number and stalk weight have been suggested as being indicative of better ratooning varieties (Milligan *et al*. 1996).

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The objectives of this study were to evaluate the performance of eighteen sugarcane promising genotypes and the control varieties 'GT54-9' and 'Ph8013' grown under different crop cycles (years) and locations at early clonal selection stages.

MATERIALS AND METHODS

Plant material and experimental conditions

The study was carried out at two locations, i.e., Mallawi Agricultural Research Station, El-Minya Governorate, Egypt (lat 28° 10' N, long 30° 75' and alt 55m asl) and Mattana Agricultural Research Station, Luxor Governorate, Egypt (lat 25° 17' N, long 32° 33' and alt 76m asl) during 2010, 2011 and 2012 harvesting seasons. Materials of sugarcane (*Saccharum* spp) consists of eighteen sugarcane promising varieties that could be considered representative of the sort of breeding materials processed in the sugarcane breeding program in Egypt and two commercial varieties, i.e., 'GT54-9' and 'Ph8013' were used as a standard. The materials were planted during the first week of March, 2009 in three rows of five meter length and 90 cm width for each genotype for the crosses in randomized complete block design with three replications at each of the two locations. Planting was achieved by placing twenty five 3-budded cane cuttings in each row. The field was irrigated right after planting and all other agronomic practices were carried out as recommended. Plant cane was allowed to first ratoon and allowed to second ratoon to study the crop cycle effects. Harvest took place twelve months after either planting in the plant cane, harvesting the plant cane for the first ratoon crop, harvesting the first ratoon for the second ratoon crop.

Phenotypic Evaluation

Data was recorded on 9 yield contributed and quality traits. A sample of ten stalks was used to measure Stalk length and diameter. A Sample of twenty stalks was crushed and juice was analyzed to determine quality traits. Studied traits include; stalk length (cm) was measured from soil surface to the visible dewlap, stalk diameter (cm) was measured at midstalk with no reference to the bud groove, stalk weight (kg) was calculated by dividing cane yield per plot by the number of stalks per plot, cane yield (ton fed^{-1}; fed = 4200 m^2) was calculated on plot basis, Brix (percent soluble solids) was measured using a hydrometer, sucrose percentage of clarified juice was determined using automated Sacharimeter according to A.O.A.C. (1980), purity was calculated as: *Purity = Sucrose%/ Brix x 100,* sugar recovery% (SR) was calculated according to the formula described by Yadav and Sharma (1980): *SR = [Sucrose% - 0.4 (Brix - Sucrose%)] x 0.73,* and sugar yield (ton fed^{-1}) was estimated by multiplying net cane yield (ton fed^{-1}) by sugar recovery%.

Statistical Analysis

Analysis of variance (ANOVA) and t-tests were performed using SAS 9.1 TS level 1M3 (SAS Institute, Cary, NC, USA). Sample groups with significantly different means were further analyzed using Fisher's least significant difference (LSD) test at a 5% probability level (SAS 9.1 TS level 1M3). Two models were used for data analysis. The full model included crop effect and crop interaction effect. The reduced model did not include crop or crop interaction effect and was analyzed for each crop. The full model used was:

$$T_{ijklm} = « + Y_i + L_j + YL_{ij} + R_{k(ij)} + C_m + YC_{im} + LC_{jm} + YLC_{ijm} + G_l + YG_{il} + CG_{ml} + YLG_{ijl} + YCG_{iml} + LCG_{jml} + YLCG_{ijml} + E_{ijkml}$$

Where

T_{ijklm} is the observation *k*, year *i*, in location *j*, in crop *m*, of genotype *l*;
μ is the over all mean;
Y_i is year *i*;
L_j is location *j*;
YL_{ij} is year *i* in location *j*;
$R_{k(ij)}$ is replication *k* in year *i* and location *j*;
C_m is crop *m*;
YC_{im} is crop *m* in year *i*;
LC_{jm} is crop *m* in location *j*;
YLC_{ijm} is crop *m* in year *i* and location *j*;
G_i is the genotype *l*;
GY_{il} is the genotype *l* in year *i*;
GL_{jl} is the genotype *l* in location *j*;
GC_{lm} is the genotype *l* in crop *m*;
GYL_{ijl} is the genotype *l* in year *i* and location *j*;
GYC_{ilm} is the genotype *l* in year *i* and crop *m*;
GLC_{jlm} is the genotype *l* in location *j* and crop *m*;
$GYLC_{ijlm}$ is the genotype *l* in year *i*, location *j* and crop *m*;
E_{ijklm} is the residual.

Analysis of variance and variance component estimates were performed for each crop (reduced model) and over crops (using the full model). Except for specific crop, all factors (genotype, replicate and interaction) were considered random. Variance components were calculated by equating appropriate mean squares to their expectations and solving for the components.

Ratoonability (RA) was estimated as:

$$RA = 100\ SR/PC$$

where, RA of trait i was expressed as the second ratoon crop (SR) yield percent (cane or sugar) of trait i of the plant cane or sugar yield.

RESULTS AND DISCUSSION

Stalk length

All studied twenty genotypes exhibited significant differences for stalk diameter and stalk length in plant cane (PC), first ratoon (FR), second ratoon (SR) and across crop cycles (CC; Table 1). The genotype by crop cycle interaction revealed significant effects on all studied traits, indicating that genotype performance differs among the crop cycles. Milligan

Table 1 Mean performance of 20 sugarcane promising varieties for stalk diameter and stalk length in plant cane (PC), first ratoon (FR), second ratoon (SR) and across crop cycles (CC).

Genotype	Stalk diameter (cm)				Stalk length (cm)			
	PC	FR	SR	CC	PC	FR	SR	CC
'GT54-9'	2.74	2.52	2.23	2.50	281.68	277.50	273.33	277.50
'Ph8013'	3.12	2.93	2.88	2.98	250.39	276.67	179.17	235.41
'G99-103'	3.01	2.47	3.17	2.88	271.51	260.00	227.50	253.00
'G2004-102'	2.29	2.03	2.37	2.23	221.74	220.00	199.17	213.63
'G2004-103'	2.50	2.23	2.65	2.46	239.05	238.33	270.83	249.41
'G2004-104'	2.08	1.93	1.82	1.94	222.06	235.83	276.67	244.85
'G2004-106'	2.18	2.12	1.93	2.08	216.58	221.67	231.67	223.30
'G2004-116'	2.50	2.27	2.52	2.43	213.50	215.00	256.67	228.39
'G2004-117'	2.37	2.20	1.95	2.17	209.01	233.33	256.67	233.00
'G2004-119'	2.37	2.25	2.30	2.31	209.77	217.50	280.83	236.03
'G2004-121'	2.61	2.52	2.22	2.45	265.19	275.83	275.83	272.28
'G2004-122'	2.13	2.05	1.98	2.05	247.09	260.00	232.50	246.53
'G2004-124'	2.32	2.12	2.08	2.17	209.40	228.33	295.00	244.24
'G2004-131'	2.31	2.28	1.78	2.12	208.95	227.50	265.00	233.82
'G2004-132'	2.16	2.12	1.72	2.00	202.66	234.17	253.33	230.05
'G2004-133'	1.97	2.28	1.70	1.99	271.06	270.00	225.00	255.35
'G2004-136'	2.04	2.13	1.88	2.02	177.94	174.17	220.00	190.70
'G2004-140'	1.88	1.87	1.70	1.81	194.50	181.67	224.17	200.11
'G2004-144''	2.44	2.05	3.02	2.50	258.58	250.83	267.50	258.97
'G2004-147'	2.35	2.13	1.97	2.15	179.17	200.00	237.50	205.56
Mean'	2.37	2.23	2.19	2.26	227.49	234.92	247.42	236.61
LSD at 5% for								
Crosses (S)	0.053	0.053	0.13		4.63	2.93	2.36	
Crop (C)	0.11				4.79			
S x C	0.19				8.3			

et al. (1990) and Orgeron *et al*. (2007) reported that genotype by crop interaction was important for sugarcane yield and its component traits.

Stalk diameter

Stalk diameter in plant cane and first ratoon varied from 3.12, 2.93 cm for the variety 'Ph8013' to 1.88, 1.87 cm for the Clone 'G2004-140', respectively, while in the second ratoon stalk diameter varied from 3.17 for the genotype 'G99-103' to 1.70 cm for the genotype 'G2004-140' (Table 1). Across crop cycles, stalk diameter varied from 2.98 cm for Ph8013 to 1.81 cm for the 'G2004-140'. Stalk diameter of thirteen genotypes, i.e., 'G2004-104', 'G2004-106', 'G2004-117', 'G2004-121', 'G2004-122', 'G2004-124', 'G2004-131', 'G2004-132', 'G2004-140' and 'G2004-147' in addition to the control varieties 'GT54-9' and 'Ph8013' decreased in older crop cycles, while in the remaining eight genotypes ('G 99-103', 'G2004-102', 'G2004-103', 'G2004-116', 'G2004-119', 'G2004-133', 'G2004-136', 'G2004-144') it was fluctuated among crop cycles which is in accordance with the results from Milligan *et al*. (1990).

Stalk length

Stalk length in both plant cane and first ratoon varied from 281.68 and 277.50 cm for the control variety 'GT54-9' to 177.94 and 174.17cm for the genotype 'G2004-136', respectively. Meanwhile, in the second ratoon it ranged from 295 cm (genotype 'G2004-124') to 199.17 cm (genotype 'G2004-102'; Table 1). Across crop cycles, the standard variety 'GT54-9' was superior in stalk length (277.50 cm), while the genotype 'G2004-136' produced the shortest stalks (190.70 cm). Stalk length for most tested genotypes ('G2004-104', 'G2004-106', 'G2004-116', 'G2004-117', 'G2004-119', 'G2004-121', 'G2004-124', 'G2004-131', 'G2004-132',

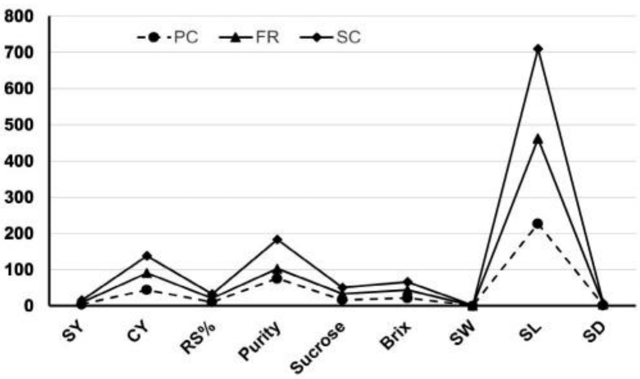

Fig 1. Mean performance of sugar yield (SY), cane yield (CY), recovery sugar (RS), purity, sucrose%, Brix, stalk weight (SW), stalk length (SL) and stalk diameter (SD) in plant cane (PC), first ratoon (FR) and second ratoon (SR).

'G2004-147' and variety 'Ph8013') increased with older crop cycles (Fig. 1), while stalk length of genotypes 'G99-103', 'G2004-102', 'G2004-133', 'G2004-136', 'G2004-140' and standard variety 'GT54-9' decreases with older crop cycles. Stalk length of three genotypes ('G2004-103', 'G2004-122' and 'G2004-144') fluctuated among crop cycles.

Stalk weight

Stalk weight in plant cane, first ratoon, second ratoon and across crop cycles varied from 0.9, 0.75, 0.8 and 0.83 kg, respectively, for the genotype 'G99-103' to 0.19, 0.45, 0.23 and 0.22 kg, respectively, for the genotype 'G2004-140' (Table 2). The superiority of the genotype G99-103 in stalk weight could be ascribed to high values in both stalk diameter and stalk length, and *vis versa* for the promising variety 'G2004-140' which produced the lowest stalk weight. Stalk weight of fifteen genotypes decreases from plant cane to first ratoon, which in agreement with previous results (Chapman *et al*. 1992, Hunsigi 1982) where a reduction in stalk weight in the ratoon crop was observed.

Cane yield

Cane yield of two genotypes, i.e., 'G99-103' and 'G2004-121' variety was significantly greater than the standard variety 'GT54-9' across all crop cycles. In all evaluated genotypes, cane increased significantly in the first ratoon by 8.5% and in the second ratoon by 3.8% compared to the plant cane. Cane yield in plant cane, first ratoon and across crop cycles varied from 85.00, 91.98 and 84.06 ton/fed, respectively, for genotype 'G2004-121' to 26.3, 31.5 and 31.12 ton/fed, respectively, for genotype 'G2004-136', while in the second ratoon it ranged from 76.81 ton/fed for genotype 'G99-103' to 28.82 ton/fed for genotype 'G2004-140'. Across crop cycles, contrary to genotype 'G2004-106' which produces low values of both stalk diameter and length and hence was the lowest in cane yield, the genotype 'G2004-121' produced the highest cane yield which is due to tall and thick stalks. Cane yield of thirteen tested varieties fluctuated with older crop cycles and cane yield of seven tested varieties increased with older crop cycles (Table 2).

Crop cycle effects on quantitative traits

Total soluble solids (Brix)

Data in Table 3, 4 and 5 revealed significant differences among evaluated genotypes for total soluble solids (Brix), sucrose percentage, juice purity, sugar recovery and sugar yield. Brix percentage in plant cane ranged from 22.88% (genotype 'G2004-140') to 19.4% (genotype 'G2004-121'). In first ratoon Brix varied from 23.41% (genotype

Table 2 Mean performance of 20 sugarcane promising varieties for stalk weight and cane yield in plant cane (PC), first ratoon (FR), second ratoon (SR), across crop cycles (CC) and cane ratoon ability (CRA).

Genotype	Stalk Weight (kg)				Cane yield				
	PC	FR	SR	CC	PC	FR	SR	CC	CRA
'GT54-9'	0.700	0.600	0.660	0.653	50.71	51.73	59.64	54.03	117.61
'Ph8013'	0.762	0.673	0.727	0.721	60.66	61.18	55.01	63.71	90.69
'G99-103'	0.898	0.753	0.832	0.828	65.23	66.67	76.81	69.57	117.76
'G2004-102	0.433	0.397	0.422	0.417	51.52	52.36	51.07	51.65	99.13
'G2004-103	0.497	0.462	0.485	0.481	58.17	59.01	51.35	56.18	88.27
'G2004-104'	0.322	0.317	0.328	0.322	38.44	42.32	38.92	39.89	101.24
'G2004-106'	0.352	0.312	0.34	0.334	30.66	31.5	31.2	31.12	101.77
'G2004-116'	0.335	0.337	0.345	0.339	31.52	34.7	30.94	32.38	98.18
'G2004-117'	0.343	0.33	0.348	0.341	39.38	40.71	40.59	40.22	103.09
'G2004-119'	0.425	0.405	0.422	0.417	57.39	58.51	53.47	56.45	93.17
'G2004-121'	0.8	0.728	0.748	0.759	85.00	91.98	75.2	84.06	88.47
'G2004-122'	0.415	0.407	0.42	0.414	39.94	41.06	40.33	40.44	101.00
'G2004-124'	0.445	0.367	0.415	0.409	35.43	35.64	40.43	37.17	114.12
'G2004-131'	0.312	0.302	0.317	0.310	35.81	36.93	37.65	36.79	105.16
'G2004-132'	0.398	0.353	0.385	0.379	38.46	38.81	43.87	40.38	114.05
'G2004-133'	0.32	0.392	0.367	0.359	39.53	52.44	44.62	45.53	112.89
'G2004-136'	0.357	0.443	0.407	0.402	26.3	35.75	35.24	32.43	134.01
'G2004-140'	0.192	0.248	0.228	0.223	27.89	38.04	28.82	31.58	103.35
'G2004-144'	0.428	0.397	0.422	0.416	38.91	40.45	41.09	40.15	105.61
'G2004-147'	0.272	0.338	0.31	0.307	29.68	45.68	37.52	37.63	126.42
Mean	0.45	0.428	0.446	0.442	44.03	47.77	45.69	46.07	106.98
LSD at 5% for									
Crosses (S)	0.06	0.02	0.03		1.26	0.59	4.11		
Crop (C)		0.05				3.51			
S x C		0.09				6.07			

Table 3 Mean performance of 20 sugarcane promising varieties brix percentage and sucrose percentage in plant cane (PC), first ratoon (FR), second ratoon (SR) and across crop cycles (CC).

Genotype	Brix %				Sucrose %			
	PC	FR	SR	CC	PC	FR	SR	CC
'GT54-9	21.44	21.48	22.46	21.79	17.73	17.54	17.69	17.65
'Ph8013'	22.21	21.45	22.56	22.07	18.14	16.63	19.71	18.16
'G99-103'	20.65	21.02	19.43	20.37	15.84	16.34	16.70	16.29
'G2004-102'	21.34	21.99	21.77	21.70	17.31	17.70	18.94	17.98
'G2004-103'	21.17	22.32	21.56	21.68	15.83	16.11	17.45	16.46
'G2004-104'	21.66	22.59	22.16	22.14	15.85	15.89	17.20	16.31
'G2004-106'	21.82	22.50	22.64	22.32	16.54	16.57	18.13	17.08
'G2004-116'	20.75	22.26	22.85	21.95	15.38	15.98	18.16	16.50
'G2004-117'	19.82	22.56	20.50	20.96	14.31	17.59	16.73	16.21
'G2004-119'	21.11	21.91	21.73	21.59	15.32	15.02	15.76	15.37
'G2004-121'	19.40	20.41	21.68	20.49	14.74	16.13	16.70	15.85
'G2004-122'	22.14	22.37	23.70	22.74	16.81	15.86	17.99	16.89
'G2004-124'	20.61	21.56	21.54	21.24	17.47	17.95	18.33	17.91
'G2004-131'	21.88	22.07	19.63	21.19	16.66	17.70	16.91	17.09
'G2004-132'	21.04	21.47	20.42	20.97	17.98	17.86	16.43	17.42
'G2004-133'	21.05	22.59	21.40	21.68	17.06	16.73	17.40	17.06
'G2004-136'	22.16	22.39	23.76	22.77	15.88	16.02	18.07	16.66
'G2004-140'	22.88	23.07	23.72	23.22	17.51	17.26	18.28	17.68
'G2004-144'	20.35	21.64	21.70	21.23	16.98	15.93	18.71	17.20
'G2004-147'	22.50	23.41	24.02	23.31	16.14	15.82	17.42	16.46
Mean	21.30	22.05	21.96	21.77	16.47	16.63	17.63	16.91
LSD at 5% for								
Crosses (S)	0.34	0.25	0.35		0.4	0.22	0.31	
Crop (C)		0.46				0.44		
S x C		0.79				0.76		

'G2004-147') to 20.41% (genotype 'G2004-121'). While, in second ratoon it ranged from 24.02% (genotype 'G2004-147') to 19.43% (genotype 'G99-103') (Table 3). Across crop cycles, Brix varied from 23.31% (genotype 'G2004-147') to 20.40% (genotype 'G99-103'). Brix percentage of nine genotypes increased in older crop cycles, meanwhile it fluctuated among crop cycles in eleven genotypes.

Sucrose percentage

Sucrose percentage in plant cane varied from 18.14% for the variety 'Ph8013' to 14.74% for the genotype 'G2004-121', while in first ratoon it varied from 17.95% for the genotype 'G2004-124' to 15.82% for the genotype 'G2004-147'. However, in the second ratoon it ranged from 19.71% for the variety 'Ph8013' to 15.76% for the genotype 'G2004-119'. Across crop cycles, sucrose percentage ranged from 18.16% for the variety 'Ph8013' to 15.37% for the genotype 'G2004-119' (Table 3).

Purity percentage

Purity percentage in plant cane ranged from 86.22% for the genotype 'G2004-132' to 72.01% for the genotype 'G2004-136', while in first ratoon it ranged from 84.22% for the same genotype 'G2004-132' to 68.25% for the genotype 'G2004-147'. In the second ratoon, however, it varied from 87.39% for the variety 'Ph8013' to 72.51% for the genotype 'G2004-119'. Across crop cycles purity percentage varied from 84.62% for the variety 'Ph8013' to 71.03% for the genotype 'G2004-147' (Table 4).

Sugar recovery

Sugar recovery in plant cane ranged from 12.24% for the genotype 'G2004-132' to 8.84% for the genotype 'G2004-117', while in first ratoon it varied from 12.05% for the genotype 13 to 8.95% for the genotype 'G2004-119'. In the second ratoon, it varied from 13.56% for the variety 'Ph8013' to 9.76% for the genotype 'G2004-119'. Across crop cycles, sugar recovery ranged from 12.12% for the variety 'Ph8013' to 9.4% for the variety 'G2004-119' (Table 4).

In general, crop cycle across studied crosses had no effect on juice quality traits. Chapman (1988) reported that older crop cycles tend to mature earlier than younger crops, but final sucrose concentration and its components, Brix, sucrose content, juice purity and sugar recovery are generally not affected by crop age. EL-Hinnawy and Masri (2009) found that crop cycles significantly affect juice quality traits.

Sugar yield

Sugar yield in plant cane, first ratoon and second ratoon crops, respectively, exhibited significant differences among

Table 4 Mean performance of 20 sugarcane promising varieties for purity percentage and recovery percentage in plant cane (PC), first ratoon (FR), second ratoon (SR) and across crop cycles (CC).

Genotype	Purity				Sugar recovery			
	PC	FR	SR	CC	PC	FR	SR	CC
'GT54-9'	82.70	81.77	78.92	81.13	11.86	11.66	11.52	11.68
'Ph8013'	81.68	78.00	87.39	82.36	12.06	10.74	11.81	11.54
'G99-103'	72.02	77.82	85.90	78.58	10.16	10.56	11.39	10.71
'G2004-102'	81.22	80.89	87.00	83.03	11.46	11.67	12.99	12.04
'G2004-103'	74.81	72.44	80.89	76.05	10.00	9.95	11.54	10.50
'G2004-104'	73.28	70.36	77.67	73.77	9.88	9.64	11.10	10.21
'G2004-106'	75.99	73.75	80.15	76.63	10.53	10.36	11.92	10.94
'G2004-116'	74.31	71.83	79.48	75.21	9.66	9.83	11.88	10.46
'G2004-117'	72.06	77.94	81.70	77.23	8.84	11.39	11.11	10.45
'G2004-119'	72.39	68.71	72.51	71.20	9.50	8.95	9.76	9.40
'G2004-121'	75.94	78.97	77.28	77.40	9.40	10.52	10.74	10.22
'G2004-122'	76.28	71.37	75.97	74.54	10.72	9.68	11.47	10.62
'G2004-124'	84.91	83.50	85.44	84.62	11.83	12.05	12.44	12.11
'G2004-131'	76.04	80.26	86.18	80.83	10.63	11.64	11.55	11.28
'G2004-132'	86.22	84.22	81.19	83.88	12.24	11.99	10.83	11.68
'G2004-133'	81.33	74.29	81.39	79.00	11.28	10.50	11.53	11.11
'G2004-136'	72.01	71.94	76.21	73.38	9.76	9.83	11.53	10.37
'G2004-140'	76.77	75.04	77.16	76.32	11.21	10.90	11.76	11.29
'G2004-144'	83.42	73.77	86.18	81.12	11.41	9.96	12.79	11.38
'G2004-147'	72.16	68.25	72.70	71.03	9.93	9.33	10.79	10.01
Mean	77.28	75.75	80.56		10.62	10.56	11.61	10.93
LSD at 5% for								
Crosses (S)	2.3	1.49	1.48		0.4	0.25	0.29	
Crop (C)		2.39				0.43		
S x C		4.15				0.75		

Table 5 Mean performance of twenty sugarcane promising varieties for sugar yield in plant cane (PC), first ratoon (FR), second ratoon (SR) and over crop cycles (CC) and sugar ratoon ability (SRA).

Genotype	Sugar yield				
	PC	FR	SR	CC	SRA
'GT54-9'	6.07	6.06	6.82	6.32	112.36
'Ph8013'	7.26	6.58	6.49	6.78	89.40
'G99-103'	6.57	6.95	8.71	7.41	132.64
'G2004-102'	5.87	6.09	6.63	6.2	112.91
'G2004-103'	5.56	5.68	5.86	5.7	105.47
'G2004-104'	3.81	4.08	4.3	4.06	113.09
'G2004-106'	3.37	3.32	3.78	3.49	112.23
'G2004-116'	3.05	3.43	3.66	3.38	120.22
'G2004-117'	3.4	4.74	4.51	4.21	132.50
'G2004-119'	5.16	5.12	5.17	5.15	100.19
'G2004-121'	7.74	9.06	8.05	8.28	104.01
'G2004-122'	4.52	4.15	4.69	4.45	103.88
'G2004-124'	4.17	4.32	4.95	4.48	118.58
'G2004-131'	3.8	4.3	4.32	4.14	113.68
'G2004-132'	4.71	4.66	4.75	4.71	101.00
'G2004-133'	4.41	5.52	5.18	5.04	117.29
'G2004-136'	2.65	3.69	4.23	3.52	159.50
'G2004-140'	3.24	4.28	3.41	3.64	105.22
'G2004-144'	4.44	4.02	5.27	4.57	118.66
'G2004-147'	3.41	4.28	4.17	3.95	122.30
Mean	4.66	5.01	5.39	5.02	116.74
LSD at 5% for					
Crosses (S)	0.22	0.15	0.48		
Crop (C)		0.44			
S x C		0.76			

varieties with each crop cycle and among crop cycles. Sugar yields from plant cane, first and second ratoons of the two genotypes 'G99-103' (6.57, 6.95 and 8.71 ton/fed, respectively) and 'G2009-121' (7.74, 9.06 and 8.05 ton/fed, respectively) were significantly greater than the control variety 'GT54-9' (6.07, 6.58 and 6.82 ton/fed, respectively). While sugar yield of variety 'Ph8013' was significantly greater than the standard variety 'GT54-9' in plant cane, first ratoon and across crop cycles (Table 5).

Sugar yield in plant cane varied from 7.74 ton/fed for the genotype 'G2004-121' to 2.65 ton/fed for the genotype 'G2004-117', while in first it ratoon it ranged from 9.06 ton fed^{-1} for the same variety 'G2004-121' to 3.43 ton/fed for the variety 'Ph8013'. In the second ratoon sugar yield ranged from 8.71 ton/fed for genotype 'G99-103' to 3.41 ton/fed for the genotype 'G2004-140'. Across crop cycles, sugar yield varied from 8.28 ton fed^{-1} for genotype 'G2004-121' to 3.38 ton/fed for genotype 'G2004-116' (Table 5).

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'Pratap Ganna-1': A better option for higher cane yield in NW zone

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In sub-tropical India (*i.e.* North-West Zone including Rajasthan, Punjab, Haryana, Western & Central Uttar Pradesh and Uttarakhand) sugarcane is grown with low to medium cane productivity (50-60 t/ha) as well as sugar recovery (9-10%), due to varying agro-climatic conditions. The variety 'Pratap Ganna-1' ('CoPk 05191') is a high yielding, early maturing variety, resistant to biotic and abiotic stresses, which is most suitable to draught prone and red rot affected areas of North-West Zone of the country.

About 'CoPk 05191'

Brief description of parent variety

The parental variety 'Co 1158' was developed from the cross between 'Co 421' (used as seed parent, which has more than 95 per cent closed anthers with very little pollen grains) and 'Co 419' (used as pollen parent, having about 90 percent open anthers with pollen fertility as low as 40 percent). The progeny of this cross exhibited earlier flowering with about 80 percent open anthers and pollen fertility of 50 percent. The variety Co 1158 in general showed good yield potential (70-75 t/ha) and about 15-16 percent sucrose content. It has cylindrical, medium-thick, erect canes, slightly oval in cross-section, yellowish green colour turning in to purple on exposure; rind hard; pith as small a cavity in bottom portion. The bud medium sized, plumpy; oval to roundish; forming an arch over the bud; inserted at leaf scar. The leaves light green in colour and medium size, purplish green sheath with red blotches; fair bloom; loose clasping; spines present in the middle of sheath; younger leaves erect, older leaves drooping from one-third length from the tip and top open. The variety responds to heavy manuring and irrigation, tolerant to drought and moderately resistant to red rot and wilt, while susceptible to smut diseases. (Sankaranrayana *et al.*, 1980).

Development of 'CoPk 05191'

The variety 'CoPk 05191' (Pratap Ganna-1) is an early maturing wonderful sugarcane variety, which was developed from variety ;Co 1158GC' during 2004-05. The crossing was attempted at National Hybridization Garden, Sugarcane Breeding Institute, Coimbatore (Tamilnadu) and the F_1 progenies of the cross were planted at Agricultural Research Station, Kota, Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan). The clonal/pedigree selection method was adopted from the seedling nursery and based on *per se* performance; 'CoPk 05191' was identified as superior clone in the early generations and station trials.

Table 1 Mean performance of 'CoPk 05191' in AICRP(s) trials.

Trait	No. of location	Mean Performance of 'CoPk 05191'			Mean Performance of 'CoJ-64'			Mean Performance of 'CoPant 84211'			Overall % superiority over standards	
		Plant Crop	Ratoon Crop	Plant+ Ratoon Crops	Plant Crop	Ratoon Crop	Plant+ Ratoon Crops	Plant Crop	Ratoon Crop	Plant+ Ratoon Crops	CoJ 64	CoPant 84211
Morphological Traits												
Cane yield (t/ha)	26	87.73	67.89	81.12	66.60	49.65	60.95	68.25	51.22	62.97	33.09	28.82
CCS (t/ha)	26	10.35	7.87	9.52	8.41	6.18	7.67	8.38	5.95	7.57	24.12	25.76
CCS (%)	26	11.75	11.66	11.72	12.63	12.40	12.55	12.09	11.61	11.93	(-)6.61	(-)1.76
Stalk length (cm)	26	208.11	189.00	201.74	175.73	165.00	172.15	190.28	181.00	187.18	14.67	7.22
Stalk diameter (cm)	26	2.42	2.30	2.38	2.30	2.11	2.34	2.21	2.11	2.18	1.68	8.40
NMCs at harvest ('ooo/ha)	26	104.68	92.36	100.57	95.31	82.50	91.04	91.34	82.74	88.47	9.48	12.03
Quality Traits												
Sucrose% (240 days)	18	15.41	-	15.41	16.64	-	16.64	16.23	-	16.23	(-)7.39	(-)5.05
Sucrose% (300 days)	26	17.12	16.95	17.06	18.16	17.88	18.07	17.50	17.13	17.38	(-)5.59	(-)1.84
Pol % at harvest	04	12.42	12.63	12.60	14.09	15.13	14.44	12.24	12.17	12.22	(-)12.78	3.11
Fiber % at harvest	08	13.54	13.96	13.68	12.85	12.84	12.84	13.23	13.23	13.28	6.54	3.01

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Table 3 Distinguishing features of Sugarcane Variety CoPk 05191.

Characteristics	Descriptor Status
Stool habit	Erect
Stem colour exposed	Greenish yellow with black spots
Stem colour unexposed	Yellowish green
Ivory marks	Present
Weather marks	Present
Internodes shape	Bobbin
Internodes alignment	Zigzag
Pithiness	Present
Splits on internodes	Absent
Wax on internodes	Medium
Node swelling	Present
Root zone colour	Grayish yellow
No. of root eye rows	Three
Alignment of root eyes	Irregular
Bud size	Medium
Bud shape	Triangular to oval
Bud cushion	Absent
Bud germ pore position	Apical
Bud groove	Absent
Growth ring colour	Yellowish green
Leaf length	110-130 cm
Leaf width	Medium (3.5-4.5 cm)
Lamina colour	Green
Leaf carriage shape	Semi-drooping
Leaf sheath colour	Green
Leaf sheath waxinss	Present
Leaf sheath spines	Present (very low)
Leaf sheath clasping	Medium
Dewlap colour	Greenish yellow
Presence or absence of ligular process	Present
Shape of ligular process	Crescent
Shape of auricles	Deltoid
Presence of flowering	Not appears in NW Zone

Thereafter, this clone was proposed for testing in All India Coordinated Zonal Research Trials for North-West Zone. It was evaluated under trials conducted at 9 AICRP (Sugarcane) centers (*viz.* Kota, Sriganganagar, Faridkot, Kapurthala, Karnal, Lucknow, Muzaffarnagar, Pantnagar and Shahjahanpur) of the zone during 2009-10 to 2010-11. The entire recommended package of practices was adopted for raising the good crop. The juice quality analyzed at 240 days and 300 days in first and second plant crop trials and at 270 days in ratoon trials, as per standard procedure (Meade and Chen 1971). The important morphological traits were observed as per standards suggested by Dutt *et al.* (1947) at the time of harvesting. The reaction to important diseases like- red rot, wilt and smut was observed in natural field situations and rated under artificial inoculation conditions as well. The response to drought and water logging conditions was recorded at the identified centers of AICRP on Sugarcane.

Morphological description of 'CoPk 05191'

The variety 'Pratap Ganna 1' ('CoPk 05191') exhibited erect cane habit, unexposed cane colour greenish yellow with black spots and turning yellowish-green on exposure; ivory and weather marks present; swallow nodes; internodes bobbin shaped with zigzag alignment; splits absent but medium wax present on internodes; pithiness present. The root zone colour grayish yellow. Three root eye rows present with its irregular alignment. The bud medium sized, triangular to oval shaped; bud germ pore position apical; bud cushion and groove absent. The medium sized, semi-drooping, green leaves; leaf sheath green in colour, waxiness and very low spines present, medium leaf sheath clasping; dewlap colour greenish yellow; ligular process present with crescent shape; auricles deltoid shaped. The flowering not appeared in North-West zone of the country.

Distinguishing Features

Variety 'CoPk 05191' could be easily identified by its erect stalk, stay green, medium-narrow, curved tip leaves, thick and bobbin shaped internodes with zigzag alignment.

Salient Features of 'Pratap Ganna-1'

The salient features of 'Pratap Ganna-1' ('CoPk 05191') are as under:

- It is an early maturing (300 days after date of planting) sugarcane variety.
- It exhibited higher cane yield (81.12 t/ha), showing 28.82 per cent, superiority over best standard check variety.
- It showed higher commercial cane sugar (CCS) (9.52 t/ha) with 24.12 per cent superiority over best standard check.
- It exhibited higher sucrose content at 240 days (15.41 per cent) and 300 days (17.06 per cent).
- This variety showed very good ratooning ability (cane yield 67.89 t/ha).
- The variety is tolerant to abiotic stresses (*i.e.* drought and water logging conditions).
- This is resistant to biotic stresses (*viz.* red rot and smut diseases and stem borer insect). In Rajasthan state, there was no any disease symptoms appeared at any crop growth stage.
- It is responsive to the higher doses of fertilizers.

CONCLUSION

The variety 'CoPk 05191' is an early maturing sugarcane variety exhibiting higher cane yield and commercial cane sugar (CCS) per unit area. It possessed tall and thick stalk with large number of millable canes. The variety exhibited higher sucrose (*i.e.* 17.06 per cent), which was comparable to standard check variety 'CoPant 84211' (17.38 per cent) at time of harvest. It exhibited moderately susceptible to resistance reaction to red rot, smut and wilt diseases at different locations. In Rajasthan state, there was no any disease symptoms appeared at any crop growth stage. The variety found highly resistant to both drought and water logging conditions and suitable for water stress prone areas. It was released and notified for commercial cultivation in Rajasthan, Punjab, Haryana, Uttar Pradesh and Uttarakhand states of the country.

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Effect of salinity on growth, yield and quality of Sugarcane

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ABSTRACT

The present study was aimed at evaluating sugarcane varieties under salinity stress. Pot experiments were conducted during three planting seasons 2012-13, 2013-14 and 2014-15 at the farm of U.P. Council of Sugarcane Research, Shahjahanpur located at 27.53° N latitude and 79.54°E longitude using ten sugarcane varieties viz., 'CoSe 01434', 'CoS 07250', 'CoSe 06456', 'CoSe 08279', 'CoS 08272', 'CoSe 06455', 'CoS 10239', 'CoS 07240', 'CoS 09240' and 'UP 05125'. Varieties 'CoSe 01434' and 'CoS 07250' were used as the standards for salinity. Salinity condition in growing medium was maintained at 8EC level by mixing calcium chloride, sodium chloride and sodium sulphate in required amounts against control (Normal soil, pH 7.7, 1.4 EC d/sm). Mean data of three years showed that the growth and yield components were reduced under saline stress as compared to the respective attributes in normal soil. Varieties 'CoS 08279', 'CoSe 06455' and 'CoS 07240' produce more shoots and NMC under saline stress than other varieties. Conclusively, on the basis of yield reduction percent, varieties 'CoS 08279' and 'CoS 07240' and 'CoSe 06455' showed greater yield potential and were found to be more tolerant to salinity stress.

Key words. Salinity stress, Soil salinity, Millable cane, Cane yield.

Salinity is a major stress to the plants that can affect physiological and biochemical process during plants development, resulting in reduced growth and yield (Ashraf 2004). Excess of chloride salts is known to have negative impact on phosphorus uptake and its availability in screened crops (Gomez and Torres 1993). Addition of NaCl sharply declines the phosphorus uptake and depresses growth in sugarcane. As a C_4 plant, sugarcane has higher water and the optima for growth. In saline fields, an excess of soluble salts are taken up by the plants which accumulates in aerial parts and reduces growth and yield (Akhtar *et al*. 2003).

The high sucrose and low fiber varieties of sugarcane have been adversely affected by salt content (Rehaja 1962). Although photosynthesis rate was decreased by salt stress, but in salt tolerant variety it was maintained at a higher level. The reductions in growth from high salinity are the consequences of both osmotic stress inducing a water deficit and effects of excess Na+ and Cl^- ions in critical biochemical processes (Munns and Tester 2008).

Reduction in water uptake by the root and hampered cell water relations are both due to the osmotic component of salinity (Wahid *et al*. 1999). Salinity has a greater effect on the gas exchange parameters of sugarcane (Plaut *et al*. 2000). A reduction in the elongation and expansion of sugarcane leaves under salinity has been attributed to a lowered efficiency of growing tissues to utilize sugars for growth (Kumar *et al*. 1994).

Sugarcane is most important cash crop of tropical as well as sub tropical regions in India. Over 7 million hectares area in different parts of country is salt affected out of which 5.7 million ha area is either saline or saline alkaline (Abrol and Bhumbla 1971). Under saline soil condition sugarcane plants are unable to absorb water and minerals from the soil because of osmotic imbalance. Excess amount of salt in the soil adversely affects plant growth and development. High salt concentration decreases the potential of soil solution creating a water stress in plants that also causes severe toxicity, salt stress and dehydration stress. A high degree of salinity results in to physiological, biochemical, molecular and genetical effects (Cushman *et al*. 1990; Tiwari *et al*. 1997; Munns *et al*. 2002; Yusuf *et al*. 2010). Salinity causes growth reduction due to dry matter allocation, water stress, relation and other biochemical, physiological process or by a combination of these factors (Greenway and Munns 1980). Salinity coupled with water stress lead to a low rate of transpiration and photosynthesis due to closure of stomata (Farquhar and Sharkey 1982; Theszen 1991; Akhtar *et al*. 2001). The short term effect of salinity on sugar cane growth and physiology have been documented by earlier workers (Liu 1967; Kumar and Naidu 1993; Meinzer *et al*. 1994, Sharma *et al*. 1997).

The biotic approach towards combination salinity/alkalinity has received considerable attention (Epstein 1985; Ashraf *et al*. 1986). The present experiment is aimed at screening of sugarcane varieties under 8EC level of salinity against normal soil (1.4 EC) at the research farm of U.P. Council of Sugarcane Research, Shahjahanpur located at 27.53°N latitude and 79.54°E longitude.

MATERIALS AND METHODS

A pot experiment was conducted for three consecutive years (2012-15) in spring planting season. Five single budded setts

Table 1 Effect of Salinity on Shoot, NMC, Yield and Juice quality of Sugarcane. (Pooled data of 3 years 2012-15)

Varieties	Shoots/Clump			NMC/Clump			Sucrose (%)			Cane Yield (Kg/clump)			Yield reduction
	N	S	Mean	N	S	Mean	N	S	Mean	N	S	Mean	%
'CoSe 01434'	10.89	8.55	9.72	8.11	7.44	7.77	16.49	16.26	16.37	2.597	2.291	2.444	11.78
'CoS 07250'	11.54	9.21	10.37	8.02	7.11	7.56	16.55	16.34	16.44	2.708	2.380	2.544	12.11
'CoSe 06456'	9.34	7.01	8.17	7.01	5.66	6.33	16.37	16.19	16.28	2.540	2.046	2.293	19.44
'CoS 08279'	10.89	9.00	9.94	8.34	7.45	7.89	16.62	16.29	16.45	2.727	2.377	2.552	12.83
'CoS 08272'	9.21	7.33	8.27	7.45	6.09	6.77	16.97	16.85	16.91	2.502	2.075	2.288	17.06
'CoSe 06455'	9.33	6.66	8.49	7.34	6.22	6.78	16.29	16.21	16.25	2.482	2.232	2.357	10.07
'CoS 10239'	9.43	6.77	8.10	6.99	5.87	6.23	16.26	16.13	16.19	2.487	1.971	2.229	20.74
'CoS 07240'	10.45	8.23	9.34	7.79	7.51	7.65	16.26	16.12	16.19	2.527	2.439	2.483	13.48
'CoS 09240'	9.90	7.77	8.83	7.79	6.90	7.34	16.37	16.24	16.30	2.512	2.042	2.277	18.71
'UP 05125'	9.65	7.01	8.33	7.65	6.49	7.07	17.07	16.76	16.66	2.492	1.960	2.226	21.34
Mean	10.06	7.75	8.96	7.65	6.67	7.14	16.52	16.33	16.40	2.557	2.183	2.370	14.62
CV		15.98			5.90			0.87			6.71		
SE for E/CD		0.75/1.59			0.24/0.51			0.08/0.017			0.09/0.19		
SE for V/CD		2.24/0.50			0.081/0.16			0.03/0.05			0.03/0.06		
SE for SXV/CD		1.07/NS			0.35/ NS			0.12/ NS			0.13/ NS		

of ten sugarcane varieties viz., 'CoSe 01434', 'CoSe 06455', 'CoSe 06456', 'CoS 07250', 'CoS 08279', 'CoS 08272', 'CoS 10239', 'CoS 07240', 'CoS 09240' and 'UP 05125' were planted in each pot containing 80 kg of soil in February every year in complete randomized design with three replications. Variety 'CoSe 01434' and 'CoS 07250' were used as standard. Nitrogen was given in the form of urea @ 180 kg N/ha, half at the time of planting and remaining half in two equal splits before the onset of monsoon. Experimental soil was sandy loam in texture having 7.7 pH, and 1.4 EC ds/m. The level of salinity was maintained at the time of planting. Other cultural and irrigational practices were given as when required as per recommendations. The salinity of (8 EC ds/m) and normal (1.4 EC ds/m) were maintained by artificially adding calcium chloride, sodium sulphate and sodium chloride salts in required amounts. After germination, thinning was done and only one plant in each pot was left for further studies.

Growth characters such as shoot population was recorded just before the onset of monsoon while the number of millable canes and cane yield were recorded at the time of harvest. Sucrose percent in juice was measured at twelve months crop age at harvest using standard methods of analysis given by Meade and Chen (1977).

RESULTS AND DISCUSSION

The data presented in Table 1 revealed that number of shoots per clump was affected significantly due to salinity. Under normal soil condition varieties 'CoSe 08279' and 'CoS 07240'produced higher tiller/clumps followed by 'CoS 09240', 'UP 05125' and 'CoS 10239', however, under saline soil condition, varieties 'CoS 08279' and 'CoS 07240' produced more tiller/clumps than rest of varieties. Number of millable canes was also significantly higher in normal soil than in saline soil in all the varieties tested. The varieties 'CoSe 08279' and 'CoS 07240' maintained higher NMC as compared to other genotypes tested indicating their endurance capacity for salinity.

Cane yield per clumps was reduced significantly due to salinity. Under saline soil condition varieties 'CoS 08279' and 'CoS 07240' expressed higher cane yield followed by 'CoSe 06455' and 'CoS 08272'. These varieties showed minimum yield reduction percent indicating higher tolerance against salinity than other varieties tested. Sucrose percent in juice was found almost similar in saline and normal soils. However, higher sucrose percent in juice was recorded in varieties 'UP 05125' and 'CoS 8272' possibly due to their early maturing nature. On the basis of above observations it may be concluded that varieties 'CoS 08279', 'CoS 07240', 'CoSe 06455' are suitable for cultivation under saline soil condition.

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Map based analysis of sugarcane and sugar production in different countries with special reference to India – a new approach

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ABSTRACT

Out of 91 sugar producing countries in world, India is second largest producer of sugarcane (18.18 %) and sugar (15.81 %) next to Brazil. India is also largest consumer of sugar (15.93 %) of the world and 7th largest exporter of sugar (2.80 %) to 113 countries of the world. The large share of total export (2951 thousand tonnes) was made to Myanmar (27.72 %), Sudan (13.05 %), Somalia (11.05 %), Sri Lanka (6.26 %), United Arab Emirats (4.85 %), Tanzania Rep (4.25 %), Pakistan (3.66 %), Kenya (2.98 %), Saudi Arab (2.33 %), Jordan (2.52 %), Ethiopia (2.57 %), Turkey (1.89 %), Djibouti (1.61 %), Oman (1.63 %), Bangladesh (1.83 %) during 205-16 (April – January). There was significant increase of nearly 51 % export of sugar in 2015-16 over 2014-15. The quantity of sugar production from sugarcane had a positive annual growth rate for all the countries except Australia and USA among the top ten sugar producing countries from sugarcane. It is clearly observed that the quantity of sugar production has to be increased annually by faster rate as demand is increasing gradually in importing countries of the world. In India, if sugar production is more than our internal consumption then country can search for new destination to export sugar to countries like Indonesia, China, Iran, Bangladesh, UAE and EU-27, as these countries will have more demand of sugar for their internal consumption in near future.

Key words : Sugarcane, Sugar per capita consumption, Sugar export / import

Sugar was considered as rare commodity and it was used as medicine rather than as sweetener. From medicine to a luxury sugar has become a necessity. Globally it is an integral part of food to provide energy. Carbohydrates such as starch, sugar and polysaccharides are very important in the human diet (Blume, 1985). Sugar is today regarded as a mass consumption item and it also accounts for a large share of the total calorie intake of an average household (Pruthi, 1995). Worldwide per capita sugar consumption reached the equivalent of an energy intake of more than 837 Kj (200 kcl) daily (Hagelberg and Harris, 1976). Presently, the sugarcane crop provides the third highest quantity of human consumed plant calories (152 kcal/capita/day) following rice (533 kcal) and wheat (530 kcal) as reported by Moore et al., 2014. Consumption of sugar has increased remarkably, faster than the growth of the world's population. Just before world war II, the annual consumption of centrifugal sugar had risen to 24 million tones while in 1980 it was about 90 million tones, raw value, and during the same period the annual per capita consumption increased from 11 to than 21 kg/year (Blume, 1985). Presently, it has gone up to 171 million tones (2015) and annual per capita consumption has risen to the level of 23 kg/year (2013). It is expected that World sugar futures will under pressure in 2016-17 due to lees production of sugar and it is estimated to fall 7.60 % (13.3 million tonnes less for 2015-16 in comparison to 2014-15) which increasing the gap between global supply and consumption. As our country is also going to face shortage of sugar production during 2016-17, we have to plan strategies to meet the demand of our internal consumption of sugar. In this paper we have discussed the total world sugar production and consumption and sugar trade in major sugar producing and consuming countries with special emphasis on India. The international sugar trade is of strategic importance to India as it influence stability of domestic sugar price despite the cyclic ups and down in sugar production. There is considerable potential for expanding sugar production in India through varietal improvement, crop management practices as well as modernization of sugar mills.

Analysis of sugarcane and sugar in different countries of the world

An attempt has been made in this study to understand the sugar production, consumption and trade in different countries of the world. Data of sugarcane and sugar producing countries (2013 and 2015) was analyzed and mapped on the country wise map of the world with the help of Geographic Information System (GIS). Sugarcane is cultivated worldwide and 80.14% of sugar is produced from cane only (Table 1). The remaining 19.86% sugar is derived from sugar beet by 23 countries, which is grown mainly in temperate zone in the north. Out of 101 sugarcane producing countries (Map 1), top ten countries contribute 81.47 % in area and 82.85 % in production of world. Asian and South American (Map 2) countries dominate in sugarcane production, which account for nearly 85 % of cane production in world. Brazil and India are two major countries contribute a large share of 56.16 % in area and 57.56 % in production of the world. Among these top ten countries, Colombia had the highest cane yield (85.96 t/ha and rest of

Table 1 Sugarcane area, production, yield and sugar production in top ten countries of the world (2013/ 2015)

Country	Area ('000 ha)	Production ('000 t)	Yield (t/ha)	Sugar Production ('000 t)
Brazil	9835.17	739267.04	75.17	35800
India	5060.00	341200.00	67.43	27250
China	1819.00	125536.00	69.01	13300
Thailand	1321.60	100096.00	75.74	10200
Pakistan	1128.80	63749.90	56.48	4700
Mexico	782.80	61182.08	78.16	6508
Indonesia	450.00	33700.00	74.89	2500
Philippines	435.41	31874.00	73.21	2500
Colombia	405.74	34876.33	85.96	2300
Argentina	370.00	23700.00	64.05	2050
World	26522.73	1877105.11	70.77	171340

Data Source : FAO database (Food and Agriculture Organization of United Nations, Rome) and International Sugar Journal, 2015.

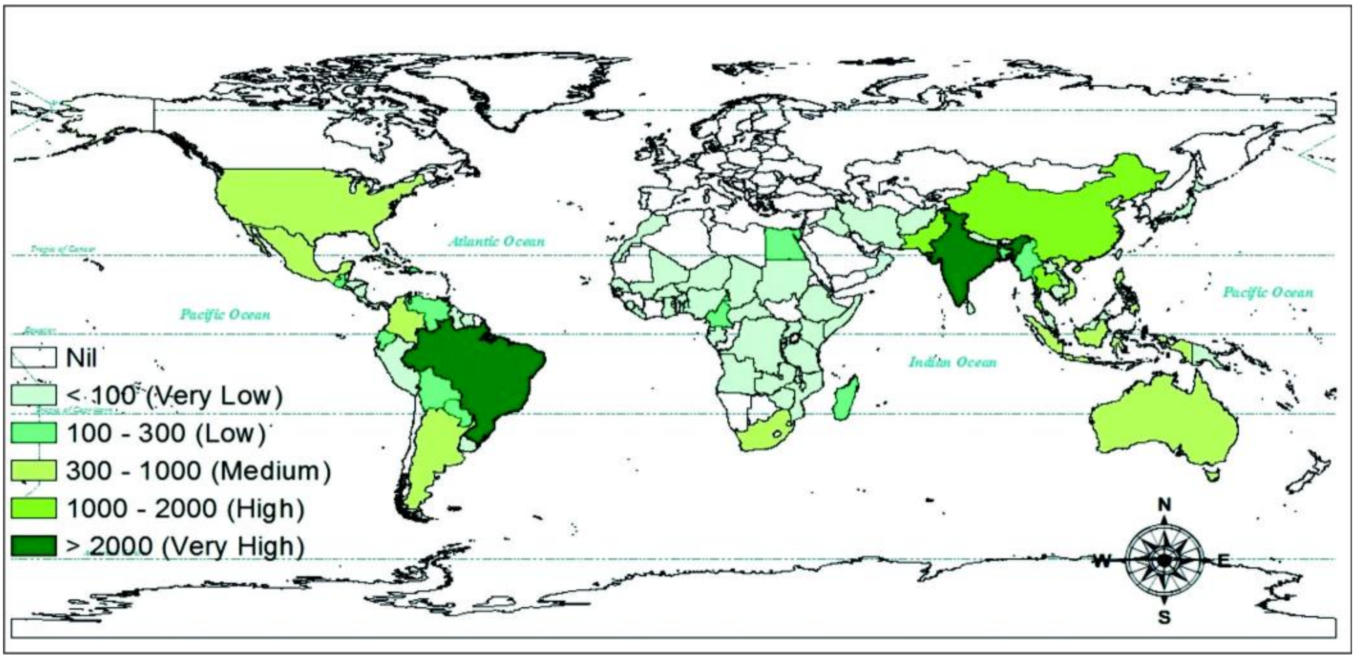
nine countries had cane yield in between 67 to 80 t/ha. Top ten high cane yield (t/ha) producing countries are Peru (133.72), Ethiopia (119.57), Egypt (115.33), Senegal (114.10), Malawi (107.41), Zambia (102.56), Burkina Faso (102.13), Guatemala (100.69) and United Republic of Tanzania (100.00) and Nicaragua (98.18) (Map 3) but these countries contribute only 2.59 % in area and 3.97 % in production of the world total of sugarcane, whereas world cane yield is reported as 70.77 t/ha. Average regional output of sugarcane production (average percentage of land used for its production times average yield in each grid cell) across the world compiled by the University of Minnesota, Institute on the Environment is depicted in Map 8.

Out of 91 sugar producing countries (Map 4), major ten sugar producing countries from sugarcane are Brazil (25.92 %), India (19.73 %), China (9.01 %), Thailand (7.38 %), Mexico (4.71 %), Pakistan (3.37 %), Australia (3.33 %), USA (2.36 %), Guatemala (2.02 %) and Indonesia (1.81 %) which accounts for 85 % of total sugar production from cane. Fifty four per cent of world sugar are produced by Brazil (20.77 %), India (15.81 %), EU (9.46 %) and China (7.72 %). Main sugar exporting countries are Brazil (44.23 %), Thailand (15.84 %), Australia (6.52 %) and Guatemala (3.63 %), these four countries account for 70.77 % of the total export of sugar in world. Out of 127 sugar importing countries (Map 6), major ten sugar importing countries are China (7.55 %), Indonesia (7.55 %), EU (6.96 %), USA (6.26 %), UAE (4.67 %), South Korea (3.87 %), Malaysia (3.83 %), Bangladesh (3.78 %), Algeria (3.68 %) and Iran (3.18 %), which accounts of 51.33 % of total import of world. Global sugar consumption has continued to increase from 162438 thousand tonne (2010-11) to 176834 thousand tonnes (2014-15) and will further continue at faster rate in under developed countries of Asia and Africa.

Consumption and trade of sugar in different countries of the world

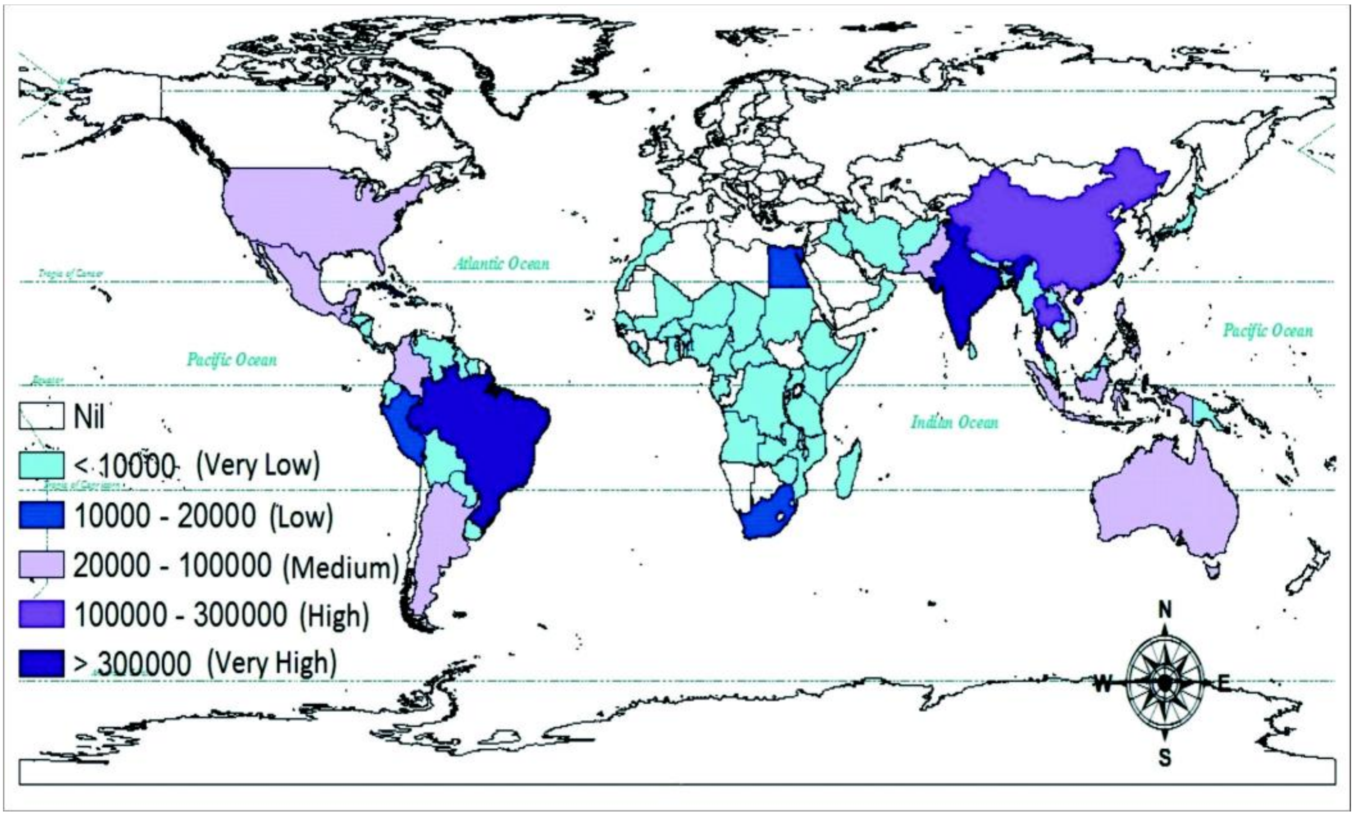
Top five human domestic sugar consumption countries are India (15.93 %), EU (10.91 %), China (9.01 %), Brazil (6.78 %) and USA (6.35 %) which accounts nearly 50 % of total sugar consumption of the world. Classification of per capita sugar consumption in 110 countries is depicted in Map 5 with five categories as Very High, High, Medium, Low and Very Low. Per capita consumption of sugar is very high (> 45 kg) in nearly 20 countries (Israel, Brazil, Cuba, Malaysia, Switzerland, Barbados, Singapore, Costa Rica, Trinidad & Tobago, Belize, New Zealand , Sudan, Gambia, Mauritania, Swaziland, Australia, Guatemala, Jamaica, Belarus) of the world. Out of 151 countries, 56 countries reported negative trend of per capita consumption of sugar (kg/year) during 2007 to 2013. Most of the countries, which had showed negative trend are from developed and developing countries. These countries are Australia, Iraq, Japan, Israel, Colombia, Kazakhastan, Swaziland, Brazil, Hong Kong, Pakistan, Canada, Russian Fed., Cuba, Liberia, Argentina, Mexico, Ukrain, Bahamas, Singapore, Norway, Kuwait, Switzerland, Syrian Arab Rep., Libyan Arab J., United Arab Emirates, Croatia and Fiji. During 2007 to 2013, per capita consumption of sugar (kg/year) is increasing at faster rate in under developed countries of Asia and Africa. Top twenty five countries where it showed increasing trend are Rwanda, Sudan, Eritrea, Zimbabwe, Cameroon U.R., Myanmar, Tanzania U.R., Bangladesh, Benin, Gabon, Rep. of Korea, Zambia, Guinea Bissau, Armenia, Lao, P.D.R., Papua N. Guinea, Zaire-Congo, Dem R., Kampuchea, Afghanistan, Thailand, Honduras, Belize, Togo, Albania and Jamaica. These countries may be the suitable destination to export sugar from India as most of these countries are not producing sugar.

After increasing tread of world sugar production from 2010-11 (162438 thousand tonnes) to 2013-14 (181404 thousand tonnes), decline in sugar production was observed in 2014-15 (171340 thousand tonnes) and will further decline next year as projected by most of the sugar forecasting agencies. Out of 91 sugar producing countries in world (Map 4), India is second largest producer of sugarcane (18.18 %) and sugar (15.81 %) next to Brazil. India is also largest consumer of sugar (15.93

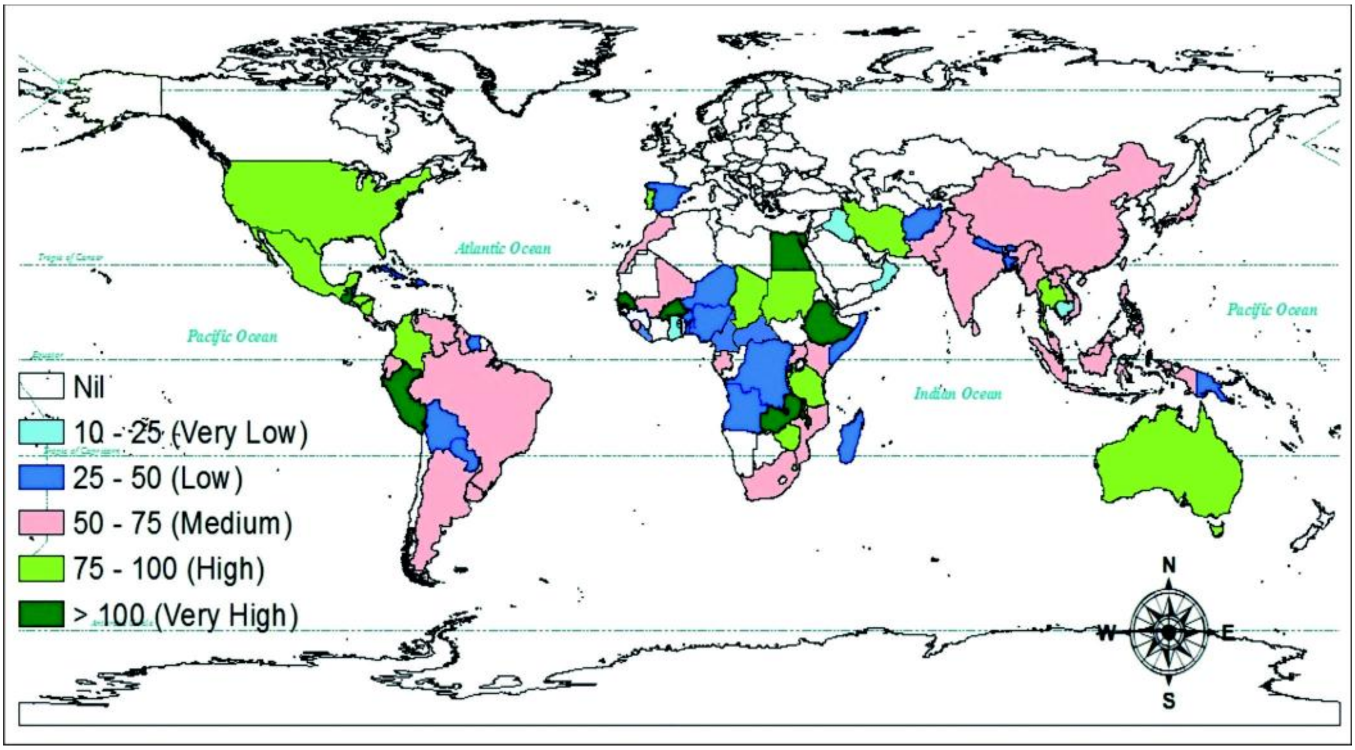


Developed by Dr Rajesh Kumar, Principal Scientist, ICAR-ISR, Lucknow, rajesh_iisr@hotmail.com

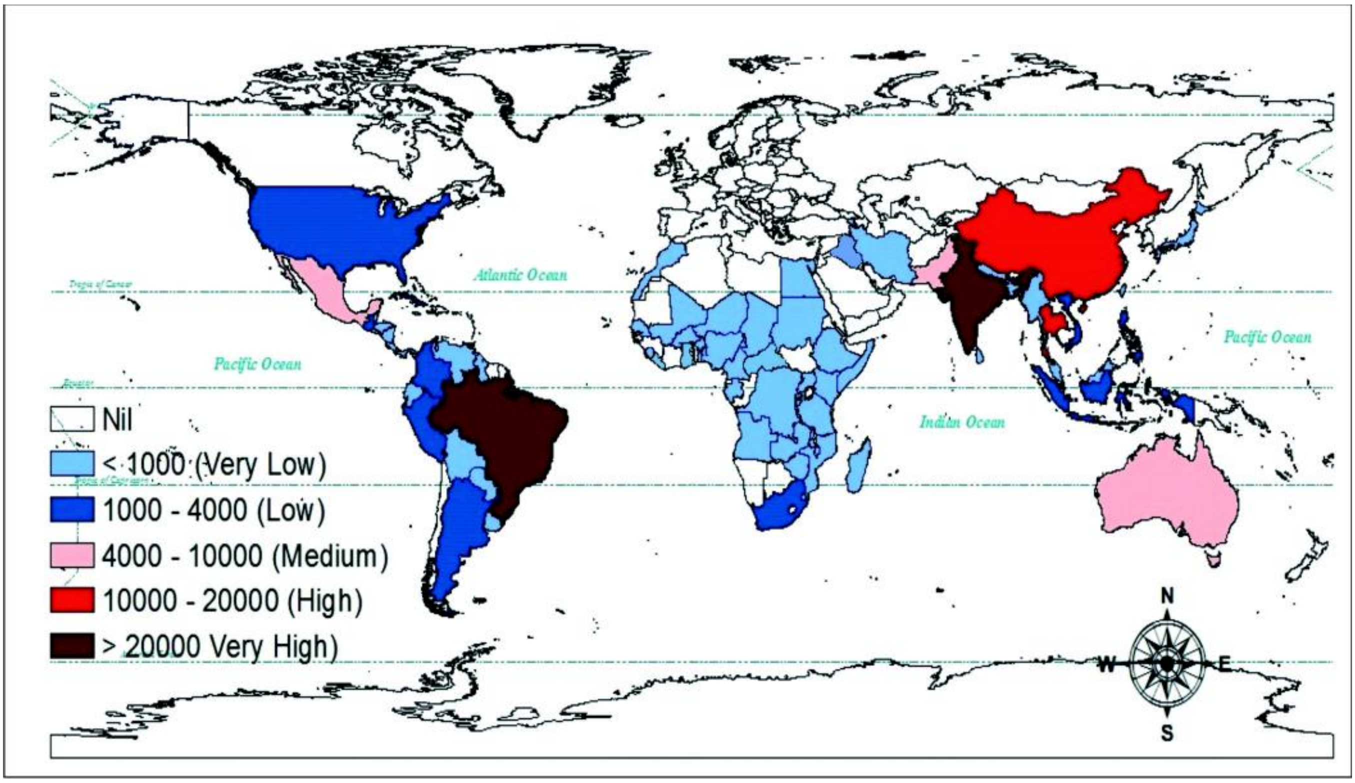
Map 1. Distribution of sugarcane area (1000 hectare) in different countries.



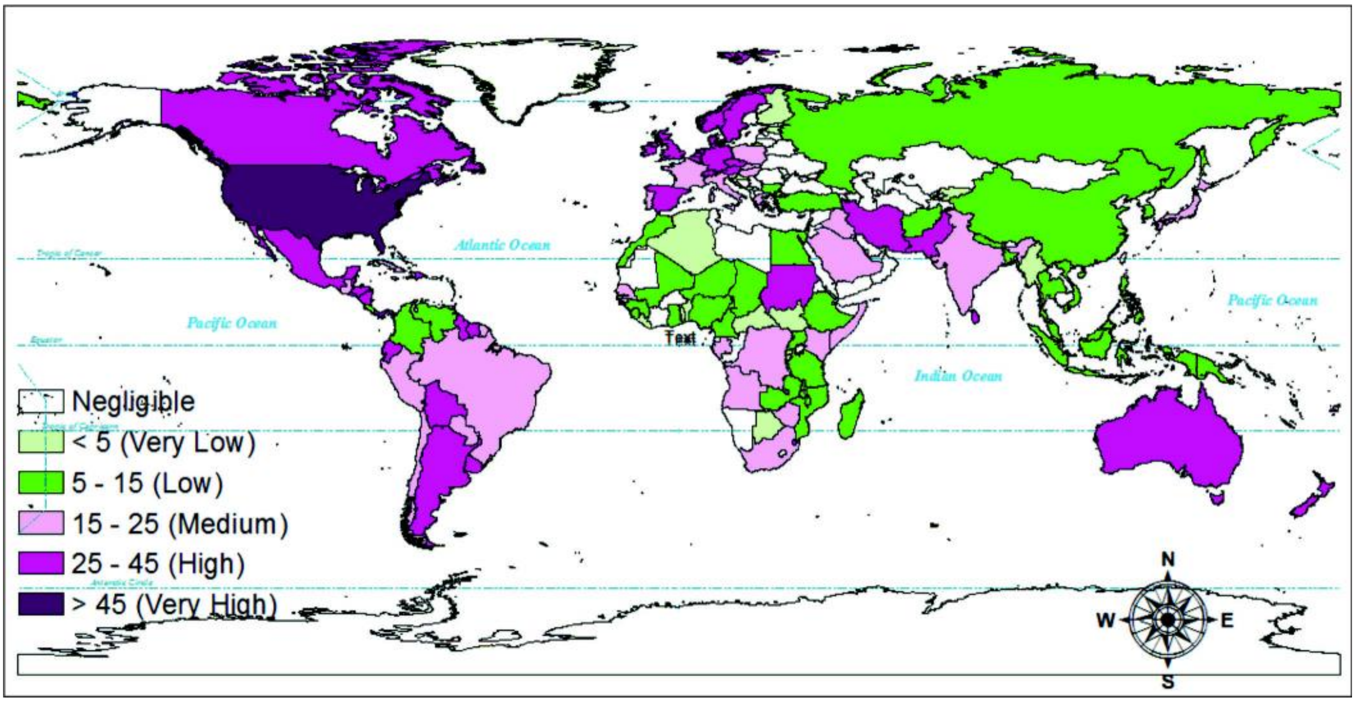
Map 2. Distribution of sugarcane production (1000 tonnes) in different countries



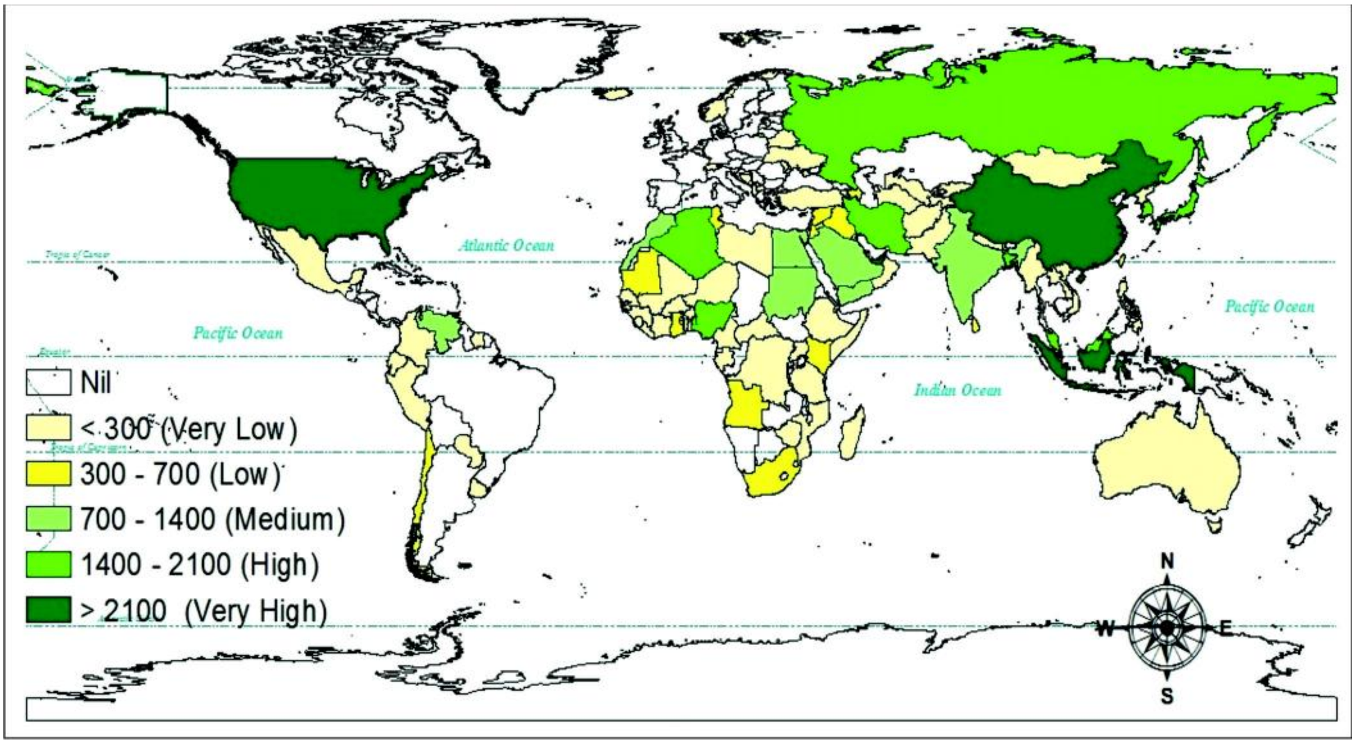
Map 3. Sugarcane yield (tonnes/hectare) in different countries



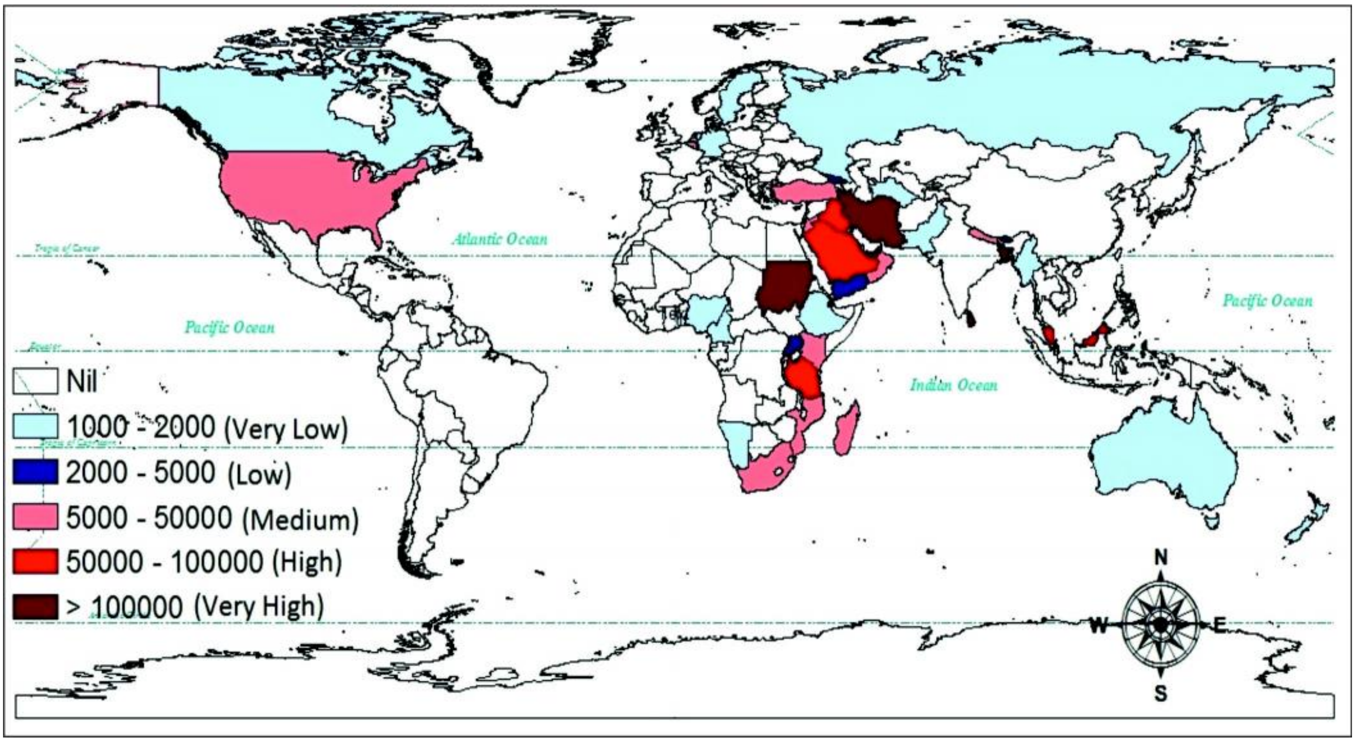
Map 4. Distribution of sugar production (1000 tonnes) in different countries



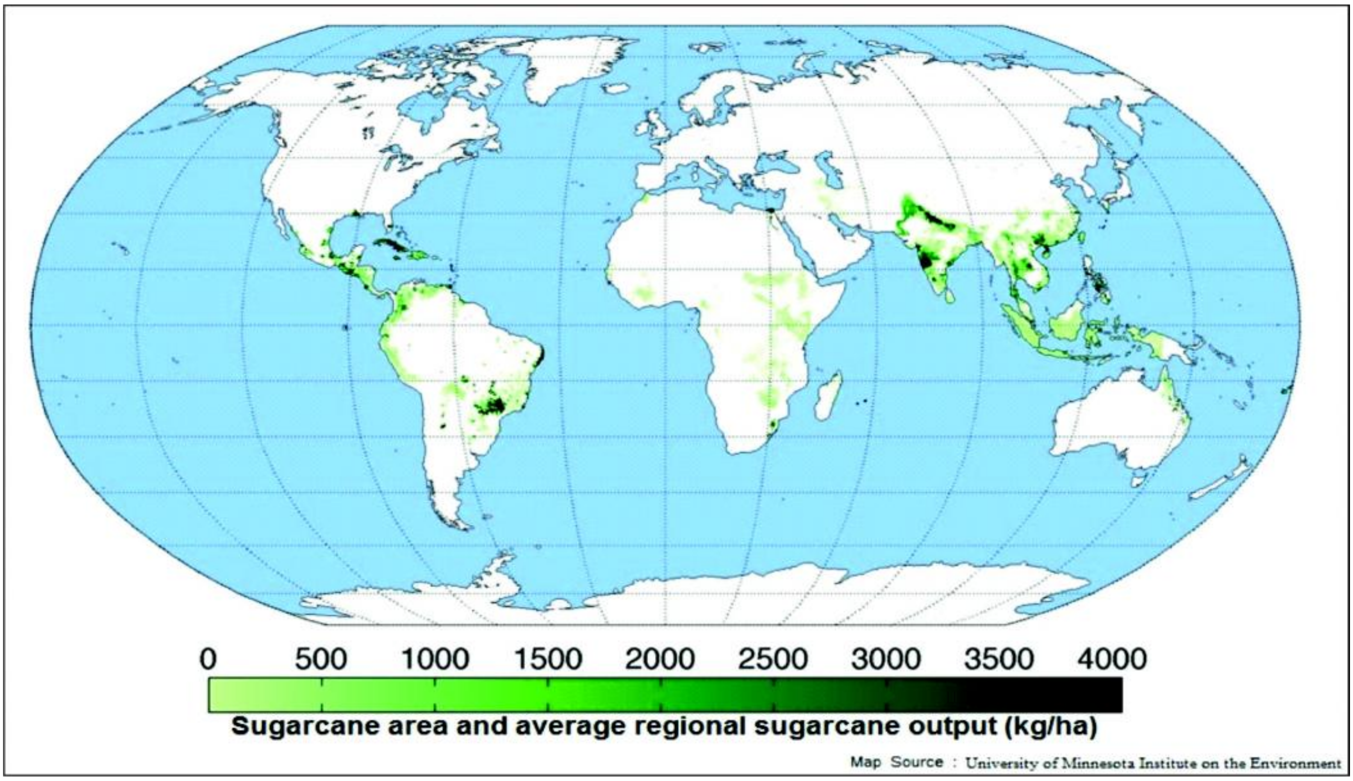
Map 5. Per capita consumption of sugar (kg) in different countries



Map 6. Distribution of sugar imports (1000 tonnes) by different countries



Map 7. Distribution of sugar export (tonnes) to different countries from India



Map 8. India is second largest producer of sugarcane (18.18%) and sugar (15.81%) next to Brazi. India is also largest consumer of sugar (15.93%) of the world and 7th largest exporter of sugar (2.80%)

%) of the world and 7th largest exporter of sugar (2.80 %) to 113 countries of the world (Map 7). The large share of total export (2951 thousand tonnes) was made to Myanmar (27.72 %), Sudan (13.05 %), Somalia (11.05 %), Sri Lanka (6.26 %), United Arab Emts (4.85 %), Tanzania Rep (4.25 %), Pakistan (3.66 %), Kenya (2.98 %), Saudi Arab (2.33 %), Jordan (2.52 %), Ethiopia (2.57 %), Turkey (1.89 %), Djibouti (1.61 %), Oman (1.63 %), Bangladesh (1.83 %)during 205-16 (April – January). There was significant increase of nearly 51 % export of sugar in 2015-16 over 2014-15. Around 35 % of sugar produced globally is made available for trade by different importing /exporting countries of the world. Most of the sugar produced by different countries of the world are consumed internally by large producing countries like Brazil (20.77 %), India (15.93 %), EU-27 (9.46 %), China (7.72 %) and Thailand (5.92 %). These five countries produced 60 % of the world total and consumed around 45 % of world total. Out of 69 sugar exporting countries of the world, Brazil (44.73 %), Thailand (15.84 %), Australia (6.52 %), Guatemala (3.63 %) and Mexico (3.32 %) are major player in export of sugar which account for nearly 75 % of the world export.

Current world sugar situation

Based on the average value of production and consumption (2010-11 to 2014-215) of sugar in different regions of the world, Asia is a largest producer of sugar (33.84 %) and also largest consumer of sugar (41.10 %). There is a deficit of 7.27 % and require to import sugar to meet the demand of internal consumption. South America is second largest producer (23.57 %) of sugar and consumed only 11.07 % of the world and have 12.5 % of surplus sugar to export (Table 2). In case of North and Central America, sugar production and consumption are same of about 11 % of the world. Africa contribute only 5.70 % of the world production where as it consume 9.91 % of world consumption and require to import 4.21 % of world. Similarly, European Union and Europe produces 23.56 % of world sugar and consume 26.34 %. It needs to import of 2.78 % of world sugar. Oceania is smallest producer of sugar (2.30 %) and also smallest consumer (only 0.90 %) and had surplus sugar to export (1.40 %).

F.O. Licht (2016) projected that Global sugar production is estimated to fall 7.60% (13.3 million tonnes less for 2015-16 in comparison to 2014-15) which increasing the gap between global supply and consumption. Sugar production is also expected to fall further in 2016-17, as the current dry weather will affect the production and yield in India, Thailand, South Africa, EU and north-east Brazil. According to revised government estimates, sugar production in India for the current year (2015-16) is expected to be 25.6 million tonnes compared to 28.3 million tonnes produced in 2014-15, a shortfall of 2.7 million tonnes. According to Indian Sugar Mills Association estimates, sugar stocks at the end of sugar season 2015-16 will be around 7.5 million tonnes compared to 9.1 million tonnes a year back. Sugar analysts have opined that lower average rainfall in 2015-16 will reduce cane area and therefore sugarcane production in 2016-17 will be adversely affected in major parts of Maharashtra and Karnataka. But this shortage is likely to be well compensated by higher cane production in UP and Tamil Nadu as good rainfall is expected in 2016-17. In UP, acreage under Co 0238 variety has increased, which may give a much higher yield and sugar recovery. India’s sugar output risks dropping below consumption for the first time in seven years, threatening to cut exports and boost global prices, particularly if imports are needed for the first time since 2008/09. India’s annual sugar demand is around 26 million tonnes, but B.B. Thombre, president of the Western India Sugar Mills Association, said the country could struggle to produce 24 million tonnes next year (2016-17). Exports of sugar are likely to be reduced because it is going to be uncompetitive from beginning of next financial year (2016-17) onwards as it is expected to rapidly rise of sugar prices in our country which has also started from March 2016. India need not to import sugar in the current sugar season ending on September 2016, due to carry forward stocks of 9.1 million tonnes from the last season.

This year (2015-16) sugar production is almost equal to the domestic consumption in our country. The sugar mills started in the current season with a significantly high opening stock of 9.1 million tonnes of sugar. If further export contracts

Table 2 Sugar production and consumption in different region of the World (Average value during the period 2010-11 to 2014-2015

Regions	Sugar Production ('000 t) (1)	Sugar Consumption ('000 tonnes) (2)	Difference (1000 tonnes) (1) – (2)	Sugar Production (%) over world total (3)	Sugar Consumption (%) over world total (4)	Difference (%) (3) – (4)
EU	17604	19001	-1397	9.05	10.01	-0.96
Europe	28230	31008	-2778	14.51	16.33	-1.82
Africa	11081	18810	-7729	5.70	9.91	-4.21
N. & C. America	21483	20289	1194	11.04	10.68	0.36
South America	45861	21029	24832	23.57	11.07	12.50
Asia	65834	78055	-12221	33.83	41.10	-7.27
Oceania	4481	1708	2773	2.30	0.90	1.40

Data Source : International Sugar Journal, 2015 take place to the extent of around 1.6 million tonnes, 9.1 million tonnes of sugar stocks in the country will be reduced to around 7.5 million tonnes which is still a significantly high opening balance as on 1st October, 2016 for 2016-17 sugar season. A climate management company, Weather Risk Management Services, has predicted above normal and well distributed monsoon for India after two successive droughts in some parts of sugarcane growing areas during 2013-14 and 2014-15. The prospects will improve cane planting in 2016-17. Sugar prices have risen substantially since mid-September 2015. India for once is all set to benefit from the world shortage as it is expected to produces sugar equal to it's internal consumption. Given concerns over the El Nino weather pattern, the 2016-17 season looks challenging for the world sugar industry and there remains a real possibility that output could be below consumption next year. This would give Indian mills, which are overflowing with stocks, further opportunity to dispose their stocks.

Recent growth of sugar in different countries of the world

The annual Compound growth rates in top ten sugarcane and sugar producing countries were estimated by fitting exponential type of equation during 2001 to 2013/2015 and results are presented in Table 3. In case of sugarcane area of major ten countries, all the countries recorded positive annual compound growth rate except Colombia. Brazil had the highest compound growth rate of 6.89 % per annum. Out of ten countries, six countries recorded compound rate in between 1.5 to 3.0 % per annum for cane area. Similar observations were also noted for sugarcane production. As far as cane yield is concern, top three countries, Brazil, India and China, recorded less than 1 % annual compound growth rate. Where as Thailand and Pakistan had highest compound growth rate of 2.70 % and 1.62 5 per annum. Further negative growth rate in cane yield was observed in Indonesia (-1.06), Colombia (-0.69), Mexico (-0.32), Philippines (-0.30) and Argentina (-0.17). Cane production (million tones) in these five countries reduced from 29.30 to 29.40 in Indonesia, from 39.85 to 33.22 in Colombia, from 51.65 to 55.78 in Mexico, 31.4 to 32.53 in Philippines and from 24.40 to 27.71 in Argentina over the period 2005 to 2015. Similarly cane area (million hectare) in these five countries changed from 0.38 to 0.47 in Indonesia, from 0.41 to 0.39 in Colombia, from 0.67 to 0.77 to Mexico, 0.37 to 0.43 in Philippines and from 0.28 to 0.39 in Argentina over the period 2005 to 2015. Reduction in cane area and production in these five countries may be observed due to decline productivity.

It is revealed from the table 3 that the quantity of sugar production from sugarcane had a positive annual growth rate for all the countries except Australia and USA among the top ten sugar producing countries from sugarcane. For sugar production from cane, impressive annual compound growth rates (%) of was recorded by top six countries, Brazil (5.16), Thailand (5.14), India (3.08), China (4.19), Pakistan (3.45)

Table 3 Annual compound growth rate (%) of sugarcane and sugar in top ten countries of the world during the period 2001 to 2015

Factors of sugarcane	Annual compound growth rate (%)									
Sugarcane Area (2001 – 2013)	Brazil (6.89)	India (1.53)	China (2.98)	Thailand (2.26)	Pakistan (0.45)	Mexico (1.60)	Indonesia (2.13)	Philippines (0.98)	Colombia (-0.28)	Argentina (2.38)
Sugarcane Production (2001 – 2013)	Brazil (7.62)	India (2.10)	China (3.77)	Thailand (5.02)	Pakistan (2.06)	Mexico (1.28)	Indonesia (1.05)	Philippines (0.68)	Colombia (-0.97)	Argentina (2.21)
Sugarcane Yield (2001 – 2013)	Brazil (0.69)	India (0.56)	China (0.76)	Thailand (2.70)	Pakistan (1.62)	Mexico (-0.32)	Indonesia (-1.06)	Philippines (-0.30)	Colombia (-0.69)	Argentina (-0.17)
Sugar Production from sugarcane	Brazil (5.16)	India (3.08)	China (4.19)	Thailand (5.14)	Mexico (1.43)	Pakistan (3.45)	Australia (-1.32)	USA (-0.62)	Guatemala (3.29)	Indonesia (1.82)
Sugar Production from sugar beet	EU-27 (0.05)	USA (0.80)	Russian (9.15)	Turkey (0.46)	Ukraine (-0.27)	Egypt (9.99)	China (-0.37)	Iran (-0.81)	Belarus (10.07)	Japan (-1.18)
Sugar Production from cane and beet	Brazil (5.16)	India (3.08)	EU-27 (0.04)	China (3.74)	Thailand (5.14)	USA (0.15)	Mexico (1.43)	Pakistan (3.45)	Australia (-1.32)	Russian (9.15)
Total Sugar distribution	India (1.38)	Brazil (4.76)	China (6.24)	EU-27 (0.09)	Thailand (6.82)	USA (1.32)	Indonesia (3.25)	Mexico (1.07)	Russia (-2.88)	Pakistan (2.88)
Sugar Human Consumption	India (2.68)	EU-27 (0.20)	China (4.32)	Brazil (1.56)	USA (1.50)	Indonesia (4.61)	Russia (-1.33)	Pakistan (1.90)	Mexico (-1.14)	Iran (3.12)
Sugar Exports by Country	Brazil (7.40)	Thailand (6.28)	Australia (-1.57)	Guatemala (3.40)	Mexico (30.55)	EU-27 (-3.31)	India (8.39)	Cuba (-8.68)	Colombia (-3.75)	South Africa (-3.70)
Sugar Imports by Country	China (11.23)	Indonesia (8.23)	EU-27 (6.95)	USA (6.95)	UAE (5.50)	South Korea (1.19)	Malaysia (2.70)	Bangladesh (7.77)	Algeria (4.64)	Iran (3.99)

Data Source (2015) : United States Department of Agriculture (http://www.usda.gov) and FAO database (Food and Agriculture Organization of United Nations, Rome) and Guatemala (3.29). Mexico (1.43) and Indonesia (1.82) also recorded significant growth rate (%). Australia and USA showed negative annual compound growth rate of -1.32 % and –0.62 % respectively. Out of top ten sugar producing countries from sugar beet, all the countries recorded either negative growth rate or less than 1 % except Russia and Belarus. Both the two countries showed phenomenal growth of sugar production from sugar beet of around 10 % per annum during last fifteen years (2001-2015).

Over all sugar production both from sugarcane and sugar beet is concern, similar observation was found as in case of sugar production from sugarcane. Highest annual compound growth rate (%) of sugar consumption was estimated in Indonesia (4.61) followed by China (4.32), Iran (3.12), India (2.68), Pakistan (1.90), Brazil (1.56) and USA (1.50). Where as negative growth rate was observed in Russia (-1.33) and Mexico (-1.14) among the top ten sugar consuming countries of the world. Among the top ten sugar exporter countries of the world, highest annual compound growth rate (%) of sugar export was recorded by Mexico (30.55) followed by Brazil (7.40), India (8.39), Thailand (6.28) and Guatemala (3.40). Where as highest negative growth rate (%) was observed in Cuba (-8.68) followed by Colombia (-3.75), South Africa (-3.70), EU-27(-3.31) and Australia (-1.57) among the top ten sugar exporting countries of the world.

Among the top ten sugar importing countries of the world, highest annual compound growth rate (%) of sugar import was observed in China (11.23) followed by Indonesia (8.23), Bangladesh (7.77), EU-27 (6.95), USA (6.95) and UAE (5.50). No negative growth was observed in top ten importing countries of the world. It clearly indicated that the quantity of sugar production have to be increased annually by faster rate as demand is increasing gradually in importing countries of the world. F.O. Licht (2015) reported that a major element of weakness is the general lack of large-scale demand for sugar as many countries have already refilled inventories that were depleted during the deficit phase of the world sugar market (Anon., 2015). It clearly indicated that the quantity of sugar production have to be increased annually by faster rate as demand is increasing gradually in importing countries of the world. If sugar is produced more than our internal consumption, then country can search new destination to export sugar to countries like Indonesia, China, Iran, Bangladesh, UAE and EU-27. As these countries will have more demand of sugar for their internal consumption in near future. These countries are also near destination to our country that will reduce the cost of transportation by road or sea rout.

CONCLUSION

Out of 91 sugar producing countries in world, India is second largest producer of sugarcane (18.18 %) and sugar (15.81 %) next to Brazil. Around 35 % of sugar produced globally is made available for trade by different importing / exporting countries of the world. Most of the sugar produced by different countries of the world are consumed internally by large producing countries like Brazil (20.77 %), India (15.93 %), EU-27 (9.46 %), China (7.72 %) and Thailand (5.92 %). The quantity of sugar production from sugarcane had a positive annual growth rate for all the countries except Australia and USA among the top ten sugar producing countries from sugarcane during 2001 to 2015. India is also largest consumer of sugar (15.93 %) of the world and 7th largest exporter of sugar (2.80 %) to 113 countries of the world (Map 7). The large share of total export (2951 thousand tonnes) was made to Myanmar (27.72 %), Sudan (13.05 %), Somalia (11.05 %), Sri Lanka (6.26 %), United Arab Emirats (4.85 %), Tanzania Rep (4.25 %), Pakistan (3.66 %), Kenya (2.98 %), Saudi Arab (2.33 %), Jordan (2.52 %), Ethiopia (2.57 %), Turkey (1.89 %), Djibouti (1.61 %), Oman (1.63 %), Bangladesh (1.83 %) during 205-16 (April – January). There was increase of nearly 51 % export of sugar in 2015-16 over 2014-15. It clearly indicated that the quantity of sugar production have to be increased annually by faster rate as demand is increasing gradually in importing countries of the world. If sugar is produced more than our internal consumption, then country can search new destination to export sugar to countries like Indonesia, China, Iran, Bangladesh, UAE and EU-27. As these countries will have more demand of sugar for their internal consumption in near future. These countries are also near destination to our country that will reduce the cost of transportation by road or sea rout.

Note : In maps, if there is any conflict between the international boundaries that is not known to the authors.

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Effect of integrated use of various bio-fertilizers and chemical fertilizers on sugarcane production and soil biological fertility.

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ABSTRACT

The experiment was conducted at Regional Research Station, CCS Haryana Agricultural University, Karnal, Haryana (India), on the plant-ratoon crops of sugarcane in sequence. The treatment consisted of control, application of recommended dose of fertilizers (RDF), 75% RDF, 75% RDF + bio-fertilizers, 50% RDF, 50% RDF + Bio-fertilizers, recommended N +phosphorus (P) as rock phosphate (RP), 100% recommended N+ P as RP+ Bio-fertilizers, 100% recommended N + 50% P as RP + Bio-fertilizers, 50% recommended N + 50% P as RP + Bio-fertilizers. In both plant and ratoon crop the application of 75% RDF + Bio-fertilizers or recommended N+P as RP+ Bio-fertilizers produced equal cane yield, yield attributing characters and juice quality (CCS%) to RDF. The application of 75% RDF, 50% RDF with or without Bio-fertilizers, 100% recommended N +P as RP, 100% or 50% recommended N+50% P as RP + Bio-fertilizer produced significantly lower cane yield and juice quality than the RDF alone. In both plant and ratoon crops enumeration of *Azotobacter*, PSB, fungi, bacteria, Actinomycetes in rhizosphere indicated that the population of all the groups was higher when bio-fertilizers were applied in combination with inorganic fertilzers, highest being with 75% RDF+Bio-fertilizers.

Keywords: Bio-fertilizers, Azotobactor, PSB, *Pseudomonas maltophila* and *Trichoderma viride*

In India continuous sugarcane cropping with the use of only inorganic fertilizers has led to depletion of biological fertility of the soil and posing threat to long term soil productivity. To stop the continuous decline in biological soil fertility it is important to use Biofertilizers in combination with chemical fertilizers. The various Bio-fertilizers can be used in integration with chemical fertilizer to increase the sugarcane production and maintain the soil fertility. Vessey (2003) explained that numerous species of soil bacteria which flourish in the rhizosphere of plants, but which may grow in, on, or around plant tissues, stimulate plant growth by a plethora of mechanisms. These bacteria are collectively known as PGPR (plant growth promoting rhizobacteria). The search for PGPR and investigation of their modes of action are increasing at a rapid pace as efforts are made to exploit them commercially as Bio-fertilizers. The modes of action of these Bio-fertilizer include fixing N_2, increasing the availability of nutrients in the rhizosphere, positively influencing root growth and morphology, and promoting other beneficial plant–microbe symbioses. Various studies conducted have shown that the use of different Bio-fertilizersviz.; *Azotobacter*, *Azospirillum* and phosphorus fixing bacteria (*Bacillus magatherium*) alone or in combined use of these micro-organism significantly increased the sugarcane and sugar yields. The combined use of these micro-organisms always recorded increase in yields over their application alone (Thakur and Singh 1996 and Shinde and Patil 1995). CCS Haryana Agricultural University, Hisar is engaged in doing research on carrier based solid biofertiliizers for last 35 years and distributing biofertilizers to the farmers for many crops. Bhatttacharyya and Kumar (2000) described that in the carrier based sold bio-fertilizers, the microorganisms have a shelf life only six months. They are not tolerant to UV rays and temperature more than 30 degrees. The population density of these microbes is only 10^8 (10 crores) c.f.u/ml at the time of production. This count reduces day by day. In fourth month it reduces to 10^6 (10 lakhs) c.f.u/ml and the end of 6 months the count is almost nil, That's why the carrier based biofertilizers were not effective and did not become popular among the farmers.. These effects are rectified and fulfilled in the case of liquid biofertilizers. The shell life of the microbes in these liquid bio-fertilizers is two years. They are tolerant to high temperature (55 degrees) and ultra violet radiations. The count is as high as 10^9c.f.u/ml, which is maintained constant upto two years. So the application of 1ml of liquid biofertilizers is equivalent to application of 1 kg of 5 months old carrier based bio-fertilizers (1000 times). Since these are liquid formulations the application in the field is also very simple and easy. They can be applied using hand sprayer, power sprayers, and fertigation tanks and as basal manure mixed along with FYM etc. They also have greater potential to fight with native population of micro-organisms.

The research work on effect of liquid biofertilizers on sugarcane was not available under Haryana conditions. Therefore experiments were conducted to study the effect of combined use of bio-fertilizers in combination of chemical fertilizer on sugarcane production and soil bio-logical fertility in Haryana soils.

MATERIALS AND METHODS

The experiment was conducted at CCS HAU Regional Research Station, Karnal, Haryana, India on the plant-ratoon crops of sugarcane in sequence. The mixture of various Bio-fertilizers containing diazotrophs (*Azotobacter*), phosphate solubilizing bacteria (*Pseudomonas striata*) and Bio-control agents (*Pseudomonas maltophila* and *Trichoderma viride*) was applied in sugar cane in combination with different levels of inorganic fertilizer (50%, 75% and 100% of recommended dose of fertilizers (RDF). The treatment consisted of control i.e. application of recommended dose of fertilizers (RDF) (150 Kg N+50 Kg P_2O_5/ha for plant crop and 225 Kg N+50 Kg P_2O_5/ha for ratoon crop), 75% RDF, 75% RDF + Bio-fertilizers(*Azotobactor* + Phosphorus Solublising Bacteria (PSB) + Bio-control agents (*Pseudomonas maltophila* and *Trichoderma viride*), 50% RDF, 50% RDF + Bio-fertilizers, 100% recommended N +phosphorus (P) as rock phosphate (RP), 100% recommended N+ P as RP+ Bio-fertilizers, 100% recommended N + 50% P as RP + Bio-fertilizers, 50% recommended N + 50% P as RP + Bio-fertilizers. 3lit/ha of liquid bio-fertilizer was used. The liquid biofertilizer consortium consisted of equal proportions on nitrogen fixing bacteria- *Azotobactor chroococcum*, Phosphorus Solublising Bacteria- Pseudomonas striate, and Bio-control agents (*Pseudomonas maltophila* and *Trichoderma viride*). All the bio-fertilizers were grown in their respective media and mixed in equal proportion before treating the sugarcane setts. The viable count of bio-fertilizers was 10 7 CFU per ml. The liquid biofertilizer consortium was diluted by 20 folds with clean water. The cut sets were dipped for 15-20 minutes and then planted on the same day. The ratoon crop was inoculated with 50 ml of dilute solution in the root zone around the sugarcane hill after removing the loose surface soil. The top soil was replaced after inoculation.

The top 15 cms of soil of experiment site was clay loam in texture and had pH (1:2) 8.9, electrical conductivity 0.40 dS/m, organic carbon 0.36%, Available P (Olsen) 5 kg/ha, Available K 140 kg/ha. Cane yield (t/ha) for plant and ratoon crops were recorded at the harvest. Yield attributing characters viz Number of millable cane, cane length (cm) and diameter (cm), number of internodes per cane were recorded at the harvest for first plant and ratoon crops only. For juice quality analysis at the harvest of both plant and ratoon crops, 10 canes stalk per plot were randomly collected, weighed and passed through a three roller sample mill for juice extraction. The crusher juice was analysed for brix (soluble solid) by brix hydrometer. After clarifying the juice with lead sub-acetate, the sucrose concentration was determined by polarimeter. The percentage of sucrose and commercial cane sugar (CCS %) in juice were determined by the methods of Meade and Chen (1977). Sugar yield was calculated by multiplying CCS% with cane yield. The microbial flora (fungi, bacteria, Actinomycetes, *Azotobacter* and phosphate solubilizing bacteria) in rhizosphere at 10 and 20 weeks after application were measured for first plant and ratoon crops only.

The response of different levels of Bio-fertilizersand inorganic fertilizers on the cane yield, cane length, cane diameter, number of internodes/plant and CCS (%) of both plant crops were determined from the ANOVA and LSD ($P< 0.5$).

RESULTS AND DISCUSSION

Effect of bio-fertilizers on cane yield and yield attributing characters

In both plant and ratoon crops the application of 75% RDF (112.5 kg N/ha +37.5 kg P_2O_5/ha for plant and 168.75Kg N/ha +37.5Kg P_2O_5/ha for ratoon) + Bio-fertilizers(Azotobacter + phosphorus solubilizing bacteria (PSB) + Bio-control agent) produced equal cane yield to the RDF (74.4 and 82.38 t/ha cane yield for 1st and 2nd plant crops and 63.13 and 72.26 t/ha cane yield for 1st and 2nd ratoon crop) (Table 1). Similarly these treatments also produced the equal yield attributing characters viz NMC, cane length and diameter to the RDF

Table 1. Effect of inorganic fertilizers and bio-fertilizers on cane yield

Treatments	Cane yield (t/ha)			
	05-06 1st Plant	06-07 1st Ratoon	07-08 2nd Plant	08-09 2nd Ratoon
RDF(150Kg N/ha+50Kg P_2O_5/ha for plant, 225Kg N/ha+50Kg P_2O_5/ha for ratoon)	74.40	63.13	82.38	72.26
75% RDF	66.00	60.00	78.11	68.03
75% RDF+ Bio-fertilizers	73.80	63.59	81.96	72.49
50% RDF	62.70	52.13	57.28	57.40
50% RDF+ Bio-fertilizers	64.50	54.41	58.82	59.54
100%Recommended N+ P as Rock phosphate	66.20	58.32	72.88	63.26
100% Recommended N + P as Rock phosphate+ Bio-fertilizers	72.80	62.82	81.14	71.68
100% Recommended N +50% P as Rock phosphate+Bio-fertilizers	63.00	56.99	68.59	60.13
50% Recommended N +50% P as Rock phosphate+ Bio-fertilizers	54.10	52.35	57.71	54.60
CD at 5%	3.33	1.75	2.60	3.31

(Table 2). The application of 75% RDF, 50% RDF with or without bio-fertilizers produced significantly lower cane yield and yield attributing characters than the RDF. The result indicated that application of bio-fertilizers can compensate the application of 25% dose of recommended nitrogen and phosphorus.

Fuentes-Ramirez (1993) *revealed that Acetobacter diazotrophicus*, a recently identified N_2-fixing bacterium strains produced 0.14 to 2.42 ug IAA mL^{-1} in culture medium. Considering that *A. diazotrophicus* is found within the plant tissue, the biosynthesis of IAA suggests that the bacteria could promote rooting and improve sugarcane growth by direct effects on metabolic processes, in addition to their role in N_2 fixation. Acosta (1999) The effects of several isolates of Azotobacter chroococcum and Azospirillum sp. on vitro plants of sugar cane was studied in Cuba. The treatments inoculated with the commercial bioproduct Biostin, the Azotobacter isolate caña OP, and the combination of them, together with the isolates of Azospirillum, produced the greatest stimulation on the vitro plants.

Shankaraiah et al. (1996) observed that with inoculation of N fixing bio agent particularly *Azotobactor* @2.0 kg/ha resulted to the tune of 6-7% higher yield (9200 kg/ha) even at reduced N levels indicating saving of fertilizer to an extent of 20%. Further it was observed that 11-12 % higher yield can achieved with application of bio-fertilizers and recommended dose of N (250 kg/ha). Naidu et al. (1987) reviewed the benefit of Bio-fertilizersviz. *Azotobacter*, *Azospirillum* and concluded that when Bio-fertilizers are applied, it is enough if 75 percent of nitrogen dose is applied as fertilizers. In well drained and moist soils *Azospirilllum* and in lift irrigated areas and sandy soils *Azotobactor* may be preferred. Singh and Singh (2004) concluded that application of Bio-fertilizers+ vermicomposting or press mud or NPK have resulted higher cane yield and nutrient uptake than Bio-fertilizersalone. Similarly Hari and Srinivasan (2005) conducted a field study to evaluate the response of sugarcane varieties to application of *Azotobacter*, *Azospirillum* and *Gluconacetobacter* under different levels of fertilizer nitrogen. *Azospirillum* significantly improved the cane and sugar yield compared to *Gluconacetobacter, Azotobacter* and un-inoculated control. *Gluconacetobacter* and *Azotobacter* were on par. *Gluconacetobacter* was better than un-inoculated control.

The application of recommended N (150 kg N for plant and 225 kg N/ha for ratoon)+P (50 kg P_2O_5 /ha) as rock phosphate+ bio-fertilizers produced equal cane yield to the RDF (74.4 and 82.38 t/ha cane yield for 1st and 2nd plant crops and 63.13 and 72.26 t/ha cane yield for 1st and 2nd ratoon crop) (Table 1). The application of 100% recommended N+ P as rock phosphate alone, 100% recommended N or 50% recommended N +50%P as rock phosphate+bio-fertilizers, produced significantly lower cane yield and yield attributing characters than the RDF. The result indicated the feasibility of substituting soluble phosphate fertilizer with rock phosphate when used in combination of bio-fertilizer. However reducing dose of P to 50% when applying through rock phosphate+ Bio-fertilizer significantly reduced the cane yield and yield attributing characters.

Study conducted by Sundra and Natarajan (1997) indicates the feasibility of substituting super phosphate with rock phosphate when used in conjugation with phosphobacteria. Whereas Rodríguez and Fraga (1999) explained that the use

Table 2 Effect of inorganic fertilizers and bio-fertilizers on cane yield attributing characters

Treatments	1st Plant crop				1st Ratoon crop			
	NMC/ha	Cane Length (cm)	Cane Diameter (cm)	No. of Internode /cane	NMC/ ha	Cane Length (cm)	Cane Diameter (cm)	No. of Internode /cane
RDF(150Kg N/ha+50Kg P_2O_5/ha for plant, 225Kg N/ha+50Kg P_2O_5/ha for ratoon)	78000	176	2.71	17.9	70142	200	2.81	21.3
75% RDF	72080	164	2.60	18.2	68857	187	2.65	21.0
75% RDF+ Bio-fertilizers	77600	174	2.70	18.2	71428	198	2.80	21.3
50% RDF	70860	160	2.50	18.4	60428	176	2.35	20.8
50% RDF+ Bio-fertilizers	71800	162	2.54	18.5	62857	180	245	20.8
100% Recommended N+P as Rock phosphate	72250	164	2.58	18.6	67357	185	2.52	21.0
100% Recommended N +P as Rock phosphate + Bio-fertilizers	77200	175	2.69	18.0	69143	197	2.75	21.25
100% Recommended N +50% P as Rock phosphate+Bio-fertilizers	71620	162	2.52	18.4	62071	182	2.60	20.8
50% Recommended N +50% P as Rock phosphate + Bio-fertilizers	65280	148	2.44	18.5	60071	178	2.38	20.5
CD at 5%	2050	2.17	0.098	NS	1476.7	5.67	0.046	NS

of phosphate solubilizing bacteria as inoculants simultaneously increases P uptake by the plant and crop yield. Strains from the genera Pseudomonas, Bacillus and Rhizobium are among the most powerful phosphate solubilizers. The principal mechanism for mineral phosphate solubilization is the production of organic acids, and acid phosphatases play a major role in the mineralization of organic phosphorous in soil.

Martínez and Martínez (2007) reported that with the inoculation of two selected solubilizing bacteria (PSB) there were significant differences in plant growth, as the stem length under the phosphate treatment and the mixture of the two bacteria was of 32 cm, while such length was of 17 cm under the positive control. Similarly, stem length with the phosphate treatment and E. cloacae was of 9 cm, as compared with 5 cm with the positive control. As for root growth, an increase of 2.57 times was observed, as related to the positive control's dry weight. Root length was increased 0.73 times, being similar to that of the KNO_3 control.

Stamford (2006) conducted the experiment with the aim to evaluate the effects of Bio-fertilizers with phosphate and potash rocks and soluble fertilizers (Triple super phosphate and potassium chloride) in chemical attributes of a Brazilian tableland soil grown with sugarcane. Two varieties of sugarcane, three sources of P and K mixture (natural apatite + natural biotite; P + K Bio-fertilizers with *Acidithiobacillus* and P + K chemical fertilizers) were applied in four levels and were compared with control treatment (no P and K fertilization). Significant differences between varieties were observed in all analyzed parameters, with better results when applied the recommended levels of Bio-fertilizers and chemical fertilizers. Stalk fresh matter increased with fertilizers and Bio-fertilizers applications, especially when applied in levels near recommendation. Total N, total P and total K in stalk dry matter increased significantly when Bio-fertilizers were applied. The results indicate potential use of Bio-fertilizers that may be used as P source; however, long-term studies are necessary due to soil pH reductions and its possible adverse effects.

Effect of Bio-fertilizers on Juice quality and sugar yield

In both plant and ratoon crops the application of 75% RDF+ Bio-fertilizers or recommended N +50 kg P_2O_5 as rock phosphate + Bio-fertilizers produced equal sugar yield of RDF (78.19 and 108.41 t/ha for 1st and 2nd plant crop and 61.74 and 94.15 t/ha for 1st and 2nd plant crop) and juice quality (CCS%) of RDF (Table.3).

The application of 75% RDF alone or 50% RDF with or without Bio-fertilizers or 100% recommended N + P as rock phosphate, 100% recommended N or 50% N+50% P as rock phosphate+Bio-fertilizers produced significantly lower juice quality and sugar yield than the recommended fertilizer.

Thopate and Jadhav (1999) observed application of *Acetobacter* culture for sugarcane @ 10 kg/ha increased the sugar yield by 3.28 t/ha with saving of 50% of recommended dose of chemical nitrogen in Maharashtra state. Similarly Thakur and Singh, 1996 reported that the use of different Bio-fertilizersviz.; *Azotobacter*, *Azospirillum* and phosphorus fixing bacteria (*Basillus magatherium*) alone or in combined use of these micro-organism significantly increased the sugar yields.

Effect of Bio-fertilizers on microbial biomass

In both plant and ratoon crops enumeration of different groups of microbes viz. *Azotobacter*, PSB, fungi, bacteria, Actinomycetes in rhizosphere of sugarcane up-to 20 weeks

Table 3 Effect of inorganic fertilizers and bio-fertilizerson juice quality

	CCS (%)				Sugar yield (q/ha)			
	05-06 1st Plant	06-07 1st ratoon	07-08 2nd Plant	08-09 2nd ratoon	05-06 1st Plant	06-07 1st ratoon	07-08 2nd Plant	08-09 2nd ratoon
RDF(150Kg N/ha+50Kg P_2O_5/ha for plant, 225Kg N/ha+50Kg P_2O_5/ha for ratoon)	10.51	9.78	13.16	13.03	78.19	61.74	108.41	94.15
75% RDF	10.39	9.40	12.90	12.80	68.57	56.4	100.76	87.08
75% RDF+ Bio-fertilizers	10.81	9.67	13.11	13.08	79.78	61.49	107.45	94.82
50% RDF	10.68	8.80	12.05	11.72	66.96	45.87	69.022	67.27
50% RDF+ Bio-fertilizers	10.41	9.15	12.40	12.14	67.14	49.79	72.937	72.28
100% Recommended N+P as Rock phosphate	10.52	8.96	12.78	12.54	69.64	52.25	93.141	79.33
100% Recommended N +P as Rock phosphate + Bio-fertilizers	10.39	9.51	13.17	13.05	75.64	59.74	106.86	93.54
100% Recommended N +50% P as Rock phosphate+Bio-fertilizers	10.67	9.01	12.60	12.34	67.22	51.35	86.423	74.2
50% Recommended N +50% P as Rock phosphate + Bio-fertilizers	10.43	8.95	12.31	11.72	56.43	46.85	71.041	63.99
CD at 5%	NS	0.273	0.241	0.318				

Table 4 Effect of bio-fertilizers on microbial population in plant crop

Treatment	Fungi (CFU X 10^3)		Bacteria (CFU X 10^3)		Actinomycetes (CFU X 10^3)		PSB (CFU X 10^3)		Azotobacter (CFU X 10^3)	
	10 weeks	20 weeks	10 weeks	20 weeks	10 weeks	20 weeks	10 weeks	20 weeks	10 weeks	20 weeks
RDF(150Kg N/ha+50Kg P_2O_5/ha for plant, 225Kg N/ha+50Kg P_2O_5/ha for ratoon)	7.3	11.4	22.0	28.1	8.5	11.2	16.3	21.7	9.6	18.4
75% RDF	6.9	10.7	20.3	26.4	8.3	10.8	16.7	21.8	9.3	18.5
75% RDF+ Bio-fertilizers	8.3	12.5	24.3	30.6	10.8	14.4	18.6	22.3	12.6	22.9
50% RDF	5.6	8.3	21.0	26.8	7.1	10.0	14.8	20.1	5.4	11.9
50% RDF+ Bio-fertilizers	6.3	8.7	21.9	27.7	8.6	11.5	16.8	21.4	7.0	13.6
100% Recommended N+P as Rock phosphate	4.3	6.6	20.0	24.8	6.5	8.9	15.3	20.3	6.5	12.7
100% Recommended N+P as Rock phosphate + Bio-fertilizers	8.3	12.9	23.8	30.9	12.3	16.1	18.5	23.7	12.4	21
100% Recommended N +50% P as Rock phosphate + Bio-fertilizers	6.8	8.1	20.7	27.3	7.3	9.6	16.4	23.4	8.3	17.5
50% Recommended N +50% P as Rock phosphate+Bio-fertilizers	5.8	9.5	21.4	28.2	6.5	9.0	16.8	23.8	7.3	16.5
Initial	5.5×10^2		9.2×10^3		5.4×10^3		8.9×10^3		42×10^2	

Table 5 Effect of bio-fertilizers on microbial population in ratoon crop

Treatment	Fungi (CFUx10^3)		Bacteria (CFUx10^4)		Actinomycetes (CFUx10^3)		PSB (CFUx10^3)		*Azotobacter* (CFUx10^3)	
	10 weeks	20 weeks	10 weeks	20 weeks	10 weeks	20 weeks	10 weeks	20 weeks	10 weeks	20 weeks
RDF(150Kg N/ha+50Kg P_2O_5/ha for plant, 225Kg N/ha+50Kg P_2O_5/ha for ratoon)	8.9	18.2	28.4	34.1	10.8	14.8	21.1	27.1	14.0	22.3
75% RDF	8.6	13.1	24.3	32.6	10.1	13.9	19.7	28.2	16.0	25.8
75% RDF+ Bio-fertilizers	9.9	19.2	29.3	34.0	14.1	18.4	21.8	29.3	16.2	29.2
50% RDF	6.0	12.3	24.6	30.1	11.7	18.1	19.2	24.4	10.5	19.1
50% RDF+ Bio-fertilizers	7.2	11.8	23.3	32.1	16.8	15.1	18.8	29.3	11.7	18.3
100% Recommended N+ P as Rock phosphate	6.8	8.8	22.4	29.4	8.1	12.8	19.3	27.0	11.6	17.2
100% Recommended N+P as Rock phosphate+ Bio-fertilizers	8.8	13.6	25.6	33.1	16.1	24.3	18.8	27.3	14.2	25.1
100% Recommended N +50% P as Rock phosphate + Bio-fertilizers	8.9	12.0	21.6	30.9	10.4	16.0	19.8	28.3	12.6	23.5
50% Recommended N +50% P as Rock phosphate+Bio-fertilizers	9.0	11.2	26.3	33.8	8.1	13.3	18.6	28.3	10.7	21.1
Initial	9.0	11.2	26.3	33.8	8.1	13.3	18.6	28.3	10.7	21.1
Treatment	5.9x10^2		9.8x10^3		5.9x10^3		9.5x10^3		5.0x10^2	

indicated that the population of all the groups increased with the increasing application of NP fertilizers (50% RDF to 100% RDF). The microbial population was higher when Bio-fertilizers were applied in combination with NP fertilzers, highest being with 75% RDF+Bio-fertilizers. The population of different groups of microbes was highest at 20 weeks. The application of recommended N +100% P as RP without Bio-fertilizers has lowest microbial population. The higher population of all the groups of microorganisms in treatments where Bio-fertilizers was used over un-inoculated showed that application of Bio-fertilizers increased the growth of other rhizosphere microorganisms in sugar cane.

The use of organic fertilizers together with chemical fertilizers, compared to the addition of organic fertilizers alone, had a higher positive effect on microbial biomass and hence soil health (Dutta et al. 2003). Application of organic manure in combination with chemical fertilizer has been reported to increase absorption of N, P and K in sugarcane leaf tissue in the plant and ratoon crop, compared to chemical fertilizer alone. Similarly Sundara et al. (2002) found that the application of PSB, Bacillus megatherium var. phosphaticum, increased the PSB population in the rhizosphere and P availability in the soil. It also enhanced sugarcane growth, yield and quality. When used in conjunction with P fertilizers, PSB reduced the required P dosage by 25%. In addition, 50% of costly superphosphate could be replaced by a cheap rock phosphate, when applied in combination with PSB.

CONCLUSION

The application of 75% RDF, 50% RDF with or without Bio-fertilizers produced significantly lower cane yield and yield attributing characters than the RDF. The results suggest that the application of Bio-fertilizers can compensate the application of 25% dose of recommended nitrogen and phosphorus. The result also indicated the feasibility of substituting soluble phosphate fertilizer with rock phosphate when used in combination of bio-fertilizer. However reducing dose of P to 50% applied through rock phosphate+Bio-fertilizer significantly reduced the cane yield and yield attributing characters.

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Improving productivity, nutrient uptake, quality and sustainability of sugarcane (*Saccharum* spp. Hybrid complex) varieties through nutrient management of NPK in clay loam soil of Rajasthan

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ABSTRACT

A field experiment was conducted at Agricultural Research Station, Kota during spring seasons of 2012-13, 2013-14 and 2014-15 on clay loam soil, to find out suitable sugarcane (*Saccharum* spp.) varieties ('Co 06033','CoLk 07201','CoH 06247' and 'CoPk 05191') under three nutrient management levels of NPK(150:45:30, 200:60:40 & 250:75:50 kg/ha), laid out in randomized block design with three replications. The variety 'CoH 06247'recorded significantly higher percent germination (45.08), tillers (1, 52,000 /ha), cane length (220.40 cm), number of millable cane (1, 22,440 /ha), cane yield (97.55 t/ha), Uptake of NPK (263.78, 17.80 and 224.37 kg/ha), net return (₹ 1, 22,570 /ha) and B: C ratio (2.20) over others varieties. While the highest commercial cane sugar (11.49 t/ha) and pol % juice (18.61) was observed with the variety 'CoPk 05191'followed by 'CoH 06247,' hence it could be adopted in the region for optimizing sugar productivity and regulating crushing schedule at factory level. The results also revealed that yield attributes *viz.*Tillers (1,40,150 /ha), number of millable cane (1,19,020 /ha), cane yield (92.86 t/ha), CCS (10.94t/ha), Uptake of NPK (261.40,18.30 and 212.50 kg/ha), net return (₹ 1,11,770/ha) and B:C ratio(2.10) were observed significantly with the application of 200:60:40 kg NPK/ha over fertility levels of NPK 150:45:30 kg/ha and at par with NPK of 250:75:50 kg/ha, indicating the response of NPK was found positive trending due to increasing levels of fertilizers up to 200:60:40 kg NPK/ha in spring season. Thus, the results indicated that application of 200:60:40 kg NPK/ha was found best nutrient management practice for getting higher yield and profitability of sugarcane variety 'CoH 06247' in spring planting.

Key words: Commercial cane sugar, Nutrient management, Sugarcane varieties

Sugarcane (*Saccharum* spp. Hybrid complex) is an important commercial crop in India being cultivated on 5.06 million ha, with an average productivity of 66.9 t/ha (ISMA, 2013). We are also the second largest producer of sugarcane in the world after Brazil. It is the most important cash crop of Rajasthan which is grown on 5375ha area, with an average productivity of 73.10 t/ha (Anonymous, 2013).Broadly speaking, in Rajasthan the low sugar recovery as well as cane production is governed by various factors at the farmers' field, out of which, imbalanced nutrient use especially NPK, adoption of old variety, planting time in the prevalent cropping system and agro-climatic conditions is the major reason responsible for this. Fertilizer use in India is inadequate, imbalanced and is in favour of nitrogen application. Escalating prices of fertilizers in the market has become a cause of concern to sustain the sugarcane productivity. Application of balanced fertilizers especially NPK is an important management practice for increasing sugarcane yield and sugar production without deterioration soil fertility. Nitrogen and phosphorus are the most important nutrient element in influencing the level of crop yield in sugarcane. Nitrogen deficiency may decrease cane yield while, excess N availability during the ripening period reduces the juice quality (Tabayoyong and Robeniol 1962).Response of sugarcane to applied nitrogen and phosphorus was higher than potassium. In addition to major nutrients, smaller quantities of secondary and micronutrients such as sulphur, zinc, iron and manganese do enhance the yield as well as quality of sugarcane. Sugarcane is an exhaustive crop which removes about 205, 24, 229, 30, 3.5, 1.2, 0.6 and 0.2 kg / ha of N, P, K, S, Fe, Mn, Zn and Cu, respectively from the soil for the cane yield of 100 t/ha (Singh *et al.* 2007). The application of K fertilizers is very low as compared to its removal from soil. The crop is responding to higher levels of fertilizers than that of recommended doses for its biomass production. Optimum nutrient management for sugarcane plant crop plays key role as it establishes vigorous stubble, which affects the ratoon yield (Shukla 2007). Fertility levels may influence the tillering pattern and other growth parameters of different varieties to a great extent. Yield potential of different sugarcane varieties may differ under different agro-climatic conditions because of their inherent capabilities for adaptation. The adoption of high yielding better quality variety is the leaf better technology that the cane grower can easily afford. In

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subtropical India sugarcane is planted in autumn, spring and summer season under different nutrient management levels. However, sugarcane could be grown ideally in February-March but for improved yield & quality identification of optimum time of planting and fertilizer dose which fits well to the local climatic and weather variable is very important. Under the present situation application of nutrient elements especially NPK is essential for increasing sugarcane yield and maintaining crop production at higher level. Considering these facts, the present study was therefore, undertaken with aimed to find out sugarcane varieties suitable for spring planting season and optimize fertilizer needs for improving productivity and quality of sugarcane on clay loam soil of south east Rajasthan.

MATERIALS AND METHODS

A field experiment was conducted during the spring seasons of 2012-13, 2013-14 and 2014-15 at Agricultural Research Station, Ummedganj, Kota (25^{o}13 latitude N & 75^{o}25 longitude E Altitude of 258 m above mean sea level) to study the effect of nutrient management on yield attributes, cane yield, juice quality and sustainability of sugarcane varieties under spring planting seasons in clay loam soil of Rajasthan. It was laid out in randomized block design with using four sugarcane varieties *viz* 'Co 06033', 'CoLk 07201', 'CoH 06247' and 'CoPk 05191' and three levels of nutrient management of NPK 150:45:30, 200:60:40 & 250:75:50 kg/ha with 3 replications. The experiment soil was clay loam having pH 8.1, medium in organic carbon (0.56 %), available nitrogen and P_2O_5 (352 and 23.8 kg/ha) and high in available K_2O (282 kg/ha).Sugarcane was planted in the last week of February (spring planted) was done at 75 cm row spacing using same seed rate of 3 budded setts and harvested in the following years after attaining 11-12 month old crop. Farm yard manure at 10 tonne/ha was incorporated uniformly over the field before last plouging. Full dose of PK and ¼ N were applied as basal per treatments and remaining N in 3 equal splits were top dressed on 30 & 60 days after planting and earthing up i.e. on onset of monsoon. The NPK fertilizers were applied through urea and DAP and muriate of potash, respectively. Seven irrigations to spring crop were given before monsoon. All the agronomic and plant-protections were carried out uniformly as and when required. The experimental location experiences sub tropical climate with dry summer extending from March to August. A perusal of 50 year weather data of the site reveals that the area received a mean annual rainfall of 851.52 mm distributed in 45.6 rainy days. The mean annual maximum and minimum temperature, relative humidity and pan evaporation ranged from 19.5 to 43.6 ^{o}C and 7.44 to 28.81 ^{o}C, 38.96 to 94.50 per cent and 1.2 to 18.4 mm per day, respectively (Table 1). Five canes were randomly selected from each plot for estimation of growth attributes, yield and quality parameters. Cane juice was extracted with power crusher and juice quality was estimated as per method given by Spencer and Meade (1955). Sugar yield was calculated as; Sugar yield (t/ha) = [S- 0.4 (B - S) x 0.73] x cane yield (t/ha) /100; where S and B are sucrose and ^{o}brix percent in cane juice. Millable cane stalk were counted in December -January for spring crop. Cane growth attributes were measured before harvesting at the time of juice analysis. Whole cane samples were analyzed for N, P and k contents. The uptake of N, P and K were calculated by multiplying their concentration with dry matter yield. The economics was worked out on prevailing market prices. Variances were subjected to Bartlett's test for homogeneity of variance. As variances were found to be homogenous pooled data for 3 consecutive years for spring were presented.

Sustainability yield index (SYI) was calculated for different treatments taking yield as dependent variable. Mean yield of each treatment (Yt) and standard deviation (Sd) over years were calculated using the yield data from 2012 to 2014 for arriving at SYI using the equation h_1 = (Yt-Sd) / Ymax X 100- where h_1 is sustainability index of h treatment over a period of n years and Ymax is the maximum yield.

RESULTS AND DISCUSSION

Growth and Yield attributes

Germination counts were recorded at 40th days after planting of sugarcane. Among the varieties, significant variation in percent germination was recorded during 2013-14 and 2014-15 while, the effect on percent germination was non- significant during 2012-13 (Table 2). Pooled data of 3 cropping season indicated that percent germination differed among the varieties. Significantly higher germination percentage was recorded with the variety 'CoH 06247' (45.08 %) over variety 'CoPk 05191'and 'CoLk 07201' which was almost at par with the variety 'Co 06033' (43.38%) on pooled analysis. The remarkable improvement in germination percentage in the variety 'CoH 06247'of sugarcane was mainly due to higher glucose content at the cellular level, whereas lower germination in variety 'CoPk 05191' was due to low conversation of higher amount of sucrose to glucose with low temperature in the subsequent month, which might have led to greater availability of glucose to the germinating buds under prevailing climatic condition vice-versa. Results obtained in the present study are in accordance with those of Singh *et al*. (2011).Varieties differed significantly for observation recorded on tiller, cane length, number of millable cane and single cane weight during the three years. Significantly higher number of tillers and millable cane (1,52,000 and 1, 30, 690/ha) were observed with variety 'CoH 06247', being 20.82,10.95 and 9.05 and 16.31,1.69 and 4.82 % higher than 'CoLk 07201','Co 06033' and 'CoPk 05191' respectively, owing to its higher tillering capacity. It was mainly because of the higher tiller production by the variety 'CoH 06247' than the others varieties during pre-monsoon period which led to higher retention of millable

Table 1 Mean monthly maximum and minimum temperature, relative humidity, evaporation and total rain fall (2012 to 2014)

Month	Temperature °C						Relative humidity (%)			Rainfall (mm)			Evaporation (mm)		
	Maximum			Minimum											
	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
January	24.2	25	19.5	8.9	9.0	8.5	69.0	87.0	94.5	2.6	-	2.0	1.4	1.3	1.5
February	25.8	24.5	24.6	10.7	10.0	10.5	70.9	80.2	83.3	1.4	1.2	4.0	2.6	2.4	2.8
March	33.5	29.3	29.5	10.5	11.5	11.8	56.1	71.5	71.5	-	1.6	-	5.7	5.4	4.8
April	36.9	35.2	36.2	15.8	17.7	18.4	35.9	65.0	65.0	-	-	-	6.4	5.0	7.2
May	42.4	43.6	43.5	20.8	23.8	25.0	50.5	51.0	63.8	-	-	-	12.0	10.0	14.5
June	44.6	34.9	40.8	28.8	27.1	28.8	55.3	63.8	48.6	123.2	157.5	130	17.3	14.8	18.4
July	36.6	38.8	35.0	27.4	25.5	26.7	66.8	70.2	71.5	156.8	529	270	5.0	3.8	4.2
August	32.7	33.4	32.4	25.1	25.5	25.3	81.0	86.2	72.5	256.2	135	124	3.8	3.4	3.8
September	33.5	33.6	34.0	25.6	25.0	24.5	74.4	68.2	55.5	104.5	212.2	50	4.0	4.2	4.9
October	35.2	32.6	34.7	20.6	20.2	21.5	54.1	70.5	46.8	-	192.4	-	4.3	3.8	5.3
November	28.0	28.2	30.4	15.95	11.8	17.3	74.9	82.8	59.4	37.5	10.6	-	1.1	1.2	2.1
December	23.5	22.4	22.9	7.85	9.5	7.7	65.1	83.2	66.2	2.5	36.8	6	1.2	1.1	1.3

canes by the variety at harvest. The result confirms the findings of Shukla (2007) and Kumar *et al.* (2012). Over all mean individual cane weight of 'CoH 06247', 'CoLk 07201','Co 06033' and 'CoPk 05191'were non-significant during the three years while, 'CoPk 05191'showed the highest single cane weight, owing to produced thicker cane than other. Kamat and Pandey (2004) also reported similar results.The variety 'Co 06033' produced longer canes (213.30 cm) than other during 2012-13 which was significantly superior over 'CoLk07201'and 'CoPk05191'and at par with 'CoH 06247'. Whereas variety 'CoH 06247' showed significantly longer canes than the others during 2013-14 and 2014-15.Pooled data of the three season indicated that significantly higher canes length (220.40 cm) were recorded with the variety 'CoH 06247'over 'CoLk 07201' and 'CoPk 05191' and at par with 'Co 06033'.The significant variation in tillers, cane length, number of millable cane and single cane weight was due to chemical composition of soluble solids in juice as well as enzymes and hormones present in cell sap, which differs from variety to variety. Kumar *et al*. (2012) also noticed significant variation on aforesaid attributes among different sugarcane varieties.

Nutrient management had significant impact on tillers and number of millable cane while, the effect on germination, cane length and single cane weight were non-significant (Table 2 and 3). Same trend in tillers and millable canes were recorded during the three years. Tillers (1, 40,150 /ha) and millable cane (1, 19,002 /ha) were significantly higher in the plot receiving 200:60:40 kg NPK/ha over 150:45:30 kg NPK/ha but on par with 250:75:50 kg NPK/ha, being 9.18 and 10.56 % higher over 150:45:30 kg NPK/ha, respectively. Number of tillers and millable canes increased significantly up to 200:60:40 NPK kg/ha. Moreover, higher dose of NPK also reduced the tiller mortality indicating the besides production of millable canes. Higher nutrition level helped in maintaining retention of tillers. The increase in the rate of physiological

Table 2. Germination, tillers and cane length of sugarcane as influenced by different varieties and nutrient management in spring season (2012-13, 2013-14 and 2014-15)

Treatment	Germination (%) at 35 DAP				Tillers at 150 DAP ($x10^3$/ha)				Cane length (cm)			
	2012-13	2013-14	2014-15	Pooled	2012-13	2013-14	2014-15	Pooled	2012-13	2013-14	2014-15	Pooled
Varieties												
'Co 06033'	39.11	45.44	45.60	43.38	126.3	140.58	144.13	137.00	213.3	217.89	220.29	217.16
'CoLk 07201'	36.25	42.70	43.34	40.76	114.9	131.88	130.66	125.81	176.8	201.79	206.90	195.16
'CoH 06247'	39.66	47.57	48.00	45.08	151.0	150.81	154.19	152.00	207.2	225.78	228.22	220.40
'CoPK 05191'	35.55	42.98	43.30	40.61	131.4	142.46	144.32	139.39	181.0	211.56	217.33	203.30
SEm ±	0.80	0.76	0.74	0.66	5.61	2.40	2.05	2.88	3.40	3.09	2.91	2.76
CD (P=0.05)	NS	2.20	2.14	1.88	16.2	6.93	5.93	8.13	9.9	8.93	8.41	7.78
Nutrient management (NPK kg/ha)												
150:45:30	35.85	43.89	44.43	41.39	120.0	130.93	134.18	128.37	193.6	207.08	211.18	203.95
200:60:40	38.22	44.54	44.83	42.53	130.6	143.14	146.71	140.15	192.8	214.84	220.35	209.33
250:75:50	38.80	45.58	45.93	43.44	142.0	150.22	149.09	147.10	197.4	220.83	223.03	213.75
SEm ±	1.40	1.52	1.48	1.28	4.88	4.80	4.11	4.00	7.50	6.18	5.83	5.65
CD (P=0.05)	NS	NS	NS	NS	14.1	13.85	11.86	11.78	NS	NS	NS	NS

process in the plant system leading to increase rate of tiller formation. Significantly higher millable canes with nutrient management level of 200:60:40 kg NPK/ha was primarily due to the improved fertility status of the soil created congenial environment for better growth and development of sugarcane plant. The results are in accordance with the findings of Shukla (2007). Desired NPK nutrients level created better nutritional environment in soil system resulting in brought significant improvement in millable cane and cane weight. Positive interaction of nitrogen and phosphorus and nitrogen with potassium is well known. The positive response with NPK on millable cane and cane weight were also reported by Pandey and Shukla (2001) and shukla (2007).

Yield and Quality

Nutrients NPK level could not influence pol % juice of sugarcane significantly (Table 4). Data of 3 cropping season indicated that yield and quality parameters differed among the varieties. The cane yield was significantly higher with variety 'CoH 06247'(97.55 t/ha) over rest of the varieties, being 16.97,8.87 and 7.22 % higher than 'CoLk 07201','CoPk 05191' and 'Co 06033', respectively, owing to higher number of millable canes and optimum canes weight at harvest. Moreover, the marked variation in cane yield could be ascribed on account of their genetic makeup to exploit available resources more efficiently. This corroborates the findings of Shukla (2007).Variety 'CoPk 05191' also showed the highest pol (18.61 %) reading, CCS (12.84 %) and commercial cane sugar yield (11.49 t/ha) at 11 month stage in spring cane which was significantly superior to rest of varieties (Table 4). The variety 'CoPk 05191' showed its superiority to others in respect of pol % in juice , followed by 'Co 06033' (17.19 %).This could be ascribed to its genetic potential compared to other varieties. The results indicated that maximum benefit from

Table 3 Growth and yield of spring planted sugarcane as by influenced by varieties and nutrient management (2012-13, 2013-14 and 2014-15)

Treatment	Single cane weight (g)				NMC ($x10^3$/ha)				Cane yield (t/ha)			
	2012-13	2013-14	2014-15	Pooled	2012-13	2013-14	2014-15	Pooled	2012-13	2013-14	2014-15	Pooled
Varieties												
'Co 06033'	791	800.00	817.53	802.84	104.20	127.78	129.24	120.41	76.75	94.16	102.04	90.98
'CoLk 07201'	815	817.00	815.33	815.78	83.30	116.89	115.61	105.27	69.25	88.82	92.13	83.40
'CoH 06247'	816	820.00	822.11	819.37	105.40	131.22	130.69	122.44	81.11	104.30	107.24	97.55
'CoPK 05191'(c)	838	835.00	814.13	829.04	99.60	125.56	125.28	116.81	79.25	95.70	93.86	89.60
SEm ±	10.50	11.92	11.96	11.46	3.20	1.69	1.84	1.95	2.96	2.27	2.28	2.15
CD (P=0.05)	NS	NS	NS	NS	9.30	4.87	5.31	5.50	8.60	6.55	6.58	6.06
Nutrient management (NPK kg/ha)												
150:45:30	827	810.20	813.15	816.78	88.40	117.42	117.14	107.65	70.27	87.90	90.33	82.83
200:60:40	839	819.50	819.08	825.86	100.50	128.17	128.38	119.02	78.92	98.47	101.18	92.86
250:75:50	824	824.30	819.60	822.63	105.40	130.50	130.09	122.00	80.63	100.88	104.95	95.49
SEm ±	12.10	12.26	12.27	10.50	2.76	3.38	3.68	2.78	2.56	3.03	2.96	2.42
CD (P=0.05)	NS	NS	NS	NS	8.0	9.75	10.62	7.84	7.40	8.75	8.54	6.83

Table 4 Quality and sugar yield of spring planted sugarcane as by influenced by varieties and nutrient management (2012-13, 2013-14 and 2014-15)

Treatment	Pol % in juice				CCS (%)				CCS (t/ha)			
	2012-13	2013-14	2014-15	Pooled	2012-13	2013-14	2014-15	Pooled	2012-13	2013-14	2014-15	Pooled
Varieties												
'Co 06033'	17.12	17.87	16.57	17.19	11.44	12.30	11.35	11.70	8.78	11.58	11.60	10.65
'CoLk 07201'	16.42	17.46	16.38	16.75	11.06	12.00	11.20	11.42	7.66	10.65	10.33	9.55
'CoH 06247'	16.30	16.74	17.98	17.01	10.87	11.47	12.39	11.58	8.82	11.97	13.28	11.36
'CoPK 05191'(c)	19.24	18.28	18.32	18.61	13.29	12.60	12.64	12.84	10.53	12.06	11.89	11.49
SEm ±	0.25	0.24	0.15	0.18	0.21	0.15	0.11	0.13	0.64	0.20	0.22	0.31
CD (P=0.05)	0.71	0.68	0.42	0.52	0.60	0.43	0.31	0.38	1.86	0.58	0.64	0.87
Nutrient management (NPK kg/ha)												
150:45:30	17.07	17.21	17.04	17.11	11.49	11.70	11.69	11.63	8.07	10.58	10.56	9.77
200:60:40	17.31	17.60	17.09	17.33	11.70	12.10	11.73	11.84	9.23	11.74	11.86	10.94
250:75:50	17.43	17.94	17.81	17.73	11.80	12.40	12.26	12.15	9.51	12.26	12.91	11.56
SEm ±	0.50	0.47	0.29	0.36	0.25	0.30	0.22	0.22	0.42	0.40	0.45	0.37
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.17	1.29	1.05

higher sugar produced variety 'CoPk 05191'could be harvested in December / January under spring planting situation.

Nutrient management levels of NPK causes significant impact on cane yield (Table 3).The cane yield (92.86 t/ha) was significantly higher in the treatment receiving application of NPK of 200:60:40 kg NPK/ha over 150:45:30 kg NPK/ha and on par with NPK of 250:75:50 kg/ha. This could be attributed to higher of millable canes and average cane weight due to increasing levels of fertilizers. Navnit Kumar (2012) also reported similar findings. As a result of this, the fertility status of the soil might have increased and thus increasing the absorption of plant nutrients. Hence, more tillers were converted into number of millable canes which lead to more yield. The results are in agreement with the finding of Khan *et al.* (2005) and Thakur *et al*. (2007). Nutrient management did not cause significant variation in pol % juice and CSS % during all the years and as in pooled data. The results are in accordance with the finding of Singh *et al*.(2008).The effect of NPK fertilization (200:60:40 kg/ha) on sugar yield (10.94 t/ha) was significantly superior over nutrient management levels of NPK 150:45:30 and at par with 250:75:50 kg/ha .The percentage increase in sugar yield by application of 200:60:40 kg NPK/ha was 11.98 %. Thus cane yield and CCS were also higher at this nutrient management practice. CCS was the function of cane yield and quality. The higher cane yield contributed greater share in improving CCS than cane quality parameters. Cane yield & CCS in spring planting were positively correlated (r = 0.81). It was due to increase in cane quality parameters in all the varieties.

Nutrient uptake

Uptake of NP and K (263.78,17.80 and 210 kg/ha, respectively) was significantly higher with variety 'CoH 06247'over 'CoLk 07201' and 'Co 06033' and at par with 'CoPk 05191' in spring planted crop, while the lowest values of N and K uptake were observed with variety 'CoLk 07201'.

Whereas uptake of nutrients (NPK) by sugarcane crop significantly increased upto 200:60:40 kg NPK/ha over fertility levels of NPK 150:45:30 kg/ha, being on par with that of 250:75:50 kg NPK/ha in spring planted crop. The magnitude of increase in uptake of NPK by the application of 200:60:40 kg NPK/ha over the nutrient management levels of NPK 150:45:30 kg/ha was 10.86, 45.24 and 26.71 %, respectively. However, P uptake was increased with each successive increase in fertility levels upto 125 % RDF of NPK (Table 5). The results further indicated that among the major nutrients, relatively higher uptake of N was recorded followed by K and P irrespective of treatments in spring crop. The results are in close agreement with the findings of Thakur *et al.* (2012). It was due to fact that added nutrients increased the N, P and K concentration in sugarcane, by providing balanced nutritional environment inside the plant and higher photosynthetic efficiency, which favoured higher dry matter accumulation, resulted in more uptakes of N, P and K by sugarcane.

Pooled data of nutrient uptake by spring crops determined (Table 5) at harvest stage showed that variety 'CoH 06247' removed the maximum NPK from soil during the cropping seasons. The increase in uptake of phosphorus might be due to the complexing properties of organic material which prevented the precipitation and fixation of nutrient and kept them in soluble form. These results are in accordance with those of Thakur *et al*. (2013).The uptake of K was season dependent, being low in cool winter month (Vijaya Shankar Babu *et al.* 2007).

Sustainability yield Index

Sustainability yield index (SYI) was highest (0.82.24) in variety 'CoH 06247'followed by 'CoPk 05191' (81.25),'Co 06033' (78.07)' and 'CoLk 07201' (76.55) percent in the different treatments in spring season (Table 5).This was

Table 5 Effect of varieties and nutrient management on nutrient uptake, sustainability yield index and economics of sugarcane under spring planting season (pooled of spring three cropping seasons)

Treatment	Nutrient uptake (kg/ha)			Sustainability yield index (SYI)	Gross return (x10^3 ₹/ha)	Net return (x10^3 ₹/ha)	B:C ratio
	N	P	K				
Varieties							
'Co 06033'	250.50	15.30	190.50	78.07	209.26	107.47	2.06
'CoLk 07201'	232.70	16.00	180.40	76.55	191.82	90.03	1.88
'CoH 06247'	263.78	17.80	210.00	82.24	224.37	122.57	2.20
'CoPK 05191'(c)	255.20	16.50	205.10	81.25	206.09	104.30	2.02
SEm ±	4.25	0.78	3.50	-	4.50	3.86	0.10
CD (P=0.05)	12.52	2.25	10.11	-	13.42	11.76	0.28
Nutrient management (*NPK kg/ha*)							
150:45:30	235.80	12.60	167.70	78.57	190.52	90.44	1.88
200:60:40	261.40	18.30	212.50	79.77	213.57	111.77	2.10
250:75:50	255.20	18.40	209.60	79.58	219.62	117.82	2.16
SEm ±	5.27	1.20	4.60	-	4.80	4.27	0.09
CD (P=0.05)	15.23	3.48	13.39	-	14.02	12.43	0.26

followed by recommended dose of nutrient management levels of 200:60:40 kg NPK/ha. SYI was maximum (79.77 %) in the nutrient management of 200:60:40 kg NPK/ha and lowest (78.57 %) in fertility levels of 150:45:30 NPK kg/ha. Mean pooled data of spring planted crop on yield presented in table 2 indicated that yield of variety 'CoH 06247' (97.55 t/ha) found significantly superior over rest of varieties. The mean cane yield (92.86 t/ha) of spring planted crop was significantly higher in receiving of 200:60:40 kg NPK/ha over fertility levels of NPK 150:45:30 kg/ha and was on par with NPK of 250:75:50 kg/ha.

Economics

Among the varieties, significantly higher gross return (₹ 2, 24,370 /ha), net return (₹ 1, 22,570 /ha) and B: C ratio (2.20) was obtained with variety 'CoH 06247', followed by 'Co 06033'and lowest in variety 'CoLk 07201', owing to higher cane yield (Table 5).The economic analysis of different treatments indicated that net return and benefit: cost ratio was influenced by various nutrient management treatments. There were differences in cost of cultivation and net return owing to different variable costs. Whereas the highest gross (₹ 2, 13,570 /ha), net return (₹ 1, 11,770 /ha) and B: C ratio (2.10) was observed with the application of 200:60:40 kg NPK /ha which was significantly higher over nutrient management levels of NPK 150:45:30 kg/ha and on par with NPK of 250:75:50 kg/ ha, indicating the response of NPK was found positive trending in economics analysis of different treatments. There was significantly improvement in gross and net return with each successive increase in fertilizer level of NPK from 75 % to 125 % of RD. Net return (₹ 1,17,820/ha) and B: C ratio (2.16) did not undergo significant changes due to application of NPK 250:75:50 kg/ha, but higher values were obtained under said the fertility level. Hence, crop had responded upto NPK level of 250:75:50 kg/ha in spring planted crop. The increase in yield attributes and yield fetched higher net return and benefit: cost ratio. The results confirm the findings of Kumar *et al.* (2014).

Thus, It may be concluded that either application of NPK 200:60:40 kg/ha or 250:75:50 kg/ha were recommended for getting higher yield and monetary return with benefit: cost ratio. Similarly, sustained soil fertility was also observed in higher nutrient uptake, hence this treatment gave better economic output, improved soil health. Among the varieties tested, 'CoH 06247' has a great promise for increased productivity and profitability of sugarcane, owing to higher number of millable canes and canes weight under clay loam soils of Rajasthan.

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Indian Journal of Sugarcane Technology **30(02)**: 110, December 2015 **Short Communication**

Five stripped Palm squirrel (*Funambulus pennati* Wroughton) damaging sugarcane in south Gujarat

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During field visit at farmer's field in Tapi district of South Gujarat, sugarcane crop was reported to be damaged by five stripped palm squirrel, *Funambulus pennati* Wroughton. In sugarcane, damage is caused primarily by squirrel eating the apical growing points (1.5 to 2 months old) of sugarcane. Scrapping the young shoots just 2-3 cm above the ground surface was observed. The damage resemble as that caused by early shoot borer i.e. wilting of central shoot (dead heart). But, the plant withstands the damage caused by squirrel which is not observed in case of early shoot borer. In case of early shoot borer, the chances of withstand the pest attack is very low, whereas in case of squirrel, all the damaged shoots found withstand the pest attack.

Moreover, it was also noticed that, young shoots of sugarcane are only eaten if the field is surrounded by a line of deciduous mixed broadleaved trees or hedgerows close to a waterway in which squirrels can hide, and damage is concentrated within a short distance from the watercourse. In addition to this, damage does not occur uniformly in the field, being more concentrated in the 4 to 5 m apart from border of field. Nevertheless, in some cases, damage was seen in the middle of the plantation.

Farmers who were interviewed confirm that squirrel damage is concentrated close to the watercourse on the boundaries of their sugarcane fields, where they eat mainly within the 4 – 6 rows of sugarcane. With rows spaced 90 cm apart, squirrels only enter the field for an average distance of 4.5 m from the edge and only a few farmers' report squirrels foraging more widely in a field.

F. pennantii is a significant pest of orchards and nurseries in India where it causes serious damage to fruits and vegetables (Barnett and Prakash 1975, Prakash and Ghosh 1992, Parshad 1999). Earlier, damage to sugarcane and groundnut crops has also been reported in India (Prakash and Ghosh,1992). Other crops damaged by palm squirrels include pineapple, mango, pomegranate, apples, guava, blackberries, grapes, sugarcane and groundnuts (Barnett and Prakash 1975, Prakash and Ghosh 1992, Chakravarthy 2004).

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