

# Indian Journal of Sugarcane Technology



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Uttar Pradesh, India  
Web: [www.iisr.nic.in](http://www.iisr.nic.in); E-mail: [praveenmeera@yahoo.com](mailto:praveenmeera@yahoo.com)

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## Effect of sulphur application on sugarcane production in Haryana

VIJAY KUMAR, MEHAR CHAND, SAMAR SINGH and RAN SINGH

Regional Research Station CCS, Haryana Agricultural University, Karnal-132001 Haryana, India.

### ABSTRACT

The experiments were conducted at Regional Research Station, CCS Haryana Agricultural University, Karnal, on Plant-Ratoon-Plant-Ratoon sequence. The experiment consisting of seven treatments i.e. the application of S @ 15, 25 and 35 kg/ha through gypsum and application of S @ 15, 25 and 35 kg/ha through SSP and Control (No sulphur) were replicated four times in RBD design. The top 15 cms of soil of experimental site was clay loam in texture and had pH (1:2) 8.7, electrical conductivity 0.35 dS/m, organic carbon 0.44%, available P (Olsen) 7 kg/ha, available K 142 kg/ha. The initial content of available S in the soil was 12.3 kg/ha. The application of S @ 25 and 35 kg/ha through Gypsum produced significantly higher cane yield over control (No sulphur) in both plant and ratoon crops. The application of S @ 25 and 35 kg/ha through Gypsum produced 5.2 and 6.7% higher cane yield of first plant crop, respectively over control (No sulphur). Similarly, the application of S @ 25 and 35 kg/ha through Gypsum produced 6.9 and 7.6% higher cane yield of second plant crop, 4.9 and 5.5% higher cane yield of first ratoon crop and 5.5 and 6.5 % higher of second ratoon, respectively over control (No sulphur). The application of S @ 25 and 35 kg/ha through Single Super phosphate (SSP) produced 8.5 and 8.2% higher cane yield of first plant crop, 7.2 and 7.7% higher cane yield of second plant crop 6.1 and 6.6% higher of first ratoon crop and 5.2 and 6.4 % higher of second ratoon crop respectively, over control. The application of S @ 25 and 35 kg/ha through Gypsum or SSP produced higher juice quality (CCS %) in second plant and its ratoon crop only. The higher available S in the soil was observed where the application of S @ 15, 25 and 35 kg/ha through Gypsum or SSP were made as compared to control (no sulphur application). The application of S @ 25 and 35 kg/ha through SSP or Gypsum were at par in terms of cane yield and juice quality. Both the sources of S were equally effective in terms of cane yield and juice quality. This indicated that the 25kg S/ha was sufficient to produce higher cane yield and juice quality and it can be applied by either sources.

**Key words :** Sugarcane, sulphur, Gypsum, SSP

The low fertility of soil is one of the important limiting factors in sugarcane productivity. With the intensive cultivation the soil are getting depleted in the available nutrient including S. Research finding of long term experiments conducted in various location in India revealed that the application of N alone depleted the native P, K, S and micro nutrient thus causing the significant yield loss (Swarup and Wanjami, 2000). Yadav and Yaduvanshi (1993) emphasized that deficiency of sulphur in constantly increasing in Indian soil and it has become the limiting factor in sugarcane cultivation. Similarly studies conducted by Singh *et al.* (2008) established the significance of balanced fertilizer with S for higher yield, higher sugarcane recovery. Further the limited use of Ammonium sulphate, single super phosphate and organic manure is also the reason for so low availability of S in the soil. The application of S in soil may result in significant increase in cane yield and more profit in present soils. The present experiments were conducted with the objective to find out the optimum rate and better source of sulphur application in sugarcane.

### MATERIALS AND METHODS

The experiments were conducted at CCS, HAU, Regional Research Station, Karnal. Important Physico-chemical properties of experimental soils and irrigation water use for experiment are given in Table 1. The treatments were T1-S @

15 kg/ha through Gypsum, T2-S @ 25 kg/ha through Gypsum, T3-S @ 35 kg/ha through Gypsum, T4-S @ 15 kg/ha through SSP, T5-S @ 25 kg/ha through SSP, T6-S @ 35 kg/ha through SSP, T7-S Control (No sulphur). Cane yield (t/ha) for plant and ratoon crops was recorded at the harvest. For juice quality analysis at the harvest of crop, 10 canes 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 commercial cane

Table 1. The initial soil analysis and quality of irrigation water used

Soil analysis					
pH	EC	OC	Available P	Available K	
	(dS/m)	%	(kg/ha)	(kg/ha)	
8.7	0.35	0.44	7	142	
Irrigation water					
EC	pH	HCO <sub>3</sub>	Cl	Ca+Mg	RSC
Micro-S/cm		me/l	me/l	me/l	me/l
650	8.4	5	0.4	3.8	1.2

sugar (CCS%) in juice were determined by the methods of Meade and Chen (1977). Sugar yield was calculated by multiplying CCS% with cane yield. Available sulphur was determined by calcium chloride method as proposed by Chesnin and Yien (1950).

The economics of S application through gypsum, SSP and no sulphur was also calculated. The response of different levels of S fertilizers on the cane yield and CCS (%) of both plant crops were determined from the ANOVA and LSD ( $P < 0.5$ ).

## RESULTS AND DISCUSSION

### Cane Yield of Plant crop

The application of S @ 25 and 35 kg/ha through Gypsum produced significantly higher cane yield over control (No sulphur) in both plant crops. The application of S @ 25 and 35 kg/ha through Gypsum produced 5.2 and 6.7% higher cane yield of first plant crop, respectively over control (No sulphur). Similarly the application of S @ 25 and 35 kg/ha through Gypsum produced 6.9 and 7.6% higher cane yield of second plant crop, respectively over control (No sulphur). The application of S @ 25 and 35 kg/ha through single superphosphate (SSP) produced 8.5 and 8.2% higher cane yield of first plant crop and 7.2 and 7.7% higher cane yield of second plant crop, respectively over control. (Table 2). The application of S @ 25 and 35 kg/ha through SSP or Gypsum were at par in terms of increasing cane yield. Both the sources of S were equally effective in terms of increasing cane yield. There was strong relation between different levels of S and plant cane yields (Figure 1).

Yadav and Yaduvanshi (1993) summarized that in marginally deficient soil application of 30 kg has shown good response to cane yield. Among different source of S, Ammonium sulphate was found to be the best followed by iron pyrite, elemental S,

Table 2. Effect of sulphur application on cane yield (t/ha) of plant and ratoon

Treatments	First Plant	First Ratoon	Second Plant	Second Ratoon
S @ 15 kg/ha through Gypsum	72.29	89.65	78.17	69.53
S @ 25 kg/ha through Gypsum	75.20	92.40	80.56	72.14
S @ 35 kg/ha through Gypsum	76.30	82.95	81.10	72.77
S @ 15 kg/ha through SSP	73.93	90.95	78.52	70.18
S @ 25 kg/ha through SSP	77.58	93.50	80.83	71.93
S @ 35 kg/ha through SSP	77.36	93.90	81.22	72.74
Control (No sulphur)	71.49	88.10	75.39	68.35
CD 5%	2.688	3.731	3.301	2.018

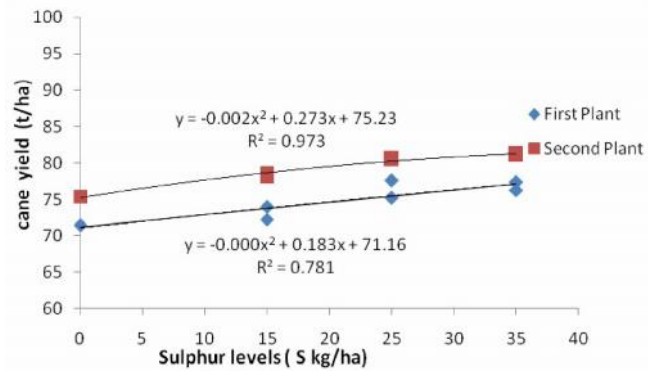


Fig. 1. Effect of sulphur application on cane yield of ratoon crops

Single super phosphate and gypsum for obtaining higher cane yield.

Ghosh *et al.* 1990 also reported that sulphur application enhanced the production of dry matter, cane and sugar.

Saha *et al.* (1998) conducted field experiments in two major sugarcane growing belts in Bangladesh, the Ganges river floodplain (Typic Eutrochrept) and the old Himalayan piedmont plain (Typic Haplaquept), to study the effects of four levels each of S and Zn (0, 20, 40 and 60 kg/ha S ; 0, 5, 10 and 15 kg/ha Zn ) in two successive cropping seasons. Sugarcane yield significantly responded to S application up to 40 kg/ha at all levels of Zn at both the locations. Yield data fitted to cubic response equations revealed that the maximum response doses of S and Zn were 44.6 and 4.8 kg/ha, with cane yields of 92.92 and 92.61 t/ha, respectively.

### Cane Yield of ratoon crop

The application of S @ 25 and 35 kg/ha through Gypsum produced significantly higher cane yield over control (No sulphur) in both plant and ratoon crops (Table 2). The application of S @ 25 and 35 kg/ha through Gypsum produced 4.9 and 5.5% higher cane yield of first ratoon crop, respectively over control (No sulphur). Similarly the application of S @ 25 and 35 kg/ha through Gypsum produced 5.5 and 6.5% higher cane yield of second ratoon, respectively over control (No sulphur). The application of S @ 25 and 35 kg/ha through Single Super phosphate (SSP) produced 6.1 and 6.6% higher of first ratoon crop and 5.2 and 6.4 % higher of second ratoon crop, respectively over control. The application of S @ 25 and 35 kg/ha through SSP or Gypsum were at par in terms of increasing cane yield. Both the sources of S were equally effective in terms of increasing cane yield. There was strong relation between different levels of S and cane yield of ratoon crops (Figure 1).

Kapur *et al.* (2007) studied direct and residual effect of S fertilization on production of sugarcane and found that in the ratoon crop, significant residual effects were observed during two years due to 40 S kg/ha and higher levels of S applied to plant crop.

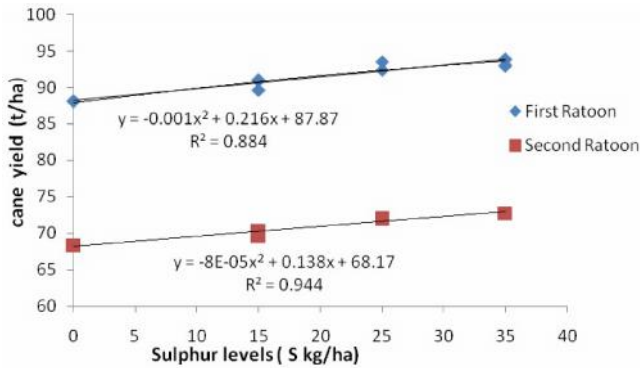


Fig. 2. Effect of sulphur application on cane yield of ratoon crops

Similarly Thomas *et al.* (2003) studied the residual effects of sulphur application on the ratoon crop of sugarcane. The application of sulphur at 60 kg/ha in the form of gypsum in the plant crop created residual effects on the growth and development of the ratoon crop and appreciably increased the cane and sugar yield. The cane yield increased to the tune of 8.47 and 10.37 per cent as compared to control. However, the residual effect of sulphur nutrition carried out to the plant crop was not reflected on the juice quality of ratoon crop.

#### Juice quality in plant crop of sugarcane

In first plant crop, the application of S @ 15, 25 and 35 kg/ha through Gypsum or SSP produced at par CCS% of as compared with control. However, in second plant crop, the application of S @ 25 and 35 kg/ha through Gypsum or SSP produced significantly higher CCS% of over control (No sulphur). The increased in the CCS% with the application of S increased the overall sugar yield (Table 3). The application of S @ 25 and 35 kg/ha through Gypsum produced 10.1 and 11.1% higher sugar yield of second plant crops respectively, over control. The application of S @ 25 and 35 kg/ha through SSP produced 9.9 and 10.7% higher sugar yield of second plant crops, respectively over control. The application of S @ 25 and 35 kg/ha through SSP or Gypsum were at par in terms of plant crop of CCS%. Both the sources of S were equally effective in terms of plant juice quality.

Naga Madhuri *et al.* (2011) conducted experiment in sandy loam soils revealed that quality parameters of cane juice and jaggery were positively and significantly influenced by the application of sulphur irrespective of sources of sulphur. Application of sulphur at 100kg/ha significantly influenced the quality of juice but it was comparable with the application of sulphur at 80kg/ha which was reflected in quality of jaggery. There is an increase of 1.27 units in juice sucrose was observed with the application of sulphur at 80kg/ha. But sources did not differ markedly on juice quality and jaggery quality parameters. As Gypsum is cheapest source compared to Elemental sulphur, it can be concluded that maximum returns can be obtained at 80 kg S/ha through Gypsum application. The positive and significant effects of sulphur on quality and cane yield have also been reported by Alam *et al.* 2000 and Singh 2001.

#### Juice quality of ratoon crop

In the first ratoon crop, the application of S @ 15, 25 and 35 kg/ha through Gypsum or SSP produced at par CCS% of as compared with control. However, in the second ratoon crop, the application of S @ 25 and 35 kg/ha through Gypsum or SSP produced significantly higher CCS% of over control (No sulphur). The increased in the CCS% with the application of S increased the overall sugar yield (Table 3). The application of S @ 25 and 35 kg/ha through Gypsum produced 11.9 and 13.3% higher sugar yield of second plant crops, respectively over control. The application of S @ 25 and 35 kg/ha through SSP produced 11.2 and 11.7% higher sugar yield of second plant crops, respectively over control. The application of S @ 25 and 35 kg/ha through SSP or Gypsum were at par in terms of ratoon crop CCS%. Both the sources of S were equally effective in terms of plant juice quality.

#### Available S in soil

The higher available S was observed where the application of S @ 15, 25 and 35 kg/ha through Gypsum or SSP was made as compared to no S application (control) (Table 4). Which indicate that the application of S increased the soil available S and maintained the available S at optimum level in sugarcane plant during crop growing season. Johnson and Richard (2005)

Table 3. Effect of inorganic sulphur application on Juice quality (CCS%)

Treatments	First Plant	First Ratoon	Second Plant	Second Ratoon	First Plant	First Ratoon	Second Plant	Second Ratoon
	CCS%				Sugar yield (q/ha)			
S @ 15 kg/ha through Gypsum	12.84	12.29	12.24	12.23	9.28	11.02	9.57	8.50
S @ 25 kg/ha through Gypsum	12.94	12.25	12.41	12.67	9.73	11.32	10.00	9.14
S @ 35 kg/ha through Gypsum	12.96	12.38	12.44	12.72	9.89	11.51	10.09	9.26
S @ 15 kg/ha through SSP	12.83	12.03	12.19	12.22	9.49	10.94	9.57	8.58
S @ 25 kg/ha through SSP	12.78	12.44	12.35	12.63	9.91	11.63	9.98	9.08
S @ 35 kg/ha through SSP	12.92	12.46	12.38	12.55	9.99	11.70	10.06	9.13
Control (No sulphur)	12.78	11.99	12.04	11.96	9.14	10.56	9.08	8.17
CD 5%	NS	NS	0.093	0.312				

Table 4. Available S (ppm) in soil in different treatments

T1-S @ 15 kg/ha through Gypsum	15.5
T2-S @ 25 kg/ha through Gypsum	17.5
T3-S @ 35 kg/ha through Gypsum	21.3
T4-S @ 15 kg/ha through SSP	16.0
T5-S @ 25 kg/ha through SSP	19.0
T6-S @ 35 kg/ha through SSP	21.5
T7-S Control (No sulphur)	12.3

found a strong relation between soil sulfur and sugarcane yield and quality. The increase in available sulphur content in soil has also been reported by Alam *et al.* (2000).

#### Economics of S

The application of S @ 15 to 35 kg/ha through Gypsum gave additional return from Rs. 2353 to 14469 over control in the first plant crop and Rs. 4641 to 14591 in the second plant crop, respectively (Table 5). The application of S @ 15 to 35 kg/ha through SSP gave additional return from Rs. 7355 to 17702 over control in the first plant crop and 8606 to 17489 in

Table 5. Economics of S application

Treatments	Cane yield (t/ha)		Cost of fertilizer (Rs)	Gross return (Rs)		Net return (Rs)		Add return over control (Rs)		Cost: Benefit Ratio	
	First Plant	Second Plant		First Plant	Second Plant	First Plant	Second Plant	First Plant	Second Plant	First Plant	Second Plant
S @											
15 Gy	72.29	78.17	836.25	220485	238419	219648	237582	2353	4641	2.81	10.04
25 Gy	75.2	80.56	893.75	229360	245708	228466	244814	11171	12971	12.50	17.48
35 Gy	76.3	81.1	951.25	232715	247355	231764	246404	14469	14591	15.21	18.10
15 SSP	73.93	78.52	836.25	225487	239486	224650	238650	7355	8606	8.80	11.31
25 SSP	77.58	80.83	893.75	236619	246532	235725	245638	18430	16326	20.62	18.40
35 SSP	77.36	81.22	951.25	235948	247721	234997	246770	17702	17489	18.61	18.48
0- No S	71.49	75.39	750	218045	229940	217295	229190	0	0	0.00	0.00
	First Ratoon	Second Ratoon		First Ratoon	Second Ratoon	First Ratoon	Second Ratoon	First Ratoon	Second Ratoon	First Ratoon	Second Ratoon
15 Gy	89.65	69.53	836.25	273433	212067	272596	211230	8392	3512	5.55	4.20
25 Gy	92.4	72.14	893.75	281820	220027	280926	219133	15624	11415	14.51	12.77
35 Gy	92.95	72.77	951.25	283498	221949	282546	220997	17214	13279	15.34	13.96
15 SSP	90.95	70.18	836.25	277398	214049	276561	213213	9460	5495	10.29	6.57
25 SSP	93.5	71.93	893.75	285175	219387	284281	218493	16448	10775	18.27	12.06
35 SSP	93.9	72.74	951.25	286395	221857	285444	220906	17580	13188	18.39	13.86
0- No S	88.1	68.35	750	268705	208468	267955	207718	0	0	0.00	0.00

the second plant crop. The cost benefit ratio (CBR) with the application of S @ 15 to 35 kg/ha through Gypsum ranged from 2.8 to 15.2 in the first plant crop and 10.04 to 18.16 in second plant crop. The cost benefit ratio (CBR) with the application of S @ 15 to 35 kg/ha through SSP ranged from 8.8 to 18.6 in the first plant crop and 11.31 to 18.48 in second plant crop. Similarly the application of S @ 15 to 35 kg/ha through Gypsum gave additional return from Rs. 8392 to 17214 over control in the first ratoon crop and Rs. 3512 to 13279 in the second ratoon crop, respectively. The application of S @ 15 to 35 kg/ha through SSP gave additional return from Rs. 9460 to

17580 over control in the first ratoon crop and 5495 to 13188 in the second ratoon crop. The cost benefit ratio (CBR) with the application of S @ 15 to 35 kg/ha through Gypsum ranged from 5.55 to 15.34 in the first plant crop and 4.20 to 13.96 in second plant crop. The cost benefit ratio (CBR) with the application of S @ 15 to 35 kg/ha through Gypsum ranged from 5.5 to 15.3 in the first plant crop and 4.2 to 14.0 in second plant crop.

#### CONCLUSION

The application of S @ 25 or 35 kg/ha through Gypsum or SSP produced higher cane yield and juice quality (CCS %) of both plant and ratoon crops. The application of S @ 15 kg/ha through Gypsum or SSP did not produced significantly higher cane yield and juice quality of both plant and ratoon crop as compared to control. The application of S @ 25 and 35 kg/ha through SSP or Gypsum produced at par cane yield and juice quality. That mean both the sources of S were equally effective in terms of cane yield and juice quality. The application of S @ 15, 25 and 35 kg/ha through Gypsum or SSP had higher available

S in soil than control. This study indicated that to produce the higher cane yield and juice quality 25kg S/ha was sufficient and it can be applied by either sources.

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## Enhancement of sugarcane production and productivity by the biofertilizers with graded chemical fertilizers

L MAHATMA\*, K V MAKWANA<sup>1</sup> AND A N SABALPARA

Department of Plant Pathology, NMCA, NAU, Navsari- 396 450, Gujarat, INDIA

<sup>1</sup>Main Sugarcane Research Station, NAU, Navsari- 396 450, Gujarat, INDIA

### ABSTRACT

Experiments were conducted for three years at Main Sugarcane Research Station, Navsari Agricultural University, Navsari, Gujarat comes under under South Gujarat Heavy Rain Fall Zone (AES-III) to see the effect of biofertilizers on the yield of Sugarcane var CoN-05071. Azotobacter @ 2000ml/ha when applied as a soil treatment twice, first at the time of planting and second at the time of earthing up along with the RDCF (250:125:125 kg/ha NPK) significantly improve the crop yield over the RDCF. This was found equivalent to the setts treatment with the combination of Acetobacter and PSB (@ 1000ml/ha each) along with the 50 per cent reduction of chemical nitrogen and phosphorous. Similarly, application of alone Acetobacter as *setts* treatment (@1000ml/ha) was not as effective as the combination of Acetobacter and PSB, however, if the Acetobacter alone is applied as *setts* treatment (@ 1000ml/ha) and soil application two times (@ 2000ml/ha each time), it is equivalent to the RDCF along with the Azotobacter and also reduces 50 per cent chemical nitrogen. However, if the Acetobacter in combination with the PSB (@ 1000ml/ha each) is applied as *setts* treatment, soil application (2000ml/ha each at each time), first at the time of sowing and finally soil application at the time of earthing up give significantly higher crop yield and is cost effective too.

**Key words :** Sugarcane, Biofertilizers, Graded-chemical fertilizers

Sugarcane (*Saccharum* spp. hybrid complex), a C<sub>4</sub> plant is most efficient in converting physical and chemical energy (solar energy, Carbon dioxide and water) into biological energy (sucrose) on the earth fulfilling 80% per cent of world's sugar demand. The crop requires higher quantity of nutrients. An average crop of sugarcane yielding 100 t/ha economical biomass removes 208kg of N, 53kg of P, 280kg of K, 30 kg of Sulphur, 3.4 kg of iron, 1.2 kg of manganese, 0.6 kg of copper respectively from the soil. These withdrawn nutrients need to be replenished to sustain the productivity. Substantial quantity of chemical sources of these nutrients has been recommended which include 70-400 kg/ha N, 27-74 kg/ha P and 25-141 kg/ha K depends upon the soil conditions, crop variety and other agroclimatic conditions for the optimum, economic and sustainable yield (Anon 2013). Crop assimilates the nutrients, especially nitrogen supplied by the chemical fertilizers, from the organic matter after mineralization by microorganisms, nutrients already available in the seed piece, through biological fixation, etc. (Carneiro *et al.*, 1995, Trivelin *et al.*, 2002 Basanta *et al.*, 2003, Boddey *et al.*, 2003, Graham *et al.*, 2002, Vitti *et al.*, 2007). Other nutrients are either supplied by the chemical fertilizers or already present nutrients in the soil are made available due to the improvement of the soil physico-chemical properties through the physical, chemical or biological activities. Nitrogen derived from the chemical fertilizers contributed only up to 40% of the total nitrogen in the plant cane at initial stages of development which decreases

during stages of maturity to approximately 10% of total nitrogen at harvest. In the first ratoon, application of nitrogen fertilizer is more effective for crop nutrition, constituting up to 70% of total nitrogen in the initial stages of development and decreasing through the cycle, reaching approximately 30% at harvest (Franco *et al.*, 2011). Biological nitrogen fixation contributes 70% of the nitrogen assimilated by the sugarcane (Urquiaga, *et al.*, 1992). Both rhizospheric and endophytic diazotrophs seems to participate in this process (Baldani, *et al.*, 1997). Under the circumstances when plants take only 40% of nitrogen from the chemical source, recommendation of only chemical fertilizers for the sugarcane crop seems illegitimate. Recommendation of biofertilizers in combination of chemical fertilizers will not only help sugarcane growing better, but also will reduce the cost of cultivation, dependency on the chemical fertilizers, environmental pollution and soil health deterioration. *Gluconacetobacter diazotrophicus* is potential microorganism and has been found to colonize sugarcane and reduce 50% chemical inorganic nitrogen in micoropropogated sugarcane (Muthukumarasamy *et al.* 2006). *Bacillus megaterium* is another bacteria used for the solubilization of fixed phosphorous by increasing its availability to the plant. Therefore, the present investigation was planned to supplement 50% of the chemical nitrogen and phosphorous by the biofertilizers by the various methods and see their effect on the yield of sugarcane.

\*Corresponding author's E-mail: mahatmalalit@yahoo.co.in

## MATERIALS AND METHODS

### Site

The experiments were performed in the Field of Main Sugarcane Research Station, Navsari Agricultural University, Navsari, Gujarat. The farm was geographically located at 20°57' N latitude and 72°54' longitude at an altitude of 10 meters above mean sea level. The area comes under South Gujarat Heavy Rain Fall Zone (AES-III). Field trials were conducted for three years in 2008, 2009 and 2011. The soil has organic carbon 0.62%, nitrogen 380 kg/ha, phosphorous 28 kg/ha and potash 230 kg/ha in the range of average to good.

### Design and treatments

Sugarcane variety 'CoN-05071' popularly grown in the south Gujarat zone was used for the experiment. The crop was planted in December every time and was mechanically harvested in the same month after one year. All the standard agronomic practices were followed. For planting sugarcane, red rot and wilt disease free two eye bud seed pieces (*setts*) of uniform diameters were used. Sugarcane *setts* were planted at 90 cm distance between two rows. Gross and net field size were 6.0x 5.4 m and 5.0x4.5 m respectively. The experiments were laid out in randomized block design with three replications. Total eight different treatments as per the table 2 including recommended doses of chemical fertilizers (RDCF 250:125:125 kg/ha NPK) for the variety in the south Gujarat zone were planted. The *setts* placed in the furrow were covered with soil. In all plots at the bottom of the furrow, basal doses of chemical fertilizers were applied. Other standard agronomical practices were followed uniformly in all the treatments.

### Biofertilizers and its application

Biofertilizers prepared by Biofertilizers Production Unit, Department of Plant Pathology, N.M. College of Agriculture, NAU, Navsari were used. *Gluconacetobacter diazotrophicus* (commonly referred as Acetobacter) was used as a nitrogen source, whereas *Bacillus megaterium* (commonly referred as PSB) was used as phosphate solubilizing bacteria. *Azotobacter croococum*, recommended by the NAU along-with chemical fertilizers in the past was also used as one of the checks. One per cent Jaggery solution was prepared by mixing 200 g Jaggery in 20 liters of water. One per cent Biofertilizer solution was prepared by mixing 200 ml of respective Biofertilizer in the above solution. Sugarcane *setts* of suitable size were dipped in this solution for minimum 30 minutes in above prepared Biofertilizers solution. Liquid Biofertilizers @ 1000ml/h were applied mixed in pulverized soil (20kg/h) as soil application at the time of sowing and earthing up. Recommended split doses of chemical fertilizers were applied as per the standard method of fertilizer application.

## RESULTS AND DISCUSSION

Analysis of the data presented in table 1 indicated that the use of biofertilizers significantly increases yield attributing

characters and yield of sugarcane viz., number of tillers, number of millable cane, cane weight, millable cane height, total cane height, number of nodes, cane yield (t/ha) and sugar yield (t/ha). However, the quality parameter of the sugar cane viz., brix, juice per cent, purity, CCS and per cent fiber remained unaffected. Among the different treatments tested, treatment (T8), RDCF + Azotobacter soil application @ 2000ml/h each two times; first at planting and second at the time of final earthing up yielded significantly higher (139.45 t/ha) than T1 (RDCF 250:125:125 kg/ha NPK) with 127.51 t/ha yield. Treatment T8 was even significantly superior then the treatment T2 (single dose of Acetobacter as *setts* treatment @ 1000ml/ha and 50 per cent reduction of chemical nitrogen) yielding only 131.48 t/ha and treatment T4 (single dose of PSB as *setts* treatment @ 1000ml/ha and 50 per cent reduction of chemical phosphorous) yielding 129.15 t/ha. Treatment T8 was at par with the T3 (Acetobacter *setts* treatment @ 1000ml/ha + soil application of *Acetobacter* @ 2000ml/h two times; first at planting and second at the time of final earthing up and 50 per cent reduction of chemical nitrogen) with 139.06 t/ha yield and treatment T6 (single dose of Acetobacter and PSB as *setts* treatment @ 1000ml/ha each and 50 per cent reduction of chemical nitrogen and phosphorous) with 141.36 t/ha yield. However, was treatment T8 significantly superior then treatment T5 (*PSB setts* treatment @ 1000ml/ha + soil application of PSB @ 2000ml/h two times; first at planting and second at the time of final earthing up and 50 per cent reduction of chemical phosphorous) with 134.27t/ha yield. Among all the treatments, T7 (Acetobacter and PSB as *setts* treatment @ 1000ml/ha each + soil application of Acetobacter and PSB @ 2000ml/h each two times; first at planting and second at the time of final earthing up and 50 per cent reduction of chemical nitrogen and phosphorous) was significantly superior with 156.87 t/ha yield maximum CBR (1:4.86). A similar trend was observed in the sucrose yield also. Results obtained during the present investigation signify the importance of Biofertilizers in the cultivation of sugarcane crop and reduction on dependency on the chemical fertilizers to reduce the environmental hazards and soil health deterioration.

## CONCLUSION

Analysis of the data revealed that Azotobacter when applied as a soil treatment twice, first at the time of planting and second at the time of earthing up along with the RDCF significantly improve the crop yield over the RDCF. This was found equivalent to the *setts* treatment with the combination of Acetobacter and PSB along with the 50 per cent reduction of chemical nitrogen and phosphorous. Similarly, application of alone Acetobacter as *setts* treatment was not as effective as the combination of Acetobacter and PSB, however, if the Acetobacter alone is applied as *setts* treatment and soil application two times, it is equivalent to the RDCF alongwith the Azotobacter and also reduces 50 per cent chemical nitrogen. However, if the Acetobacter in combination with the PSB is

Table 1. Effect of biofertilizers and graded doses of chemical fertilizers on the yield of sugarcane Var. CoN-05071 (Pooled data of three years)

Treat-ment	Treatment detail	Germination % at 45 DAP	Tillering ('000/h)	NMC ('000/ha)	Cane wt (kg)	MCH (cm)	No of nodes	Dia. (cm)	Yield (t/ha)	Sucrose (t/ha)	CBR
T <sub>1</sub>	250 :125:125 NPK Kg/ha (RDF) In two split doses, first at time of sowing and second at time of earthing up.	70.88	192.33	104.67	1.20	208.67	28.67	3.75	127.51	16.70	-
T <sub>2</sub>	125 :125: 125 NPK kg/ha + Acetobacter <i>setts</i> treatment @ 1000ml/h	72.09	228.33	115.33	0.91	180.67	26.00	3.62	131.48	17.13	1:0.09
T <sub>3</sub>	125:125: 125 NPK kg/h + Acetobacter <i>setts</i> treatment @ 1000ml/ha + Acetobacter Soil application @ 2000/h. Two times; first at planting and second at the time of final earthing up	71.46	234.00	113.00	1.47	224.67	30.67	3.30	139.06	18.17	1:1.17
T <sub>4</sub>	250:62.5:125 NPK kg/ha + PSB <i>setts</i> treatment @ 1000ml/ha	72.78	207.67	104.67	0.92	183.00	29.67	4.16	129.15	16.83	-
T <sub>5</sub>	250:62.5:125 NPK Kg/ha + PSB <i>setts</i> treatment @ 1000ml/ha + PSB soil application @ 2000ml/ha. Two times, first at planting and second at the time of final earthing up	74.61	211.67	110.00	0.99	185.67	29.33	4.18	134.27	17.51	1:0.17
T <sub>6</sub>	125:62.5 :125 NPK Kg/ha + Acetobacter + PSB both as <i>setts</i> treatment @ 1000ml/h each	73.85	214.00	105.33	1.09	200.00	27.67	3.63	141.36	18.48	1:3.41
T <sub>7</sub>	125:62.5 :125 NPK Kg/h + Acetobacter + PSB <i>setts</i> treatment both @ 1000ml/h + Acetobacter + PSB soil application both @ 2000ml/ha two times, first at planting and second at the time of final earthing up	73.70	260.67	133.00	1.46	230.67	34.00	3.14	156.87	20.45	1:4.86
T <sub>8</sub>	RDF + Azotobacter soil application @ 2000ml/ha, two times first at planting and second at the time of final earthing up	75.53	212.00	105.67	1.25	201.33	29.67	4.18	139.45	18.25	1:1.27
S.Em.±		-	6.32	3.59	0.03	6.21	1.04	-	1.38	0.19	-
CD (at 5%)		-	19.19	10.90	0.09	18.83	3.14	-	4.19	0.58	-
CV		NS	4.98	5.59	4.55	5.33	6.08	NS	1.74	1.84	-

applied as *setts* treatment, soil application first at the time of sowing and finally soil application at the time of earthing up give significantly higher crop yield and is cost effective too.

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## **‘CoPb 08212’: A high yielding and early maturing sugarcane variety for North Western Zone of India**

G S SANGHERA, L KASHYAP, R KUMAR, V TYAGI, RUPINDER PAL SINGH, O SINGH, K S THIND  
and B KUMAR

*Punjab Agricultural University, Regional Research Station, Kapurthala-144601, Punjab, India*

### ABSTRACT

A new high yielding, early maturing sugarcane clone ‘CoPb 08212’ was developed from Co 89003 poly cross (PC). The genotype was initially tested in different clonal stages, evaluated in preliminary yield trial, advance yield trial and finally tested in zonal yield trials against the popular check varieties ‘CoJ 64’ and ‘CoPant 84211’ in early maturity group under All India Coordinate Research Project on Sugarcane for its performance regarding cane yield, its components, quality traits and resistance to red rot disease for three consecutive years 2010-11 to 2013-14 at nine locations in North Western zone of the country. The clone ‘CoPb 08212’ exhibited a mean cane yield of 78.49 (t/ha) as compared to 69.70 (t/ha) and 66.18 (t/ha) for ‘CoJ 64’ and ‘CoPant 84211’ recorded an increase of 12.61 and 18.59 percent over checks, respectively across years and locations. It also out yielded ‘CoJ 64’ by a margin of 15.16% for cane yield under recommended nitrogen levels. It recorded higher commercial cane sugar (9.79 t/ha), sucrose (18.02%) and pol % cane (13.85) at harvest and matures in 240 to 270 days that led to early from November onwards. ‘CoPb 08212’ was free from smut and wilt diseases screened under field conditions while moderately resistant to CF08 and CF09 red rot pathotypes under artificial inoculation conditions. It also exhibited better tolerance against borer complex. ‘CoPb 08212’ has tall (231.0 cm), medium thick (2.11cm), cylindrical, purple green canes and asymmetric auricles (i.e. lanceolate/transitional) as distinguishable features. Based on superiority of the clone ‘CoPb 08212’ over checks in 2 plant + 1 ratoon crops for cane yield and quality traits, it has been identified as new variety of sugarcane by the varietal identification committee for its release in North Western Zone comprising states of Punjab, Haryana, Rajasthan, Utrakhnad and UP. This outcome will be helpful to both sugarcane growers and industry for their sustenance by enhancing sugar recovery of the state as well as north zone.

**Key words:** Sugarcane, Variety, ‘CoPb 08212’

Sugar Industry is the second largest agro-based industry in India and contributes significantly to the socio-economic development of rural population. This sector plays an important role in rural economy of the country as it supports 6 million farmers and their families and also provides direct employment to over 0.6 million skilled and semi skilled persons in sugar mills and integrated industries situated in rural areas (Solomon *et al.* 2003). It also provides raw material to sugar and over 25 other industries producing alcohol, paper, chemicals and cattle feed. The industry has enabled the country to be self-reliant in this highly sensitive essential commodity (sugar) of mass consumption. The raw material is produced in more than 10 states both in tropics and sub-tropics with an annual production of over 350 MT sugarcane for producing around 25 million tonnes of white sugar and 6-8 million tonnes of jaggery and khandsari to meet the domestic consumption of sweeteners (Solomon, 2014).

Sugarcane (*Saccharum* spp hybrid complex) is one of the important commercial crops of the tropical and sub tropical region of the country, cultivated in an area of 5.03 m ha having a productivity of 70.86 t/ha. It forms basic raw material for the manufacturing of sugar in the country. Therefore, it has high

industrial importance (Solomon, 2014). The crop, per hectare yield and percent sugar recovery are the two factors of prime importance in breeding programme of this crop. Variety is the pivot around which the entire production system revolves. New varieties are continuously evolved by the Sugarcane Breeding Institutes, Agricultural Universities and Sugarcane Research and Development Centres country over. The farmers prefer the varieties based on sugar yield potential, ability to ratoon, tolerance or resistance to insects - pests and diseases, their soil type and site suitability and length of the growing season (Nair, 2010). Sugarcane is considered to be mature and ready for harvesting if it attains over 17% sucrose and 85% purity of cane juice (Wagih *et al.* 2014). The varieties, which attain such level at 8-10, 10-12 months age, if planted in February/March are broadly classified as early and mid-late maturing types, respectively under Indian climatic conditions (Solomon *et al.* 2007). The main idea of maturity-based classification of varieties is to facilitate harvesting of variety at proper time in order to enhance over all recovery and consequently the sugar production (Jackson, 2005).

Besides maturity, important considerations in choosing an appropriate variety include cane yield, juice quality, age group, suitability to the growing conditions, ratooning potential,

resistance to pests and diseases and adverse growing conditions. Some of the desirable varietal attributes one should look for are high yield potential, high sucrose content, good field appearance, higher tillering capacity, medium thick to thick and long stalks, long internodes, erect growing habit, non-lodging, non-flowering or shy flowering, good ratooning ability, absence of spines on the leaf sheaths, absence of splits on the stalks, less bud sprouting and resistance to prevailing local problems (Reddy *et al.* 2014). Hence, variety selection is very critical and has a large effect on sugarcane crop performance and yield.

In addition, proper proportion of area should be planted under early and mid-late maturing varieties to ensure proper supply of cane of desired quality throughout the crushing season to sugar mills to increase the total sugar recovery (Chattha *et al.* 2013). Some sugarcane crop must be harvested before achieving maximum sucrose levels to sustain early season (October-November) milling operations (Uppal *et al.* 2008). Further, early maturing varieties are preferentially harvested during this time recognizing the fact that though they may not have reached their peak sucrose content, but may have higher sucrose content than other late maturing varieties (Miller and James, 1977). To meet out the requirements of both the farmers and industry, it is always better to have more number of varieties with different maturity period so that proper and effective varietal scheduling can be practiced to ensure quality cane supply to the factories throughout the crushing period for their economic sustainability (Solomon *et al.* 2007). Sub-tropical region contributes more than 55% area of the sugarcane, however, cane yield and sugar recovery (%) is lower in comparison with tropical India (Reddy *et al.* 2014). In Punjab state, sugarcane occupied an area of 94 thousand hectares during 2014-15 and recorded the average cane yield of 74.9 tonnes per hectare. The average sugar recovery was 10.04 percent during 2015-16 crushing season (Anonymous, 2015). In India, crushing season normally starts from November end and continues till April or May with varying patterns of minimum and maximum temperatures (Srivastava *et al.* 2009). The decline in sugarcane quality is high especially during late crushing period (March onwards) as compared to early crushing phase due the inversion of sucrose into monosaccharides by invertases, organic acids and dextran formation by microorganisms (Saxena *et al.* 2010). Therefore, breeding efforts have to be concentrated on the development of early maturing varieties that can maximize sugar production early in the harvest period. Keeping in view the current scenario in North-West Zone in general and Punjab state in particular, where growers need to meet specific mill delivery timings; it could be fulfilled by planting varieties with early maturity to provide a spread of harvesting times and maximize sugar yield and productivity across the whole season. Therefore, it is very essential to identify a few early maturing, high yielding and high sugared varieties so that issue of delay in onset of the crushing season could be tackled. The concerted efforts

of sugarcane scientists in this study had led to development new clone 'CoPb 08212' that can address the above mentioned problem of the region to a great extent in terms of the requirement of high cane and sugar yields with other economic traits including desirable levels of resistance to pests and diseases.

## MATERIALS AND METHODS

A high yielding, early maturing sugarcane clone 'CoPb 08212' was developed from 'Co 89003' poly cross (PC) at Regional Research Station, Ludhiana/Kapurthala, Punjab. The genotype was selected from original seedlings in 2003, tested in different test stages, evaluated in preliminary yield trial, advance yield trial and finally tested in zonal yield trials against the popular check varieties in early maturity group under All India Coordinated Research Project on Sugarcane (AICRPS) for its performance regarding cane yield and its components, quality traits and resistance to red rot disease for three consecutive years 2010-11 to 2013-14 at nine locations. The experiment involving three sugarcane clones viz. 'CoPb 08211', 'CoPb 8212', 'CoS 08233' and two checks 'CoJ 64' and 'CoPant 84211' was laid out in randomized complete block design (RBD) with three replications having plot size of six rows of six meters row length at inter row spacing of 75 cm under plant and ratoon crops. The crop was planted during March and harvested in January month; ratoon crop was established in late January and harvested in December month during all the three years of experimentation. The recommended packages of practices were adopted for raising a good and healthy crop stand during the crop seasons as per the technical programme. Data were recorded on agro-morphological characters viz., number of millable canes at harvest, stalk length (cm), single cane weight (kg) and diameter of cane (cm), juice quality parameters namely brix (%), sucrose (%), purity (%) and CCS (%). Cane yield was recorded at harvest on plot basis and expressed in tons/hectare (t/ha). Commercial cane sugar (CCS) yield (t/ha) was calculated as: cane yield (t/ha) x CCS %/100. Whole cane samples were taken at the time harvest and cane juice was extracted with power crusher and juice quality traits were determined using sucrolyser as per the standard procedure given by Meade and Chen (1971).

The experimental plant material used in present study was evaluated for red rot resistance under artificial inoculation. Red rot pathotypes CF 08 (from 'CoJ 84') and CF 09 (from 'CoS 767') were multiplied on oat meal agar medium in Petri dishes at 25±1°C. For inoculations, freshly sporulating 7-10 days old cultures were used. The spores were washed with sterile distilled water and homogenized by shaking and spore suspensions with concentration of 2X10<sup>4</sup> conidia ml<sup>-1</sup> was maintained. Experimental plant material was planted in the field area using single bud setts. Ten canes per treatment were inoculated by a suspension of two pathotypes viz. CF 08 and CF 09 by artificial inoculation under field conditions using plug method (Srinivasan and Bhatt, 1961). The inoculations

were done in the third internode from the base of the standing canes injecting 1.0 ml of spore suspension ( $2 \times 10^4$  conidia  $\text{ml}^{-1}$ ) with the help of hypodermic syringe. The core was then replaced and the openings were sealed with modeling clay. Disease data were recorded after 60 days of inoculation. The condition of the top was recorded and the canes split longitudinally. Observations were recorded on the number of internodes transgressed by the pathogen. The canes were rated 0-9 as per scale of Srinivasan and Bhatt (1961). Further, the incidence of sugarcane borer complex was recorded for early shoot borer, top borer and stalk borer as per the technical programme and guidelines of AICRIP(S) in Entomology (Anonymous, 2013).

The data recorded for cane yield and quality parameters were analyzed according to randomized block design analysis (Senedecor and Cochran, 1967) using statistical software CPCS-1 package developed by Cheema and Singh (1990). The significance of variation among the treatments was compared by applying 'F' test and critical difference (CD) at 5 percent level of significance. The analysis of variance for each trait was based as per linear model suggested Panse and Sukhatme (1978) and interpretations were made accordingly.

## RESULTS AND DISCUSSION

Analysis of variance studies over year and location across the zone revealed significant difference among the clones in 2 plant + 1 ratoon data recorded for different parameters namely cane yield, number of millable canes at harvest, stalk length, single cane weight and diameter of cane and juice quality parameters namely commercial cane sugar (CCS) yield, brix (%), sucrose (%), purity (%), pol (% cane) and CCS (%) indicating the genetic difference among clones for these parameters and scope of their improvement. Significant differences among the sugarcane clones with high magnitudes of variances for cane yield, single cane weight, cane length and sucrose per cent has been reported in earlier study (Sanghera *et al.* 2014). Differential response of clones (Smiullah *et al.* 2013) sett size, seed rate and sett treatment on yield and quality of sugarcane has also been reported by Patel and Patel (2014). The performance of newly developed elite clone 'CoPb 08212' with respect to cane yield and components, juice quality parameters in comparison to standard varieties revealed that clone 'CoPb 08212' recorded an average cane yield of 78.49 (t/ha) and found superior to the checks 'CoJ 64' (69.70 t/ha) and 'CoPant 84211' (66.18 t/ha) by a margin of 12.61 and 18.59 percent, respectively (Table 1).

Average sugar yield (CCS t/ha) among clones ranged from 7.88 of 9.79 (t/ha). Highest CCS (t/ha) was recorded in favour of 'CoPb 08212' (9.79 t/ha) while the checks varieties 'CoJ64' and 'CoPant 84211' recorded a sugar yield of 8.58 t/ha and 7.88 t/ha, respectively showed the better performance of 'CoPb 08212' over checks to the tune of was 14.06% over 'CoJ 64' and 24.25 % over 'CoPant 84211' for this important trait (Table 1). The zonal performance of the clone 'CoPb 08212'

Table 1. Mean performance of CoPb 08212 and standards for cane yield and quality traits (2 Plant + 1 Ratoon) under North West Zone

Genotypes	CCS (t/ha)	Cane yield (t/ha)	Pol (% cane)	Sucrose (%)	Purity (%)
CoPb 08212	9.79	78.49	13.85	18.02	88.83
CoJ 64	8.58 (14.06)	69.70 (12.61)	13.86 (-0.05)	17.78 (1.37)	88.89 (-0.06)
Co Pant 84211	7.88 (24.25)	66.18 (18.59)	13.54 (2.26)	17.29 (4.22)	88.13 (0.79)
CD at 0.05	0.81	5.65	NS	0.05	NS

Value in the parenthesis showed % increase over standards

with respect to CCS (t/ha) in 2 plant + 1 ratoon crop is depicted in Fig. 1 which showed that 'CoPb 08212' has higher crop yield and CCS (%) across nine locations which accounts for higher CCS (t/ha). A good range of CCS (t/ha) among clones over years and location has been documented (Sanghera *et al.* 2015). Breeding and selection for high early season sugar content in a sugarcane improvement program has been advised by Cox *et al.* (1994) who selected elite clones with high early CCS (%) and recycled into the breeding population with a short generation interval.

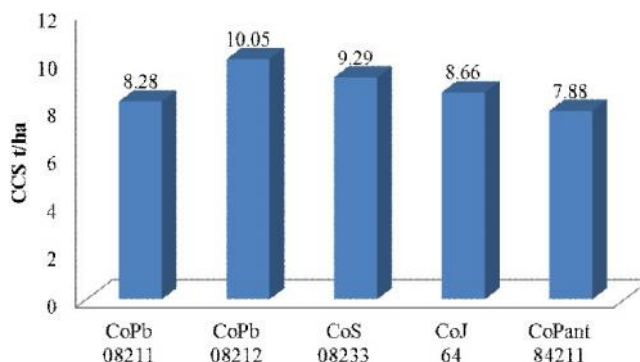


Fig. 1. Performance of CoPb 08212 for CCS (t/ha) at zonal level

Data on quality parameters viz. percent sucrose, percent purity in juice and pol (% cane) is also appended in Table 1 which showed that the 'CoPb 08212' fall in early maturity group as it recorded a mean juice sucrose percent (18.02) at 10 month harvest. It was found superior to to both the checks 'CoJ 64' and 'CoPant 84211' with an increase of 1.37% and 4.22%, respectively. Charumathi and Naidu (2015) recorded a mean juice sucrose and CCS per cent (18.61 and 14.79) in early maturing clone 'CoA 11323' that was on par with the best standard 'CoA 92081'. Comparisons of cultivars released in different years and locations indicate that sugarcane breeding programs have delivered increased sugar yields via improvements in cane yield, with much smaller contributions

from sugar content (Jackson, 2005). Possible reasons for slow rates of genetic gain in sugar content include: that insufficient weighting has been applied to sugar content in comparison with cane yield in selection of parents, that most favourable alleles for sugar content are fixed in current cultivars, and that gene effects contributing to levels of sugar content above current cultivars are negatively correlated with cane yield (Gonzales and Galvez, 1998). In India, crushing season normally starts from November end and continues till April or May with varying patterns of minimum and maximum temperatures (Srivastava *et al.* 2009). The decline in sugarcane quality is high especially during late crushing period (March onwards) as compared to early crushing phase due the inversion of sucrose into monosaccharides by invertases, organic acids and dextran formation by microorganisms (Solomon *et al.* 2006, Saxena *et al.* 2010). The clone 'CoPb 08212' was found at par with the best standards 'CoJ 64' and 'CoPant 84211' for juice purity percent. The higher yield of clone 'CoPb 8212' has attributed to maximum number of millable canes 99.80 (000/ha), stalk length (231.0 cm) and single cane weight (0.89kg) that were comparable to the different standard checks (Table 2). Similar trends of cane yield attributes in sugarcane were recorded by Charumathi and Naidu (2015) in early maturing clone 'CoA 11323' for cane length (287.67 cm) and single cane weight (1.23 kg) that were compared to early standard 'Co 6907' (233.33cm, 2.10 cm and 1.04 kg). The present results are also in agreement with previous report (Sanghera *et al.* 2015).

Table 2. Mean performance of CoPb 08212 and standards for Stalk length, stalk diameter, single cane weight and number of millable canes (2 Plant + 1 Ratoon) under North West Zone

Genotypes	Stalk length (cm)	Stalk diameter (cm)	Single cane Wt.(kg)	Number of millable canes (000/ha)
CoPb 08212	231.0	2.11	0.89	99.80
CoJ 64	197.0 (17.26)	2.24 (-5.8)	0.79 (12.71)	97.0 (2.89)
Co Pant 84211	203.0 (13.79)	2.16 (-2.6)	0.82 (8.13)	91.24 (9.38)
CD at 0.05	15.25	NS	0.06	3.20

Value in the parenthesis showed % increase over standards

The test clones were screened against two pathotypes of red rot using plug method under artificial conditions and incidence was recorded after 60 days of inoculation ensuring ideal conditions for disease development under field conditions. Comparative disease score of new clone and standard presented in Table 3 revealed that check variety 'CoJ 64' was highly susceptible to red rot disease having red rot score of 8.5 and 8.2 against CF 08 and CF 09 pathotypes, respectively while Copant was highly susceptible (8.5) to pathotype CF 08 and moderately resistant to CF 09 (3.5). Reaction of new clone was found moderately resistant to two red rot

Table 3. Reaction of CoPb 08212 and standards against important diseases under artificial inoculation conditions

Disease/ Pathotype	Red Rot		Wilt	Smut
	Pathotype/method			
Genotypes	Plug method (CF 08)	Plug method (CF 09)	Natural	Artificial inoculation by steeping method
CoPb 08212	MR (3.6)	MR (3.5)	R	MR (8.5)
CoJ 64	HS (8.5)	HS (8.3)	R	S (24.5)
CoPant 84211	HS (8.2)	MR (3.5)	R	MR (8.5)

CF 08 from CoJ 84, CF 09 from CoS 767

Scale: R = Resistant (0-2), MR = Moderately Resistant (2.1-4), MS = Moderately Susceptible (4.1-6), S = Susceptible (6.1-8), HS = Highly Susceptible (>8)

#### Smut

R = Resistant (0%), MR = Moderately Resistant (1-10%), MS = Moderately Susceptible (10.1-20.0%), S = Susceptible (20.1-0.0%), HS = Highly Susceptible (>30.0%)

pathotypes CF 08 (3.6) and CF 09 (3.5) under artificial inoculation by plug method. The moderate resistance reaction among various sugarcane genotypes ranging from 2.1-4.0 to red rot pathogen among different pathotypes have been reported by earlier workers (Ali *et al.* 2007 and Majid *et al.* 2001). Similar moderately resistant reaction of red rot disease in mutated populations of 'CoJ 64' sugarcane variety was reported by Kaur *et al.* (2016). The susceptibility of checks 'CoJ 64' to both red rot pathotypes (CF 08 and CF 09) has also been reported across the zone (Anonymous, 2014).

Further, 'CoPb 08212' had better tolerance to borer complex (early shoot borer, top borer and stalk borer) as compared to standards ('CoJ 64' and 'CoPant 84211') over years and locations (Table 4). Variable response of test clone to borer complexes in sugarcane has been documented (Radadia and

Table 4. Incidence of major insect pests on CoPb 08212 and standards

Genotypes	Early shoot borer*	Top borer **	Stalk borer***
CoPb 08212	3.05	5.96	4.33
CoJ 64	5.99	8.87	7.00
Co Pant 84211	5.32	7.45	5.33

\*Percent incidence based on dead-hearts recorded in post-germination phase at 30 days interval up to 120 days from sowing

\*\* Cumulative Percent incidence during the 3rd and 4th broods (July, August and September)

\*\*\* Percent incidence at harvest (recorded on 75 canes per replication).

Incidence of pyrilla, black bug and whitefly was observed in traces in the research trials on CoPb 08212 as well as the check varieties.



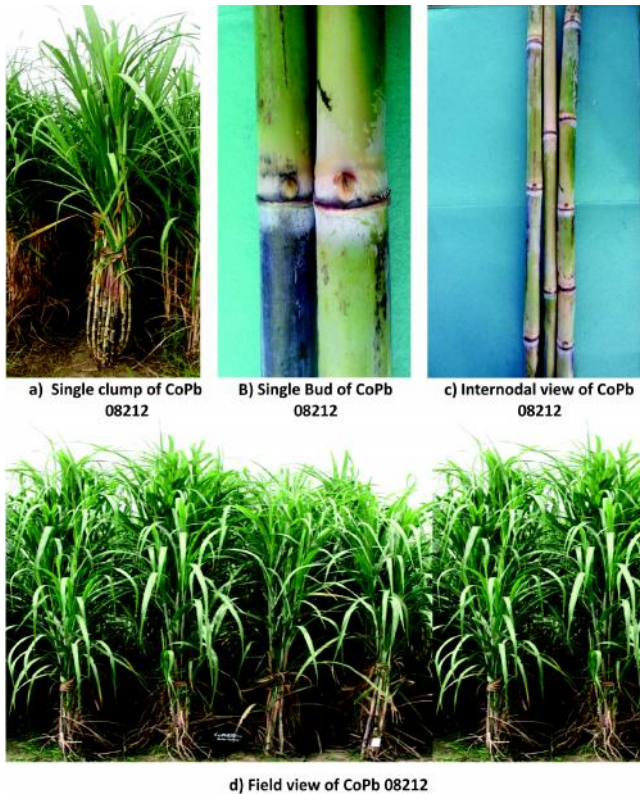


Fig. 2. Features of CoPb 08212, a) Single clump b) bud shape c) Internode d) Field view of the variety

Shinde, 2013). Additional advantage of this clone is also attributed to its tolerance to frost and medium tolerance to lodging. The clone 'CoPb 08212' has tall, medium thick, cylindrical purple green canes and asymmetric auricles (i.e. lanceolate/transitional) as distinguishable features (Fig. 2).

Sugar industry and sugarcane farmers are looking for new varieties, which will improve cane yield and sugar productivity in the state /zone. The concerted efforts of sugarcane scientists in this study had led to development new clone 'CoPb 08212' having desirable morphological characters, higher cane yield, sugar yield and resistance to insect pest and diseases and can be a good agro-industrial friendly candidate variety. Keeping in view the diverse features of this potential clone, it has been recommended by the varietal identification committee for its release in early maturing group in North-Western zone comprising states of Punjab, Haryana, Rajasthan, Uttarakhand and UP that will add to diversity of varieties in this maturity group for enhancing cane and sugar yield in this zone.

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## Characterization of sugarcane varieties (*Saccharum* spp. hybrid) for sprouting, tillering and cane yield characteristics in Southern Ethiopia

ABDUL QAYYUM KHAN, KIYA ADARE TADESSE and BERHANU LEMMA ROBE

Department of Plant Science, College of Agricultural Sciences, Arba Minch University, Southern, Ethiopia

### ABSTRACT

Study was undertaken with objective of characterization of introduced sugarcane varieties for sprouting, tillering and cane yield characteristics for identification of promising ones. Field experiment was conducted by planting two budded sets of sixteen sugarcane varieties, 'B 41227', 'DB 228 57', 'N 14', 'N53 219', 'N Co 334', 'B 52 298', 'E 188 56', 'B 59 212', 'B 4906', 'CP 69 1059', 'N 52 216', 'Mex 54 245', 'B 60267', 'Co 622', 'C 86 56' and 'C 86 165' in randomized block design at Arba Minch during 2015-16. At 30 days after planting, high sprouting of buds was recorded in varieties, 'E 188 56', 'C 86 56', 'B 52 298', 'DB 228 57', 'N 14', 'N Co 334' and 'B 41 227' (>90 %). At 40 days, bud sprouting was 165 % over all varieties indicating onset of tillering. Number of sprouts in all varieties was more than 2, 4 and 6 per bud at 50, 60 and 70 days after planting. High number of tillers at 70 days were in varieties, C 86 56 and B 4906 (> 9/bud) and the lowest in Co 622 (> 4/bud). At 135 days after planting high tillering was recorded in varieties, 'N 52 219', 'B 4906', 'Co 622', 'N Co 334', 'N 53 216' and 'DB 228 57' (>9 to >8/bud) and lowest in variety, 'B60267' (> 4/bud). At 210 days, cane forming stalks were high in varieties, 'N 53 216', 'E 188 56', 'N 52 219', 'N Co 334' and 'C 86 165' (>5 to >4/bud) and low in varieties, 'B 60267' and 'CP 69 1059' (> 2/bud). Millable canes at 240 days were high in varieties, 'C 86 165', 'N Co 334', 'E 188 56' and 'N52 219' (171.30'000/ha- 162.97'000/ha) and low in varieties, 'B 60267' and 'CP 69 1059' (91.91'000/ha - 96.30'000/ha). Cane length was more in varieties, 'Mex 54 245', 'B 6026', 'B 59212', 'Co 622', 'B 41227' and 'E 188 56' (>3.37 m) at 12 month age. Cane diameter was medium thick canes in varieties, 'B 59 21' and 'B 60 267' (> 2.5 cm), medium in varieties, 'B 52 298' and 'Mex 54 245', 'B 41 227', 'N 14', 'N 53 216' and 'DB 229 57' (2.43 cm - 2.31 cm), and thin in varieties, 'B4906', 'N 52 219' and 'E 188 56' (< 2 cm). High cane weight was recorded in varieties, 'B 59 212', 'B 60267', 'Mex 54 245', 'B 52 298', 'Co 622', 'N 53 216', 'B 41227' and 'DB 228 57' (2.11 kg - 1.31 kg). Variety, 'N Co 334' formed high number of internodes. High number of millable canes were in 'C 86 165', 'N Co 334', 'E 188 56', 'N 52 219', 'N 53 216', 'N 14' and 'Co 622' (146.30'000/ha- 124'000/ha). Estimated cane yield was maximum in 'B59212' (217.09 t/ha) followed by 'N 52 216', 'Co 622', 'B 41227', 'Mex 54 245', 'B52 298', 'N 14', and 'DB 228 57' (174.68 -150.35 t/ha). Next high cane yield was in 'B 60 267', 'N Co 334', 'E 188 56' and 'B 4906' (146 t/ha- 117. 19 t/ha) Lowest cane yield was in 'CP 69 1059' (97.99 t/ha). Varieties with good cane yield may be evaluated for confirmation of their performance and selection of promising ones.

**Key words:** Sugarcane, sprouting, tillering, cane characteristics, yield

Sugarcane is grown for production of sugar and other by-products such as molasses, ethanol, bagasse and filter press mud in sugar factories in Ethiopia. It is also grown for chewing purpose by farmers in villages where it cannot be supplied to sugar factories. It generally matures in 16 to 20 months and five to six ratoon crops are raised in the same field after harvesting of the previous crops. It is cultivated on about 37,000 hectares in four sugar estates where four sugar factories produce about 300,000 tons of sugar per year (Shimelis *et al.*, 2011; Firehun *et al.*, 2013). There is a shortage of sugar production in the country. Current sugar production is able to meet only 60 percent of sugar consumption demand. Per capita consumption of sugar in Ethiopia is about 5.1 kg which is very low even by African standards (16.3 kg) and world standard (23.7 kg) (ISO, 2012). Thus, there is an immediate need to increase sugarcane and sugar production in the country (Firehun *et al.*, 2013).

Varieties play pivotal role in increasing sugarcane and sugar production as these are the primary dependable input for crop

production and for the supply of quality canes to sugar Mills. Performance of varieties depend on agronomic characters such as bud sprouting, tillering and cane yield characteristics, namely, cane height, thickness, cane weight and number of millable canes. Therefore, varieties need to be characterized for the above agronomic characteristics for identification of promising ones. It is very important for Ethiopia where sugarcane varieties are introduced from different countries, namely, Barbados, Coimbatore (India), Natal (South Africa), Coimbatore- Natal (South Africa), Mauritius, Mexico and Guyana (Negi, 2009). Sugarcane varieties are not developed through breeding in Ethiopia because of limitation of flowering and seed setting at the sugarcane research centres. Current improved sugarcane varieties are derived from inter-specific hybridization involving four species of the genus *Saccharum*, namely, *S. officinarum*, *S. barberi*, *S. sinense* and *S. spontaneum*. Somatic chromosome number in the varieties varies from 90 to 130 (Sreenivasan *et al.*, 1987; Srivastava, 2000). Out of the total chromosomes in sugarcane varieties, 80

per cent contribution is from *S. officinarum*, 10 per cent from *S. spontaneum* and the remaining 10 per cent from other species, *S. barberi*/*S. sinense* (D' Hont *et al.*, 1996). Thus, improved sugarcane varieties being inter-species hybrids are taxonomically known as *Saccharum* spp. hybrid complex. Introduced sugarcane varieties are maintained at Ethiopian Sugar Corporation Sugar Estate, Wonji - Shoa. Varieties need to be evaluated for their characteristics and performance at suitable places. Arba Minch University is near to a newly developing Omo- Kuraz Sugar Project in southern Ethiopia where six new sugar factories are being installed (Ethiopian Investment Agency, 2012). The present study was, therefore, undertaken with objective of characterization of sugarcane varieties for sprouting, tillering, cane stalk characteristics and cane yield at Arba Minch University, Ethiopia.

#### MATERIALS AND METHODS

The materials for the study consisted of 16 varieties of sugarcane whose two budded seed pieces were obtained from Research and Training Division of Ethiopian Sugar Corporation, Wonji- Shoa. The seed pieces were treated in hot water at 50 °C for two hours followed by fungicidal treatment at the hot water treatment unit at Sugar factory, Wonji- Shoa. The study was carried out at Arba Minch University Farm, Arba Minch which is located at 6.04 °N latitude, 37.36 °E with an altitude of 1218 m. above sea level. It is 505 km away in south of Addis Ababa. Average maximum and minimum temperatures were 35°C and 17.8°C during February and March, 2015 which were suitable for good sprouting of buds during the period. Average temperatures at latter months both Maximum (35°C – 28°C) and minimum (17°C - 18.4°C) were also suitable for growth and development. Rains occurred during April, May, June, September, October, November and December, 2015 (60.5 mm – 54 mm). The experiment was provided supplemental irrigations at appropriate time. Average relative humidity was more than 43 per cent in February, 2015 which increased with receipt of rains. Average sun shine hours varied from 10 hours in February to 7.4 hours in May, 5.8 hours in June to 7.6 hours in October, and around 10.5 hours in November, 2015 to February, 2016. Thus, weather conditions during experiment period from February 2015 to March 2016 were quite suitable for sugarcane growth and development.

Physico-chemical characteristics of soil were analysed in Soil Testing Lab. of Ethiopian Sugar Corporation, Wonji- Shoa. Average proportions of sand, silt and clay particles in the soil were 12.0, 37.3 and 50.7 per cent, respectively. The pH of soil was 7.8. The soil was rated as clay and slightly alkaline (Murphy, 1968). Average organic carbon per cent was 1.68 which was medium (Tekalign, 1991). Total nitrogen per cent was 0.3 which was in high range (Landon, 1991). Cation exchange capacity was 66.30 which was very high (Landon, 1991). The soil had good amount of ions, organic carbon, total nitrogen and available phosphorus (25.43 ppm) and potassium (413.70 ppm).

Exchangeable cations (meq/100 g) were: Na<sup>+</sup> (0.84), K<sup>+</sup> (0.98), Ca<sup>++</sup> (44.70) and Mg<sup>++</sup> (10.0) which were fairly good. Thus, soil of the experimental field was suitable for growing sugarcane.

#### Experimental layout and design

The experiment with 16 varieties was planted in randomized complete block design with two replications on February 16, 2015 in furrows drawn at 20 cm depth in well prepared field with a light irrigation one day before on February 15, 2015. The plot size for each variety was 3 rows of 3 m spaced 1 m apart. Two budded setts were placed in furrows with buds facing sides at intra row spacing of 60 cm between setts. Experiment was fertilized at the rate of 150 kg N and 69 kg P/ha. 50 per cent of N and full dose of P was applied using Diammonium phosphate and Urea at the time of planting in furrows. Insecticide Ethiozinone water emulsion was sprayed on the setts in furrows at the rate 1.0 kg active ingredient per hectare to control insects. The setts were covered by 5 cm layer of soil followed by light irrigation in the afternoon. The next irrigation was provided 6 days after planting followed by other irrigation just after 4 days. The exposed setts were covered by the soil 3 days after planting and also after next irrigation. The remaining 50 % dose of N was applied in two splits using Urea, one after germination at 45 days and the other at tillering phase 90 days after planting. Weeding, irrigation and earth up in the experiment were given as and when required to raise the good crop.

#### Recording of data

Data on sprouting of buds and tillers per plot were recorded at 20, 30, 40, 50, 60 and 70 days after planting. Number of tillers arising from the middle 3 setts excluding border ones in each of 3 rows of the plot were recorded at 4.5 month age to avoid border effect on the tiller formation. Number of cane forming stalks and millable stalks were recorded from 3 stools in the middle of each of 3 rows of the plot at 7 and 8 months age, respectively.

Cane length, cane diameter, number of internodes per cane and cane weight were recorded on 6 canes per plot, two canes from middle stool in each of 3 rows of the plot at 12 months age (370 days). Cane length was measured from the cut end of the basal internode to top internode after removal of growing top. Cane diameter was measured at above ground, middle and top internode. Internodes were counted in the same sample canes. Average cane length, cane weight, cane diameter at lower, middle and top internodes and average internodes per cane were calculated. Cane diameter was classified as: < 2.0 cm: thin, 2- 2.5 cm medium thin, 2.5- 3.0 cm medium, 3.0- 3.5 cm medium thick, > 3.5 cm thick following Akhtar *et al.* (2001). Number of millable canes were counted in middle three stools or clumps in each of 3 rows of the plot at 12 month age (370 days). Estimated cane yield was calculated by multiplying average cane weight with number of millable canes.

### Statistical Analysis

Data were subjected to General linear Model procedure of statistical analysis for randomized complete block design following SAS software package (SAS, 2004). Treatment or variety means for the characters were compared by Duncan multiple Range Test (Gomez and Gomez, 1984).

## RESULTS AND DISCUSSION

### Sprouting

Sprouting per cent of buds differed significantly among varieties at 20, 30 and 40 days after planting. Bud sprouting ranged from 100% in variety, 'E 188 56' to 40% in 'N 52 219' at 20 days after planting. The next high sprouting of 90% to 80% were observed in varieties, 'C 86 56', 'B 52298' and 'C 86 165'. The general mean for sprouting over varieties was 66.98% at 20 days. At 30 days, sprouting was over 100% in varieties, 'E 188/56', 'C 86 56' and 'B 52 298', and over 90% in varieties, 'DB 228 57', 'N 14', 'N Co 334' and 'B 41227'. The general mean for sprouting over all varieties at 30 days was 88.85%. The general mean for sprouting of buds at 40 days was 165.52% in all 16 varieties which ranged from maximum of 318.33% in 'B 4906' to low of 98.33% in variety 'N 52 219'. This showed that the sprouts at 40 days included primary shoot and the tillers indicating thereby the onset of tillering at this stage.

High sprouting of buds in two budded setts observed in present study agreed with results of other workers in Ethiopia. Tadesseet *al.* (2009) reported 88.57% sprouting of buds in seven varieties at 25 days at Tendaho Sugar Project. Sime (2013) reported high bud sprouting at 45 days in variety, 'N 14' at Wonji- Shoa sugar estate from middle and top portion of cane.

### Tillering up to 70 days after planting

Number of tillers or sprouts per bud inclusive of primary shoot differed significantly among 16 varieties at 50, 60 and 70 days after planting. Number of tillers per bud at 50 days ranged from 5.22 in variety 'B 4906' to 2.53 in 'N 52 219' with a general mean of 3.39 tillers per bud. This indicated that each bud at 50 days had formed more than two tillers in most of the varieties. Number of tillers per bud at 60 days ranged from 7.22 in variety 'C 86 56' to 3.68 in 'Co 622' with general mean of 5.04. This indicated that more than 4 tillers per bud were formed in most varieties at 60 days. At 70 days after planting, high number of tillers were in varieties, 'C 86 56' and 'B 4906' (10.88/bud and 10.30/bud) and lowest in variety, 'Co 622' (5.15/bud) with a general mean of 7.35 which indicated that more than 6 tillers per bud were formed at 70 days in most of the varieties. It was worth noting that the number tillers on average were more than 2, 4 and 6 per bud at 50, 60 and 70 days, respectively, which indicated that there was a linear increase in tiller

Table 1. Sprouting per cent of buds in sugarcane setts at 20, 30 and 40 days after planting and average number of tillers including primary shoot per bud at 50, 60 and 70 days after planting

Varieties	Bud sprouting%			Number of tillers per bud		
	20 days	30 days	40 days	50 days	60 days	70 days
'B41227'	61.67e	90.00f	153.33d	3.43f	4.98e	6.83e
'DB 228 57'	66.67e	98.33d	130.00e	2.92f	4.83e	6.62f
'N14'	78.33e	95.00e	118.33e	2.75f	4.52e	6.55f
'N 52 219'	40.00g	83.33h	98.33g	2.53g	4.25e	6.53f
'NCo334'	56.67f	93.33e	121.67e	2.58g	4.93e	7.57d
'B 52 298'	90.00c	106.67b	181.67c	3.80d	5.37c	7.37e
'E 188 56'	101.67a	101.67c	200.00b	3.98c	5.35c	6.60f
'B59 212'	66.67e	85.00g	178.33c	3.67e	5.43c	7.32e
'B4906'	76.67e	88.33f	318.33a	5.22a	6.50b	10.30b
'CP 69 105'	45.00g	80.00h	153.33d	3.15f	4.57e	6.75e
'N 53 216'	36.67g	78.33i	105.00f	2.35h	4.10e	6.32f
'Mex 54 245'	55.00f	70.00k	121.67e	3.62e	5.18d	7.30e
'B60267'	56.67f	81.67h	181.67c	3.03f	4.15e	5.90f
'Co622'	66.67e	75.00j	120.00e	2.63f	3.68f	5.15f
'C 86 56'	91.67b	110.00a	286.67a	4.88b	7.22a	10.88a
'C 86 165'	81.67d	85.00g	180.00c	3.75d	5.50c	9.63c
Mean	66.98	88.85	165.52	3.39	5.04	7.35
SE (±)	10.06	6.32	20.15	0.39	0.45	0.87
LSD (at 5%)	30.31*	19.06*	60.73*	0.12*	0.13*	0.5*
CV %	21.23	10.06	17.21	16.41	12.58	16.78

formation per bud at every 10 days interval from 40 days to 70 days. As in the present investigation, high sprouting and tillering was observed in variety 'B 4906' in a varietal evaluation study at Wonji- Shoaby Getaneh *et al.* (2013).

#### **Tillering at 4.5 months after planting**

Varieties differed significantly for number of tillers per bud or thousand per hectare ('000/ha). High number tillers were formed in varieties, 'B 4906', 'N 52 219', 'C 622', 'N Co 334', 'N 53 216' and 'DB 228 57' (10.58/bud, or 352.78'000/ha to 9.17/bud, or 305.56'000/ha). Lowest number of tillers, per bud were in variety, 'B 60 267' (5.56/bud, or 183.82'000/ha). The general mean for tillering was 8.43 tillers per bud including primary shoot or total tillers 281.05'000/ha at 4.5 month after planting. In terms of tiller/m<sup>2</sup>, average number of tillers including the primary shoot was 28.10/m<sup>2</sup> which was quite high in present study. According to Bell and Garside (2005) formation of tillers lower than 8 to 10 per m<sup>2</sup> would reduce cane yield. In the present study Highest and low number of tillers observed in varieties, 'B 4906' and 'CP 69 1059' in present study matched with results reported by Getaneh *et al.* (2013) in a variety evaluation study at Wonji- Shoa, Ethiopia.

#### **Number of cane forming stalks and millable canes at 7 and 8 month safter planting**

Culm forming tillers with visible internodes were called cane forming stalks at 7 months. Varieties differed significantly for cane forming stalks. Higher number of cane forming stalks per bud were recorded in varieties, 'N 53 216', 'E 188 56', 'N 52 218'

and 'N Co 334', 'C 86 165' (6.14/bud-5.42/bud, or 204.63'000/ha - 180.56 000/ha), whereas low number in varieties, 'CP 69 105' and 'B 60267' (3.00/bud-3.17/bud, or 100.'000/ha-105.23'000/ha). However, comparing the general mean for cane forming stalks (4.67/bud) with general mean for tiller numbers at 4.5 month (8.43/bud) it was evident that the number of cane forming stalks was less than the number of tillers at 4.5 months. The primary cause for reduction in number of cane forming stalks was the competition among the developing tillers for light and nutrition leading to death of many tillers. Competition for light for reduction in number of tillers later was reported by Singles and Smit (2009). Mortality was observed to be highest in late formed tillers 4 months (120 days) after planting by Vasanthaet *et al.* (2012).

At 8 month age, high number of millable canes per hectare were in varieties, 'C 86 165', 'N Co 334', 'E 188 56' and 'N52 219' (171.30'000/ha - 62.97'000/ha). Low number of millable canes were in varieties, 'B 60267' and 'CP 69 1059' (91.91'000/ha - 96.30'000/ha). It may be mentioned that general mean for number of millable canes (136.01'000/ha) at 8 months was less than the general mean for cane forming stalks (155.74'000/ha) at 7 months. It could primarily be due to the competition among the developing cane stalks for light and nutrition. The decrease in number of millable stalks from the cane forming tillers with increasing age is commonly observed in sugarcane because of competition among cane stalks for light and nutrition The relatively faster growth in developing cane stalks at grand growth stage had led to competition for

Table 2. Number of tillers (NT) and number of cane forming stalks (NCS) per bud and per hectare ('000/ha) at 4.5 month and 7 months, and number of millable canes (NMC) at 8 month in sugarcane varieties

Varieties	At 4.5 months		At 7 months		At 8 month
	NT/ bud	NT ('000/ha)	NCS/bud	NCS ('000/ha)	NMC('000/ha)
'B41227'	6.78e	225.93e	5.42c	180.56c	139.82d
'DB228/57'	9.17c	305.56c	4.47e	149.08e	130.56e
'N14'	8.69c	289.82c	5.19d	173.15d	145.37c
'N52/219'	10.53a	350.93a	5.61b	187.04b	162.97b
'NCo334'	9.86b	328.70b	5.61b	187.04b	166.67b
'B52/298'	8.03d	267.60d	4.11e	137.04e	130.56e
'E188/56'	7.33e	244.44e	6.11a	203.71a	163.89b
'B59/212'	6.86e	228.71e	4.00f	133.33f	115.75f
'B4906'	10.58a	352.78a	3.89f	129.63f	125.00f
'CP69/1059'	7.33e	244.44e	3.00h	100.00h	96.30h
'N53/216'	9.22c	307.41c	6.14a	204.63a	147.22c
'Mex54/245'	8.19c	273.15c	3.67g	121.72g	108.34g
'B60267'	5.56f	183.82f	3.17h	105.23h	91.91h
'Co622'	9.97b	332.41b	4.75d	158.34d	144.45d
'C86/56'	7.89d	262.96d	4.22e	140.75e	136.11d
'C86/165'	8.94c	298.15c	5.42c	180.56c	171.30a
Generalmean	8.43	281.05	4.67	155.74	136.01
SE (±)	0.73	24.11	0.46	15.17	10.76
LSD (at 5%)	2.17*	72.29*	1.36*	45.48*	32.27*
CV %	12.14	12.14	13.77	13.77	11.19

sunlight interception causing shading over late and slow growing culm forming stalks, which affected their photosynthetic ability adversely suppressing their growth and ultimately leading to death of such culm forming stalks.

#### **Cane length, cane weight and number of internodes in cane at 12 months**

Cane length was more in varieties, 'Mex 54 245', 'B 60267', 'B 59212', 'Co 622', 'B 41227' and 'E 188 56' (3.78 m - 3.37 m), whereas it was less in varieties, 'N 14', 'N52 219' and 'C 86 165' and 'DB 228 57' (3.12 m - 3.16 m). In the present study, cane length in varieties, 'B41 227', 'N Co 334' and 'B 59 298' were in descending order which matched with plant height trend in these varieties at Tendaho Sugar Project reported by Tedesse *et al.* (2009). However, the descending order of cane length in varieties, 'N Co 334', 'N 53 216' and 'N 53 219' in present study differed from that Ethiopian sugar estate, Finchaa (Getanehet *et al.*, 2013).

Cane diameter at bottom was maximum in variety 'B52298' (3.10 cm) followed by 'B 59212', 'DB 228 57', 'B 60267' and 'Mex 54 245' (2.95 cm - 2.63 cm). Low cane thickness at bottom was in 'N 52 219', 'N Co 334', 'E 188 56' and 'B 4906' (2.16 cm - 2.26 cm). Cane thickness of varieties at the middle portion was less than that at the bottom. Cane diameter in middle portion in varieties, 'B 59212' and 'B60267' was 2.68 cm and 2.52 cm which indicated that varieties formed medium thick canes (Akhtar *et al.*, 2001). Other varieties with good thickness (medium) were 'B 52 298' and 'Mex 54 245', 'B 41 227', 'N 14', 'N 53 216' and 'DB 229 57' (2.43 cm - 2.31 cm). Medium thin canes were in varieties, 'C 86 56', 'C 86 165', 'CP 69 1059' and

'Co 622' (2.16 cm - 2.04 cm). Thin canes were in varieties, 'B4906', 'N 52 219' and 'E 188 56' (1.92 cm - 1.99 cm). Cane thickness at top portion was maximum in varieties, 'B 59 212' and 'B 60267' (2.81 cm - 2.43 cm) confirming medium thickness. Other varieties with good cane thickness at top were 'B 41227', 'DB 228 57' and 'Mex 54 245' (2.41 cm - 2.28 cm). Low cane thickness at top was in varieties, 'C 86 56', 'E 188 56', 'B4906', 'N Co334' and 'CP 69 1059', 'N53 219' and 'C86 165' (1.74 cm - 1.99 cm). The overall cane thickness by averaging cane thickness at bottom, middle and top portions was more in varieties, 'B 59212', 'B 60267' and 'B 59298' (2.82 cm - 2.59 cm) than the general mean thickness of the varieties (2.3 cm), which confirmed that the cane thickness in these was medium (2.5 - 3.0 cm). On the basis of overall thickness, thin canes were produced in varieties, 'B 4906' and 'E 188 56' (1.99 cm). The varieties with medium thin canes were 'N 52219' and 'N Co 334' (2.02 cm - 2.03 cm). In present study, cane thickness in 'N 52219' and 'N Co 334' was less than that at Finchaa Sugar Estate (2.48 and 2.40 cm) reported by Getanehet *et al.* (2013a). The difference in thickness could be due to narrow row spacing (1.0 m) in present study as compared wide row spacing (1.45 m) at Finchaa. At wider spacing cane thickness is generally increased due to decrease in inter plant competition (Yadav and Singh, 2007). Further, the differences in latitudes between Arba Minch (6° 04' N) and Finchaa (9° 31' N) and agro-climatic conditions could possibly have caused the differences in varieties for cane diameter.

Number of internodes in variety 'N Co 334' (27.75) was significantly higher than varieties, 'N 14', 'C 86 56', 'B 52 298', 'N 53 216' and 'CP 69 1059' (19.50 - 20.75). The average length

Table 3. Cane height (CH), cane diameter at bottom (CDB), middle (CDM) and top (CDT) portion, cane weight (CW) and number of internodes (NI) in cane stalk at 12 months in sugarcane varieties

Varieties	CH (m)	CDB (cm)	CDM (cm)	CDT (cm)	Mean (cm)	NI (No)
'B41227'	3.37c	2.49g	2.39d	2.41b	2.43d	24.17b
'DB228/57'	3.16c	2.72d	2.30d	2.33c	2.45c	22.50b
'N14'	3.12c	2.56f	2.38d	2.25d	2.40d	19.50c
'N52/219'	3.15c	2.16j	1.93g	1.97f	2.02g	22.75b
'NCo334'	3.36c	2.18i	2.01f	1.91f	2.03g	27.75a
'B52/298'	2.97d	3.10a	2.43c	2.24e	2.59b	20.58b
'E188/56'	3.37c	2.23i	1.99f	1.77g	1.99g	22.25b
'B59/212'	3.65c	2.95b	2.69a	2.81a	2.82a	21.85b
'B4906'	3.03c	2.26i	1.92g	1.80g	1.99g	21.92b
'CP69/1059'	3.18c	2.43g	2.15e	1.91f	2.16e	20.75b
'N53/216'	3.21c	2.58e	2.31d	2.25d	2.38d	20.25b
'Mex54/245'	3.78a	2.63e	2.39d	2.28d	2.43d	24.67b
'B60267'	3.69b	2.85c	2.52b	2.43b	2.60b	24.70b
'Co622'	3.40c	2.38h	2.04f	2.10f	2.17e	24.50b
'C86/56'	3.25c	2.51g	2.19d	1.74h	2.15f	19.75c
'C86/165'	3.15c	2.33h	2.15e	1.99f	2.16e	24.42b
Grand Mean	3.3	2.52	2.24	2.14	2.3	22.64
SE (±)	0.20	0.16	0.07	0.10	0.09	2.30
LSD (at 5%)	0.59*	0.47*	0.22*	0.30*	0.26*	6.91*
CV %	8.48	8.87	4.56	6.65	5.30	14.38

of internode in 'N Co 334' was 12 cm (cane length, 3.36 m/ internode number, 27.75 cm) which was less than variety 'N 14' (16 cm) with short cane length (3.12 m) and least number of internodes (19.50). As in the present study, 'N Co 334' had formed on average, one internode more than variety 'N 53 216' at Finchaa Sugar estate (Getaneh *et al.* 2013a) confirming the ability to form more number of internodes. However, the number of internodes in other varieties was around general mean (22.64).

#### **Cane weight, number of millable canes and estimated cane yield**

Cane weight was recorded more in varieties, 'B 59212', 'Mex 54 245B 6026', 'B 52298' and 'Co 622' (2.18 kg - 1.43 kg). Low cane weight was in varieties, 'E 188 56', '52 219', 'N Co 334', 'B 4906' and 'CP 69 105' (0.92 kg - 1.12 kg). The cane weight in latter varieties had generally the similar order of cane weight at Wonji- Shoa (Getaneh *et al.*, 2013). Cane weight is a varietal characteristic governed by the genotype of variety which generally depends on the cane diameter, cane height and the interior cane stalk contents and filling (Bell *et al.*, 2004).

Table 4. Cane weight, number of millable canes (NMC) and estimated cane yield (ECY) at 12 month (370 days) in sugarcane varieties

Varieties	Cane weight (kg)	NMC t/ha	ECY (t/ha)
'B41227'	1.35e	118.52d	162.04c
'DB228/57'	1.31e	114.82e	150.35c
'N14'	1.26e	125.00c	153.70c
'N52/219'	0.98f	138.89b	136.11d
'NCo334'	1.02f	141.67b	144.03d
'B52/298'	1.43b	112.97e	157.50c
'E188/56'	0.92g	139.82b	128.13d
'B59/212'	2.11a	102.78f	217.09a
'B4906'	1.07f	110.19e	117.19d
'Cp69/105'	1.12e	87.04g	97.99e
'N53/216'	1.38b	125.93c	174.67b
'Mex54/245'	1.64b	96.30f	158.54c
'B60267'	1.77b	83.65h	146.68d
'Co622'	1.38d	124.08c	172.93b
'C86/56'	0.97f	116.67d	113.35d
'C86/165'	1.02e	146.30a	147.99d
Grand Mean	1.29	117.79	148.98
SE ( $\pm$ )	0.14	9.33	20.07
LSD (at 5%)	0.41*	27.99*	60.18*
CV %	17.66	11.21	19.10

Millable canes at 12 month age were recorded significantly high in varieties, 'C 86 165', 'NCo 334', 'E 188 56', 'N 53219', 'N 52216', 'N 14', and 'Co 622' (146.30'000/ha - 124.67'000/ha). The trend of millable canes in varieties, 'N Co 334', 'B 52298', 'N 14' and 'B 41227' in the present study matched with that recorded at Ethiopian sugar estates at Tendaho, Metahara, Finchaa and Wonji- Shoa (Tedesse *et al.*, 2009; Ayele *et al.*, 2012; Ayele, *et al.*, 2014). The trend of millable canes in varieties,

'B 53 216', 'N Co 334' and 'B 52219' also matched with that observed at Finchaa Sugar Estate by Getaneh *et al.* (2013). Millable canes in varieties, 'E 188 56', 'DB 228 57', 'B 52298', 'B 4906', 'B 60267' and 'CP 69 1059' recorded in present study were in the same order except variety, 'B 4906' at Wonji- Shoa Sugar Estate (Getaneh *et al.*, 2013). Millable canes at 12 months were generally less than that recorded at 8 month age but of the same order. Reduction in number of millable with the advancement of age is commonly observed due to loss or death of some millable canes caused by shading, lodging uprooting and damage of old roots anchoring millable canes in the stool. The reduction in millable canes from the early formed cane stalks or tillers was observed by other workers (Tadesse *et al.*, 2009; Getaneh *et al.*, 2013a and Getaneh *et al.* 2013b). In terms of stalks numbers/m<sup>2</sup>, the average numbers of millable stalks at 8 month and 12 month age with row spacing of 1.0 m were 13.6/m<sup>2</sup> and 11.7/m<sup>2</sup> in present study, which was comparable to 12.5 stalks/m<sup>2</sup> at row spacing of 0.5 m in a study in Australia (Bull and Bull, 1996).

Estimated cane yield at 12 month was recorded maximum in variety 'B 59212' (217.09 t/ha) followed in varieties, 'N 52216', 'Co 622', 'B 41227', 'Mex 54 245', 'B 52298', 'N 14', and 'DB 228 57' (174.68 t/ha - 150.35 t/ha). Cane yield in descending order was numerically less than general mean (148.98 t/ha) in seven varieties, 'C 86 165', 'B 60267', 'N Co 334', 'N 52 219', 'E 188 56', 'B 4906' and 'C 86 56' (147.99 t/ha - 113.35 t/ha). Lowest estimated cane yield was in 'CP 69 1059' (97.99 t/ha). The level and order of estimated cane yield in some varieties in present study generally matched with that recorded at Tendaho, Metahara, Finchaa and Wonji-Shoa Sugar Estate, Ethiopia (Tedesse *et al.*, 2009; Ayele *et al.*, 2012, Getaneh *et al.*, 2013a and ; Getaneh *et al.*, 2013b and Ayele *et al.*, 2014).

The results on characterization of sugarcane varieties for bud sprouting, tillering, cane forming stalks and millable canes at 7 and 8 month age, cane yield components, cane length, cane thickness and cane weight, and millable canes at 12 month age indicated there were differences in varieties for these characters. Good cane yielding varieties may be evaluated for confirmation their performance and for selection of suitable varieties for plantation at Omo- kuraz sugar development project, southern Ethiopia.

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## Impact of date of sowing on manifestation of root yield and quality traits in sugarbeet (*Beta vulgaris* L.) under punjab conditions

GULZAR S SANGHERA<sup>1</sup>, LENIKA KASHYAP, VIKRANT TYAGI, RUPINDER PAL SINGH and B SHARMA

Punjab Agricultural University Regional Research Station, Kapurthala-144601, Punjab, India.

### ABSTRACT

The present study was conducted to assess the effects of different dates of sowing on yield and quality traits in sugarbeet (*Beta vulgaris* L.) under subtropical conditions in Punjab. The experiment was conducted using five sugarbeet genotypes viz; Calixta, Magnolia, Cauvery, Shubra and Indus grown in randomized block design over nine environments involving three sowing dates at PAU RRS Kapurthala, Punjab during *Rabi* season 2014-2015. Analysis of variance performed for various traits revealed highly significant differences among genotypes for initiation of root swelling, root length, root diameter, root fresh weight, root dry weight, juice purity, root yield and sugar yield. Significant differences among sugarbeet genotypes for traits like number of leaves at root swelling stage, root diameter, root fresh weight, root dry weight at harvest and root yield, sucrose (%), juice purity (%) and sugar yield were also observed. 15 October date of sowing had significant effect on traits like initiation of root swelling (DAS), whole plant weight, root dry weight, root yield and sugar yield. 30 October sowing had highest root fresh weight while sucrose (%) was highest on 15 November sowing. Highest means of dry root weight, sucrose (%) was recorded by genotype Calixta while genotype Magnolia recorded highest juice purity (%). The highest means of root fresh weight and root dry weight was recorded for 15 October sowing date. Root swelling initiation started earlier when sown on 15 November. However, 15 October sowing date was best suited for earlier root swelling, root yield and sugar yield while 15 November was best for quality parameters of sugarbeet in terms of sucrose (%) and juice purity (%). Based on these findings, the respective ideal genotypes for yield, yield related and quality traits regarding different dates of sowing can be exploited to realise maximum genetic potential of genotypes.

**Keywords:** Sugarbeet, germination, root yield, sucrose, juice purity.

Sugarbeet (*Beta vulgaris* L.) belongs to the family *Chenopodiaceae*, is considered as the second important sugar crop whose root contains high concentration of sucrose. It is commercially grown for sugar production, especially in temperate countries (Rashid 1999). Top fifteen sugarbeet producing countries are Russian Federation, Ukraine, United States of America, Germany, France, Turkey, China, Poland, Egypt, United Kingdom, Iran (Islamic Republic of), Belarus, Netherlands, Italy and Belgium. Sugarbeet is mainly produced in Europe and, to a lesser extent, in Asia and North America (Kumar and Pathak 2013). It is a crop of significant economic importance and it accounts for about 25% of worldwide sugar production (Draycott 2006).

Although sugarbeet is a temperate crop, some sugar beet genotypes that can be grown under tropical climatic conditions have been developed by private companies and hence, the beet is known as “tropical sugarbeet”. This tropical sugar beet is a short duration crop (5-6 months) with high sucrose content (14-20%) compared to sugarcane which is a long duration crop (12-14 months) with low sucrose (10-12%) content (Syngenta, 2004).

For India, sugarbeet is an introduced crop and few farmers are growing it in a limited area. As such it has good prospects

for bridging the gap between present sugar production and anticipated national sugar requirement. In addition to sugar, it provides valuable by-products like green beet tops and beet molasses which are of value as cattle feed and in fermentation industry. Therefore, in Northern belt of India, the possibility of cultivation can be explored being an important sugar crop that may supplement sugarcane crop for maintaining sugar industry of the states.

Punjab state has favorable climatic conditions where sugarbeet can be successfully cultivated. Though it is a short season *Rabi* crop (sown in October-November and harvested in April-May), its yield are equivalent to that of sugarcane. It has better tolerance to salinity and sequestration of heavy metals with threshold to salinity tolerance as high as 7 ds m<sup>-1</sup> (Katerji *et al.* 1997). Since, the sugarbeet crop matures in April-May, when the cane-crushing season is nearly over, it can extend the crushing season of sugar mills by nearly two months.

Improving sugarbeet yield and quality are the main goals of plant breeders to enhance sugar production in order to gradually bridge the gap between sugar consumption and production. Sugarbeet has emerged as a promising entity to be adopted in crop rotation as a winter crop not only in fertile soils, but also in poor, saline, alkaline and calcareous soils.

<sup>1</sup>Corresponding author E-mail: sangheragulzar@pau.edu

Hence sugarbeet is capable of occupying an important place in the sugar economy of the country (Iqbal and Saleem, 2015, Marshall *et al.* 2009 and Sun and Hughes, 1998). The sugarbeet growing was found to be profitable compared to the existing cropping systems in the post rainy season in Rajasthan, Punjab, Haryana, Maharashtra and North Karnataka (Kulkarni *et al.* 2013). Farmers are willing to experiment new crop options looking at the profitability of the crop especially in sugarcane growing areas and saline affected areas. For farmers, sugarbeet is important for three main reasons. First, it is a dependable cash crop; second, it ameliorates salt affected soils with promoting soil fertility through sound farming practices and third, the by-products.

Based on these facts and considering the economic value of the crop, we focused on the assessment of effect of dates of sowing on root yield and quality traits in sugarbeet genotypes to discern the feasibility of sugarbeet cultivation in subtropical conditions of Punjab.

#### MATERIALS AND METHODS

The present study was conducted at the PAU Regional Research Station, Kapurthala during *Rabi* 2014-2015 which represents the subtropical conditions of the country. The experimental material comprised of five sugarbeet genotypes/varieties ('Calixta', 'Magnolia', 'Cauvery', 'Shubra' and 'Indus') procured from different sources. All the varieties were sown in randomized block design (RBD) in a plot size of 36 m<sup>2</sup> having three replications with an inter-row and intra-row spacing of 75cm and 15 cm, respectively. All the cultural operations were followed to reach the ideal crop stand. Proper irrigation was also maintained to the crop to ensure avoidance of any water stressed condition. The data were collected on five randomly selected competitive plants and averaged for germination (%), initiation of root swelling (days), number of leaves at maximum growth stage, root length (cm), root diameter (cm), root fresh weight (kg), root dry weight (kg), root yield per (t/ha), Brix (%), sucrose (%), juice purity (%) and sugar yield (t/ha) were recorded. Brix (°) was measured from each plot from fresh roots using hand refractometer. Sucrose (%) was estimated in fresh samples of beet root by using saccharimeter according to the method described by AOAC (1995) and purity (%) in juice was computed by using the equation: Sucrose (%)/Brix (°) x 100.

#### STATISTICAL ANALYSIS

The mean values for all the yield related and quality traits were subjected to statistical analysis as per the analysis of variance for randomized plot design (Gomes and Gomez, 1984) using SAS software ver. 9.2 (SAS Institute Inc., 2003) and interpretations were made accordingly.

#### RESULTS & DISCUSSION

Various morphological and physical characteristics of five sugarbeet genotypes viz. 'Calixta', 'Magnolia', 'Cauvery', 'Shubra' and 'Indus' were recorded (Table 1). Genotypes 'Calixta', 'Shubra' and 'Indus' had green colored hypocotyls while 'Magnolia' and 'Cauvery' had light purple hypocotyls. Leaf color and vein color in all the genotypes were invariably of green color. Root color of all the genotypes was observed to be white. Initiation of visible root swelling among genotypes ranged from 35 ('Calixta') to 38 (Indus) days after sowing and number of leaves during this stage varied from 6.11 ('Cauvery') to 7.26 ('Indus'). It was reported that storage root development begins slowly at the age of two months, picks up speed at three months under sub tropical conditions these observations are in complete agreement with earlier study (Anonymous, 2010) correlated under temperate conditions. The genotypes differed among themselves with respect to number of leaves at maximum growth stage. The maximum number of leaves per plant was produced by genotype 'Indus' (18.52) while minimum by genotype 'Magnolia' (17.22). The results obtained for the recorded observations were in corroboration with the findings of Islam *et al.* (2012).

Analysis of variance with respect to sowing dates, genotypes and their interactions on root yield and quality parameters in sugarbeet is presented in Table 2. Perusal of data revealed significant differences among dates of sowing for manifestation of sugarbeet traits was significant for initiation of root swelling, root fresh weight, root dry weight, root yield and quality parameters like sucrose (%), juice purity and sugar yield. Analysis of variance also exhibited significant differences among sugarbeet genotypes for traits like number of leaves at root swelling stage, root diameter, root fresh weight, root dry weight, root yield, sucrose (%), juice purity and sugar yield. Mean sum of squares for interactive effect between date of sowing and genotypes were significant for four traits- root

Table 1. Morphological characters of sugarbeet genotypes used in present study

Genotypes	Hypocotyl color	Leaf color	Vein color	Root color	Initiation of root swelling (days)	No. of leaves at root swelling	No. of leaves at max. growth stage
'Calixta'	Green	Green	Green	White	34.89	6.93	17.60
'Magnolia'	Light purple	Green	Green	White	35.15	6.30	17.22
'Cauvery'	Light purple	Green	Green	White	36.19	6.11	18.48
'Shubra'	Green	Green	Green	White	35.85	6.59	17.81
'Indus'	Green	Green	Green	White	37.64	7.26	18.52

Table 2. Mean sum of squares for date of sowing and genotypes and their interactions in Sugarbeet

Traits	Mean Sum of Squares			
	Source of Variation	Date of Sowing (D)	Genotypes (G)	D X G
	d. f.	2	4	8
Germination (%)		1.40	29.21	12.65
Initiation of root swelling (days)		2.82**	19.80	7.89
No. of leaves at maximum growth stage		39.21	7.92	4.37
Root length (cm)		60.62	5.69	9.72
Root diameter (cm)		5.63	30.13*	6.09
Root fresh weight (kg)		30.94**	2.37**	0.48
Root dry weight (kg)		0.72**	0.51**	0.08**
Root yield (t/ha)		5605.05**	241.60**	522.07*
Brix (%)		19.07	5.89	1.78
Sucrose (%)		30.64**	5.80**	2.08*
Juice purity (%)		123.89**	29.94**	23.97
Sugar yield (t/ha)		71.21**	7.72	13.17**

dry weight, root yield, sucrose (%) and sugar yield. Germination forms the basis for optimum plant population necessary for securing better yield of any crop. Highest sugarbeet germination was observed in genotype 'Cauvery' (87.33%) (Table 3). Among the dates of sowing tested, 15 October exhibited highest germination (86.53%) over all the genotypes closely followed by 30 October (86.46%). The root swelling initiation among genotypes ranged from 34.89 to 37.04 with an average of 35.82 DAS, the genotype 'Calixta' being the earliest for root swelling and Indus being the last to initiate the root swelling (Table 3). 15 November favoured the root swelling initiation the most being the earliest at 34.11 DAS. All the genotypes were statistically at par for number of leaves at maximum growth stage ranging from 17.22 ('Cauvery') to 18.52 ('Indus'). Among the dates of sowing tested, 15 October

recorded the highest number of leaves at maximum growth stage (18.62) closely followed by 30 October sowing (18.44). Root length was the maximum at 15 October sowing (29.43 cm) while other two dates of sowing were statistically at par with each other having root length of 27.4 cm and 27.47 cm for 30 October and 15 November sowing, respectively. Among genotypes, root length ranged from 27.72 cm in 'Magnolia' to 30.84 cm in 'Indus'. The results obtained for this trait over locations were in corroboration with the studies of Abo El-Ghait (1993), who also reported that location and sowing variations had a significant effect on root length. The dates of sowing were statistically at par for root diameter. Of the sugarbeet genotypes tested, root diameter ranged from 9.11 cm to 9.98 cm. the genotype 'Calixta' recorded the maximum root diameter (9.98 cm) followed by 'Indus' (9.82 cm) and

Table 3. Mean performance of root yield and quality traits affected by date of sowing and genotypes in Sugarbeet

Traits	Date of Sowing			C.D. (p=0.05)	Genotypes					C. D. (p=0.05)
	15-Oct	30-Oct	15-Nov		'Calixta'	'Magnolia'	'Cauvery'	'Shubra'	'Indus'	
Germination (%)	86.53	86.46	86.2	N.S.	86.89	84.70	87.33	86.15	86.93	N.S.
Initiation of root swelling (DAS)	36.66	35.68	34.11	0.21	34.89	35.15	36.19	35.85	37.04	N.S.
No of leaves at maximum growth	18.62	18.44	16.91	N.S.	17.96	17.22	18.48	17.74	18.52	N.S.
Root length (cm)	29.43	27.4	27.45	N.S.	28.28	27.72	28.80	28.02	30.84	N.S.
Root diameter (cm)	9.65	9.64	9.45	N.S.	9.98	9.57	9.44	9.11	9.82	0.30
Root fresh weight (kg)	3.00	3.14	2.26	0.49	2.93	3.26	3.43	2.69	3.24	0.41
Root dry weight (kg)	0.91	0.74	0.66	0.25	0.92	0.86	0.81	0.65	0.62	0.21
Root yield (t/ha)	88.08	73.13	66.25	3.52	80.86	73.48	75.48	75.68	73.62	N.S.
Brix (%)	16.81	17.99	17.86	N.S.	17.71	16.73	17.73	17.81	17.82	N.S.
Sucrose (%)	14.19	14.47	15.73	0.63	15.43	14.31	15.39	15.31	15.23	0.21
Juice purity (%)	82.73	85.57	85.63	1.64	83.01	84.22	85.67	85.53	84.71	1.37
Sugar yield (t/ha)	12.53	10.52	10.22	0.99	11.96	10.59	11.17	10.96	10.76	N.S.

'Magnolia' (9.57 cm) (Table 3). Dates of sowing also had significant effect on root fresh weight. 30 October date of sowing recorded the highest root fresh weight (3.14 kg) followed by 15 October (3.0 kg) and least being the 15 November (2.26 kg) (Table 3). Therefore, the dates from 15 October to 30 October would be ideal for sowing of sugarbeet in Punjab to get the better yields. The superiority of sowing sugar beet on 30 October with respect to root fresh weight may be due to the suitable weather conditions during early growth stages of plant that had not only maximum growth of roots but also rapid growth and formation a good canopy able to make efficient photosynthesis. These results are in harmony with those earlier reported by different workers (Badawi 1985, Badawi *et al.* 1995 and Kandil *et al.* 2002). Variety 'Cauvery' recorded the highest root fresh weight of 3.43 kg followed by 'Magnolia' (3.26 kg) and 'Indus' (3.24 kg). Differential response of sugarbeet genotypes for root fresh weight has earlier been documented by Al-Jbawi and Entessar (2000).

There was also a significant effect of date of sowing on root dry weight. The maximum value of dry root weight was recorded for 15 October date of sowing (0.90 kg) while the minimum value of this trait was recorded for 15 November date of sowing (0.66 kg) (Table 3). This observation paved the way for the fact that 15 October date of sowing favours enhanced root dry weight. These results stood in harmony with those obtained by Badawi (1985) and Kandil *et al.* (2002) in sugarbeet. The maximum root dry weight was possessed by genotype 'Calixta' (0.92 kg) while the minimum root dry weight was exhibited by genotype 'Indus' (0.62 kg). The results recorded were in corroboration with those reported by Theurer (1979) and Hossain *et al.* (2015) in sugarbeet. The interaction between dates of sowing and genotypes also had significant effect on root dry weight. The 15 October date of sowing

produced the maximum root dry weight of 0.91 kg while 15 November date of sowing could only produce 0.61 kg of dry roots among all the genotypes (Table 4). The mean performance of genotype 'Calixta' was highest (0.92 kg) followed by 'Magnolia' (0.86 kg) while genotype 'Indus' had lowest root dry weight (0.62 kg) across all the dates of sowing. As already mentioned, the effect of interaction between locations and genotypes was significant on dry root weight. Root yield, being the economic part of sugarbeet, was favored by early sowing in such a way that 15 October date of sowing had the maximum root yield (88.08 t/ha) while 15 November date of sowing had the lowest root yield (66.25 t/ha). The genotype 'Calixta' recorded the maximum root yield of 80.86 t/ha followed by Shubra (75.68 t/ha) while the minimum (73.48 t/ha) was produced by Magnolia. The effect of interaction between sowing dates and genotypes was significant on root yield. The sowing of genotype 'Cauvery' on 15 October gave the highest root yield (102.08 t/ha) followed by 'Calixta' on same date (94.32 t/ha). Contrarily, lowest root yield was accompanied with 15 November date of sowing (Table 4). However, the genotype 'Cauvery' gave the lowest root yield (60.55 t/ha) when sown on 15 November. These results showing differential behavior of locations, dates of sowing and genotypes and their interactions are in agreement with those reported by various workers like Badawi (1985), EL-Kassaby and Leilah (1992 b), Badawi *et al.* (1995), Ghonema (1998), Abdou (2000), Abo-Salama and EL-Sayiad (2000) and Kandil *et al.* (2002) in sugarbeet.

To talk of quality traits evaluated in sugarbeet, Brix (%) was found unaffected by any sources of variation tested. The data appended in Table 2 clearly showed that the performance of dates of sowing and genotypes was significantly variable for sucrose (%). Among the dates of sowing, 15 November sown

Table 4. Mean performance of different traits for interaction between date of sowing and genotypes in Sugarbeet

Traits	DOS (D)	Genotypes (G)					Mean	C. D. (p=0.05)		
		'Calixta'	'Magnolia'	'Cauvery'	'Shubra'	'Indus'		D	G	D X G
Root dry weight (kg)	15-Oct	1.16	1.04	0.78	0.85	0.72	0.91	0.25	0.21	0.31
	30-Oct	0.90	0.81	0.89	0.54	0.59	0.75			
	15-Nov	0.66	0.69	0.72	0.52	0.47	0.61			
	<b>Mean</b>	<b>0.91</b>	<b>0.85</b>	<b>0.79</b>	<b>0.64</b>	<b>0.62</b>	<b>0.75</b>			
Root yield (t/ha)	15-Oct	94.32	92.54	102.08	72.96	78.53	88.08	3.52	2.85	1.91
	30-Oct	79.67	72.30	64.58	74.22	74.94	73.14			
	15-Nov	68.23	71.76	60.55	63.46	67.26	66.25			
	<b>Mean</b>	<b>80.74</b>	<b>78.87</b>	<b>75.73</b>	<b>70.21</b>	<b>73.58</b>	<b>75.82</b>			
Sucrose (%)	15-Oct	13.56	14.67	14.13	13.51	13.87	13.95	0.63	0.21	0.76
	30-Oct	14.76	13.84	13.84	13.94	13.51	13.98			
	15-Nov	14.18	14.49	14.24	14.49	14.18	14.32			
	<b>Mean</b>	<b>14.16</b>	<b>14.33</b>	<b>14.07</b>	<b>13.98</b>	<b>13.85</b>	<b>14.08</b>			
Sugar yield (t/ha)	15-Oct	13.52	12.19	15.49	10.68	10.8	12.53	0.99	N.S.	1.21
	30-Oct	11.95	10.18	9.11	10.52	10.78	10.51			
	15-Nov	10.69	11.04	9.41	10.09	9.91	10.22			
	<b>Mean</b>	<b>12.05</b>	<b>11.14</b>	<b>11.34</b>	<b>10.43</b>	<b>10.49</b>	<b>11.08</b>			

sugarbeet had maximum sucrose (15.73%) followed by 30 October (14.47%) and 15 October (14.19%). Therefore, it can be concluded that early sowing of sugarbeet from 15 October to 30 October results in low sucrose accumulation while sowing on 15 November shows promising results for enhancement of sucrose (%) in sugarbeet. Similar results are in confirmation with earlier studies by Badawi (1985), Ghonema (1998), and Kandil *et al.* (2002). Regarding the effect of genotypes on sucrose, it was observed that genotype 'Calixta' had the highest sucrose (15.43%) closely followed by 'Cauvery' (15.39%), and 'Shubra' (15.31%). Considering the interaction between dates of sowing and genotypes, it was observed that genotype 'Magnolia' possessed the highest mean sucrose (14.35%) while the genotype 'Indus' had lowest sucrose of 13.05% over the dates of sowing (Table 4). Delayed sowing of sugarbeet on 15 November favored the juice purity than earlier sowing. Among the genotypes tested, 'Cauvery' recorded the highest juice purity (85.67%) followed by 'Shubra' (85.53%) while the lowest juice purity was found for 'Calixta' (83.00%). Similar findings are acceptable with those supported by Leilah and Nasr (1992), Ghonema (1998) and Abo-Salama and EL-Sayiad (2000) in sugarbeet. Sugar yield is considered as the most important quality trait in sugarbeet. The final sugar recovery content in sugarbeet determines the amount of sugar to be recovered from sugarbeet. Out of different sowing dates examined, 15 October sowing proved to be highly beneficial to get maximum sugar yield of 12.53 (t/ha) followed by 30 October sowing, where 10.52 (t/ha) sugar yield was obtained. The desirable effect of sowing sugarbeet on 15 October on sugar yield might be attributed to the seasonable environmental conditions during this period. These results are in agreement with evaluation of yield and quality components in sugarbeet by Badawi (1985), EL-Kassaby and Leilah (1992 b), Badawi *et al.* (1995), Ghonema (1998), Abdou (2000), Abo-Salama and EL-Sayiad (2000) and Kandil *et al.* (2002).

The effect of interaction between dates of sowing and genotypes was also significant on sugar yield. Genotype 'Calixta' had the maximum sugar yield of 13.52 t/ha for 15 October date of sowing while 'Cauvery' genotype had lowest sugar yield of 9.11 t/ha for 30 October date of sowing (Table 4). The distribution pattern for trait root yield (t/ha), sucrose (%) and sugar yield (t/ha) effected by interactions among dates of sowing and genotypes is presented in Fig. 1, Fig. 2 and Fig. 3, respectively.

### CONCLUSION

15 October date of sowing in sugarbeet had significant effect on traits like initiation of root swelling (DAS), whole plant weight, root dry weight, root yield and sugar yield. 30 October sowing had highest root fresh weight while sucrose (%) was highest on 15 November sowing. Highest mean root dry weight, sucrose (%) was recorded by genotype 'Calixta' while genotype 'Magnolia' recorded highest juice purity (%).

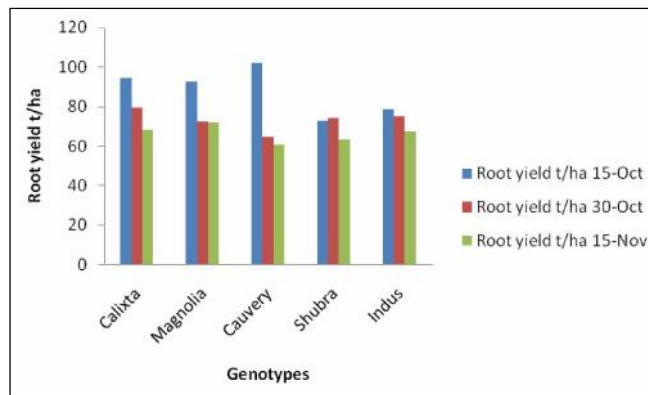


Fig. 1. Root yield (t/ha) influenced by interaction between genotypes and date of sowing in Sugarbeet

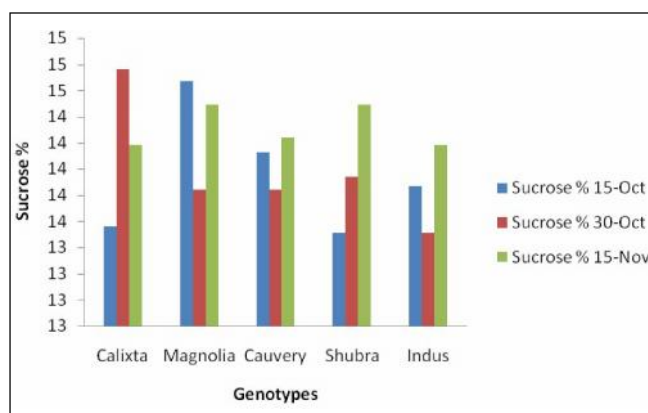


Fig. 2. Sucrose (%) influenced by interaction between genotypes and date of sowing in Sugarbeet

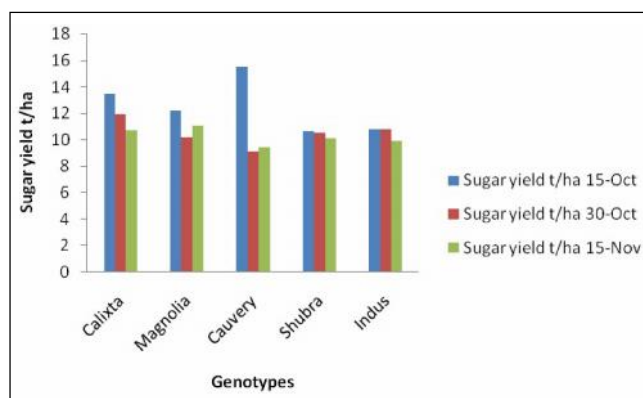


Fig. 3. Sugar yield (t/ha) influenced by interaction between genotypes and date of sowing in Sugarbeet

The highest means of root fresh weight and root dry weight was recorded for 15 October sowing date. Root swelling initiation started earlier when sown on 15 November. However, 15 October sowing date was best suited for earlier root swelling, root yield and sugar yield while 15 November was the best for quality parameters of sugarbeet in terms of sucrose (%) and juice purity (%). Based on these findings, the ideal genotypes

with respect to favorable dates of sowing can be put to use for maximum exploitation of genetic potential with respect to yield and quality traits in sugarbeet in different regimes.

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## Multivariate technique in sugarcane yield forecast

S R KRISHNA PRIYA<sup>1</sup>, K K SURESH<sup>2</sup> and P K BAJPAI<sup>3</sup>

<sup>1</sup> Assistant Professor, Department of Statistics, PSG College of Arts and Science, Coimbatore -14

<sup>2</sup> Professor and Head, Department of Statistics, Bharathiar University, Coimbatore

<sup>3</sup> Retd. Principal Scientist, IISR, Lucknow

### ABSTRACT

Reliable forecasts of crop production, before harvest constitutes, is a problem of topical interest. Such forecasted information is a requisite of government organizations, agro-based industries, traders and agriculturists. In the present study sugarcane yield forecast has been done using discriminant analysis. In discriminant analysis, the discriminant scores are calculated from discriminant function. Yield forecast models are built using these discriminant scores as independent variable in place of weather variables thus reducing number of variables to avoid multicollinearity. For the yield forecast, three models have been fitted using discriminant scores namely linear, quadratic and cubic. The goodness of fit of the fitted models was tested using  $R^2$ , MAE, MSE and RMSE values. The quadratic model performed better based on the above values among fitted models.

**Key words :** Sugarcane, Multivariate technique

Forecasting is a scientific technique which involves systematic use of endogenous and exogenous parameters to foretell future. The technique is used for governments' policy decisions in regard to procurement, distribution, buffer-stocking, import-export, price fixation and marketing of agricultural commodities. The information is used for operations planning of agro-based industries, traders and agriculturists. Forecasts and estimates of yield of commercial crops like sugarcane, cotton or jute are of considerable importance to trade and industry, because availability of raw materials during the season is the basis of all calculations of manufacturing processes.

Several studies have been carried out in past to develop suitable forecast models for various crops using multiple-regression technique (Khatri and Patel 1981; Mandal and Kar 1993; Werker and Jaggard 1998; Mall and Gupta 2000; Kandiannan *et al.* 2002a, 2002b). Wheat yield has been forecasted using weather variables (Khistaria *et al.* 2004; Varmola *et al.* 2004a, 2004b). Historical data on weather variables from different agro-climatic zones have been used for developing models for prediction of coconut yield (Kumar *et al.* 2009).

For sugarcane crop, studies have been carried out in the past using multiple regression technique (Jha *et al.* 1981; Chandrahas *et al.* 1983; Singh and Bapat 1988). Plant biometrical characters have been used as independent variables in these studies.

The use of weather variables as such involves multicollinearity among the variables which would inflate the variances of regression coefficients. It has been observed that regressions based on different subsets of data produce very different results, raising questions of model stability. Multi-

collinearity in the data causes serious problems in estimation, prediction and interpretation. Further the estimated regression coefficient may be unrealistic in magnitude or sign.

To overcome the above drawbacks in the present study, the yield forecast model has been developed using discriminant scores in the place of weather variables in order to avoid multi-collinearity.

### MATERIALS AND METHODS

The present study has been conducted at Coimbatore district. The selected predictor variables in this study are:  $X_1$  – Maximum Temperature,  $X_2$  – Minimum Temperature,  $X_3$  – Relative humidity in the Evening,  $X_4$  – Dry bulb in the Evening,  $X_5$  – Wet bulb in the Evening,  $X_6$  – Evaporation,  $X_7$  – Solar radiation for period of 24 years has been collected from weather station located at Sugarcane Breeding Institute, Coimbatore.

The sugarcane yield (tonnes/hectare) figures of Coimbatore district for a period of 20 years (1981-2004) have been used as dependant variables for developing the models. The yield figures which are used as dependent variable have been collected from Season and Crop Report, issued by State Government of Tamilnadu.

The data for a period of 20 years (1981-2000) has been used in developing forecast models and remaining four years (2001-2004) data has been used for validation of models.

### Discriminant Analysis

Discriminant analysis is multivariate techniques which study the differences between two or more groups of objects with respect to several variables simultaneously. The basic prerequisites for applying discriminant analysis are that two are



more groups exist which differ with respect to several variables and that these variables are measured at interval or ratio level. Discriminant analysis is helpful to analyze differences between groups and providing means of classifying any object into groups with which it is most closely associated. Further, analysis also helps us to infer relative importance of each characteristic (variables) in discriminating between different groups in population.

### Terminologies

(i) *Linear Discriminant Function*: The linear discriminant function is given by:

$$Z = W_1 X_1 + W_2 X_2 + \dots + W_n X_n \quad \dots(2.1)$$

where,

$Z$  = Discriminant score

$W_i$  = Discriminant weight associated with the  $i^{th}$  independent variable

$X_i$  =  $i^{th}$  independent variable.

It has been assumed that population covariance matrices are equal and have full rank. If the assumptions of equal covariance matrices are rejected one could use quadratic discriminant function for classification purposes. It has been found that for small sizes the performance of linear discriminant function is superior to quadratic discriminant function as number of parameters that need to be estimated for quadratic discriminant function is nearly doubled.

(ii) *Discriminant Score*: Discriminant function is used to define Discriminant score which is also referred to as  $Z$  score. Discriminant score is calculated by multiplying each variable values with their corresponding weights and by adding those products together get the discriminant scores which are obtained for each individual.

(iii) *Cutting Score or Cutoff Value*: Cutoff value is the criterion (score) under which each individual's discriminant score is judged to determine into which group the individual is classified.

(iv) *Discriminant Weight*: Discriminant weight is also called discriminant coefficient. Its value is determined by a variable structure for original variable. Independent variables having large discriminatory power has larger weights and vice versa.

(v) *Discriminator Variables*: Variables providing best discrimination between various groups are called discriminator variables.

### Two Groups Discriminant Analysis

Discriminant analysis has the following objectives:-

- Selection of discriminator variables.
- Development of discriminant function.
- Classification of the future observations.

(i) *Selection of Discriminator Variables*: The initial step in discriminant analysis is to assess the significance of discriminating variables and also to know whether the selected

discriminating variables significantly differentiate between two groups or not. The statistical test for testing the difference between means of two groups is Wilks'  $\Lambda$  test statistic. To assess the statistical significance of Wilks' test, it is converted into an F-ratio in case of an individual variable. Chi square statistic is used for approximation of Wilks' in case if there is more than one discriminator variable.

(ii) *Development of Discriminant Function*: The objective of discriminant analysis is to maximize between groups and within group sum of squares ratio that results in best discrimination between groups. This is done by identifying a linear combination  $Z$  such that it results in best discrimination between the various groups where  $Z$  is referred to as Linear Discriminant Function. The projection of a point on to the discriminant function is called Discriminant Score.

Let the linear combination or discriminant function that forms the new variable be

$$Z = w_1 x_1 + w_2 x_2 \quad \dots(2.2)$$

where  $Z$  is the discriminant function and  $w_1$  and  $w_2$  are weights assigned to the two variables. The objective of discriminant analysis is to identify the weights  $w_1$  and  $w_2$  such that,

$$\} = \frac{SSB}{SSW} \quad \dots(2.3)$$

is maximized where  $SSB$  is the pooled between groups sum of squares and  $SSW$  is the pooled within group sum of squares.  $SSB$  is obtained by pooling  $SSB$  obtained for each of the  $j^{th}$  variable,

$$SSB_j = n_1 (\bar{x}_{j1} - \bar{x}_j)^2 + n_2 (\bar{x}_{j2} - \bar{x}_j)^2$$

where  $n_1$  and  $n_2$  is number of observations in group 1 and group 2,  $\bar{x}_{j1}$  and  $\bar{x}_{j2}$  are means of  $j^{th}$  variable ( $j=1,2$ ) in first

and second groups,  $\bar{x}_j$  is the mean of the  $j^{th}$  variable for whole data. Within group sum of squares is obtained by adding the squares of observations of the groups. The discriminant function given by Equation (2.2) is obtained by maximizing Equation (2.3) and it is referred to as Fisher's linear discriminant function.

(iii) *Classification of the Future Observations*: One of the objectives of discriminant function is to classify observations into predefined groups. Even though classification is a separate procedure from discrimination sometimes it is also used as a part of the discriminant analysis. The classification of observations is done by using discriminant scores. Figure 2.1 represents a one dimensional plot of the discriminant scores commonly referred to as a plot of observations in discriminant space. First the discriminant space is divided into two mutually exclusive and collectively exhaustive regions,  $R_1$  and  $R_2$ . As there is only one discriminant score, then consequently, a point will divide the one dimensional space into two regions

and that value of the discriminant score is called the cutoff value. After which discriminant score is plotted in the discriminant space and classified as most admired or least admired if computed discriminant score falls in region  $R_1$  or  $R_2$  or observations are classified as most admired and least admired if the computed discriminant score is greater than or less than the cutoff value.

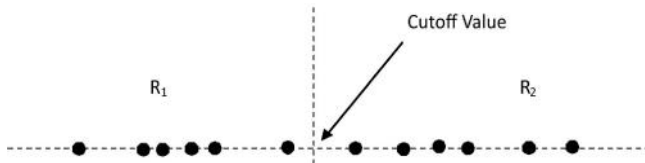


Fig. 2.1 One Dimensional Plot for Discriminant Scores

**Fisher’s Linear Discriminant Function**

In deriving the discriminant function, multivariate observation  $X$  is transformed into univariate observation  $\lambda$  such that  $\lambda$ ’s derived from different populations are separated as much as possible. Linear combinations of  $X$  are taken to create  $\lambda$ ’s because they are simple functions of  $X$  to be handled easily. This approach does not assume that the populations are normal but assumes that the population covariance matrices of different populations are equal.

Let  $X$  is a  $p \times 1$  random vector whose variance–covariance matrix is given by  $\Sigma$  and the total *SSCP* (it is the sum of squares cross product matrix and it is obtained by summarizing the sum of squares and the sum of the cross products in a matrix; this matrix is computed by multiplying the total covariance matrix by its degrees of freedom) matrix by  $T_{p \times p}$ . Let  $\lambda$  be a  $p \times 1$  vector of weights. The discriminant function will be then given as,

$$\lambda = X' \lambda \quad \dots(2.4)$$

The sum of squares of resulting discriminant scores will be given as

$$\lambda' \lambda = (X' \lambda)' (X' \lambda) = \lambda' X X' \lambda = \lambda' T \lambda, \quad \dots(2.5)$$

where  $T = X X'$  is the total *SSCP* matrix for the  $p$  variables.

Since

$$T = B + W$$

where,  $B$  and  $W$  are, the between groups and within group *SSCP* matrices (these matrices are obtained by multiplying the pooled between groups covariance matrix and pooled within groups covariance matrix by their corresponding degrees of freedom) for the  $p$  variables. Equation (2.5) is written as

$$\lambda' \lambda = \lambda' (B + W) \lambda = \lambda' B \lambda + \lambda' W \lambda \quad \dots(2.6)$$

In Equation (2.6),  $\lambda' B \lambda$  and  $\lambda' W \lambda$  are between groups and within group sum of squares for the discriminant score  $\lambda$ . The

objective of discriminant analysis is to estimate the weight vector,  $\lambda$  of discriminant function given by Equation (2.4) such that

$$\lambda = \frac{\lambda' B \lambda}{\lambda' W \lambda} \quad \dots(2.7)$$

is maximized. The vector of weights  $\lambda$  is obtained by differentiating  $\lambda$  with respect to  $\lambda$  and equating to zero. That is

$$\frac{\partial \lambda}{\partial \lambda} = \frac{2(B\lambda)(\lambda' W \lambda) - 2(\lambda' B)(W\lambda)}{(\lambda' W \lambda)^2} = 0$$

Now, dividing throughout by  $\lambda' W \lambda$  (as  $\lambda' W \lambda$  is a positive definite quadratic form and  $\lambda' W \lambda > 0 \forall \lambda, \lambda$  is non null)

$$\frac{2(B\lambda) - 2 \frac{(\lambda' B \lambda)}{(\lambda' W \lambda)} (W\lambda)}{(\lambda' W \lambda)} = 0$$

$$\text{or } \frac{2(B\lambda - \lambda' W \lambda)}{(\lambda' W \lambda)} = 0 \quad [ \text{as } \lambda = \frac{\lambda' B \lambda}{\lambda' W \lambda} ]$$

$$(B - \lambda' W) \lambda = 0$$

$$(W^{-1} B - \lambda' I) \lambda = 0 \quad \dots(2.8)$$

Equation (2.8) is a system of homogeneous equations and for a non trivial solution

$$|W^{-1} B - \lambda' I| = 0 \quad \dots(2.9)$$

That is the problem reduces to finding eigenvalues and eigenvectors of a non symmetric matrix,  $W^{-1} B$ , with eigenvectors giving the weight matrix for forming discriminant function.

For two group’s case, Equation (2.8) is further simplified. The population between groups *SSCP* matrix obtained from the sample between groups matrix which is defined as,

$$B_s = \sum_{i=1}^g n_i (\bar{x}_i - \bar{x})(\bar{x}_i - \bar{x})'$$

where  $n_i$  is the number of units in the corresponding group and  $g$  is the number of groups and  $\bar{x}_i$  is the mean vector of the corresponding group and  $\bar{x}$  is the over all mean vector of the groups.

Now  $B$  for two group’s case is obtained from  $B_s$  in the following way, in the two group’s case  $B_s$  is denoted as  $B$ ,

$$B = n_1 (\bar{x}_1 - \bar{x})(\bar{x}_1 - \bar{x})' + n_2 (\bar{x}_2 - \bar{x})(\bar{x}_2 - \bar{x})'$$

or

$$\begin{aligned}
 B &= n_1 \left( \bar{\mu}_1 - \frac{n_1 \bar{\mu}_1 + n_2 \bar{\mu}_2}{n_1 + n_2} \right) \left( \bar{\mu}_1 - \frac{n_1 \bar{\mu}_1 + n_2 \bar{\mu}_2}{n_1 + n_2} \right)' \\
 &+ n_2 \left( \bar{\mu}_2 - \frac{n_1 \bar{\mu}_1 + n_2 \bar{\mu}_2}{n_1 + n_2} \right) \left( \bar{\mu}_2 - \frac{n_1 \bar{\mu}_1 + n_2 \bar{\mu}_2}{n_1 + n_2} \right)' \\
 B &= \frac{n_1}{(n_1 + n_2)^2} (n_1 \bar{\mu}_1 + n_2 \bar{\mu}_2 - n_1 \bar{\mu}_1 - n_2 \bar{\mu}_2)(n_1 \bar{\mu}_1 + n_2 \bar{\mu}_2 - n_1 \bar{\mu}_1 - n_2 \bar{\mu}_2)' \\
 &+ \frac{n_2}{(n_1 + n_2)^2} (n_1 \bar{\mu}_2 + n_2 \bar{\mu}_2 - n_1 \bar{\mu}_2 - n_2 \bar{\mu}_2)(n_1 \bar{\mu}_2 + n_2 \bar{\mu}_2 - n_1 \bar{\mu}_2 - n_2 \bar{\mu}_2)' \\
 B &= \frac{n_1 n_2^2}{n_1 + n_2} (\bar{\mu}_1 - \bar{\mu}_2)(\bar{\mu}_1 - \bar{\mu}_2)' \\
 &+ \frac{n_1 n_2^2}{n_1 + n_2} (\bar{\mu}_2 - \bar{\mu}_1)(\bar{\mu}_2 - \bar{\mu}_1)' \\
 \text{or } B &= \frac{n_1 n_2 (n_1 + n_2)}{(n_1 + n_2)^2} (\bar{\tau}_1 - \bar{\tau}_2)(\bar{\tau}_1 - \bar{\tau}_2)' \\
 \text{or } B &= \frac{n_1 n_2}{n_1 + n_2} (\bar{\tau}_1 - \bar{\tau}_2)(\bar{\tau}_1 - \bar{\tau}_2)' \quad \dots(2.10)
 \end{aligned}$$

where  $\bar{\tau}_1$  and  $\bar{\tau}_2$ , are  $p \times 1$  vectors of means for group 1 and group 2.

$$c = \frac{n_1 n_2}{(n_1 + n_2)'}$$

$\bar{\tau}_1$  and  $\bar{\tau}_2$  are denoted as  $\tau_1$  and  $\tau_2$  and also let, then

Equation (2.10) reduces to

$$B = c(\tau_1 - \tau_2)(\tau_1 - \tau_2)'$$

Therefore the equation (2.8) is written as

$$W^{-1}c[(\tau_1 - \tau_2)(\tau_1 - \tau_2)' - \{I\}X]X = 0$$

$$W^{-1}c(\tau_1 - \tau_2)(\tau_1 - \tau_2)'X = \{X\}$$

$$\frac{c}{\{X\}} W^{-1}c(\tau_1 - \tau_2)(\tau_1 - \tau_2)'X = X \quad \dots(2.11)$$

Now since  $(\tau_1 - \tau_2)'X$  is a scalar. Equation (2.11) is written as

$$X = kW^{-1}(\tau_1 - \tau_2), \quad \dots(2.12)$$

where  $k = \frac{c}{\{X\}}(\tau_1 - \tau_2)'X$  is a scalar so it is a constant. Since

the within group variance covariance matrix,  $\Sigma_w$  is proportional to  $W$  and it is assumed that  $\Sigma_1 = \Sigma_2 = \Sigma_w = \Sigma$ , Equation (2.12) is also written as

$$X = k \Sigma^{-1}(\tau_1 - \tau_2) \quad \dots(2.13)$$

Assuming a value one for the constant  $k$ , Equation (2.13) is written as

$$X = \Sigma^{-1}(\tau_1 - \tau_2)$$

or

$$X' = (\tau_1 - \tau_2)' \Sigma^{-1} \quad \dots(2.14)$$

The discriminant function given through Equation (2.14) is Fisher's discriminant function. It is obvious that different values of constant  $k$  give different values for  $X$  and hence the absolute weights of discriminant function are not unique. The weights are unique only in relative sense.

### Evaluating the Significance of Discriminating Variables

The first step in discriminant analysis is to assess the significance of discriminating variables and also to know whether selected discriminating variables significantly differentiate between two groups or not. The statistical test for testing difference between the means of two groups is as follows. The null hypothesis and the alternative hypothesis for each discriminating variable are:

$$H_0: \tau_1^0 = \tau_2^0$$

$$H_1: \tau_1^0 \neq \tau_2^0$$

where  $\tau_1$  and  $\tau_2$  are the means of single variable for group 1 and group 2. This hypothesis is also be tested using an independent sample t- test. Alternatively Wilks'  $\Lambda$  test statistic is used. Wilks' is computed using the following formula:

$$\Lambda = \frac{SS_W}{SS_T} \quad \dots(2.15)$$

where  $SS_W$  (pooled within sum of square matrix) is obtained from the  $SSCP_p$  matrix, which in turn is obtained by adding respective sum of squares and sum of cross products of respective groups and  $SS_T$  (total sum of square matrix) is obtained from  $SSCP_t$  matrix which is obtained by multiplying

$S_t$  by total degrees of freedom  $(n_1+n_2-1)$ . Smaller the value of

$\Lambda$ , greater the probability that null hypothesis will be rejected and vice versa. To assess the statistical significance of the Wilks' test, it is converted into an F-ratio using the following transformation

$$F = \left( \frac{1-\Lambda}{\Lambda} \right) \left( \frac{n_1 + n_2 - p - 1}{p} \right) \quad \dots(2.16)$$

Given the null hypothesis is true, F ratio follows F-distribution with  $p$  and  $(n_1+n_2-p-1)$  degrees of freedom.

**Selection of Discriminator Variables and Determination of Number of Discriminant Functions**

Since discriminant analysis involves the inversion of within group matrices, accuracy of computations is severely affected if matrices are singular or near singular (i.e. some of the discriminator variables are highly correlated or are linear combinations of other variables). The tolerance level provides a control for desired amount of computational accuracy or the degree of multicollinearity one is willing to tolerate. The tolerance of a variable is equal to  $1 - R^2$ , where  $R^2$  is the square of multiple correlation coefficients between variable and other variables in discriminant function. Higher the value of  $R^2$ , lower the value of tolerance and vice versa. That is, the tolerance is a measure of amount of multicollinearity among discriminator variables. If tolerance of a given variable is less than the specified value, then the variable is not included in discriminant function. The maximum number of discriminant functions that are computed is equal to minimum of  $G-1$  and  $p$ , where  $G$  is the number of groups and  $p$  is the number of variables. As the number of groups is two, only one discriminant function is possible.

**Statistical Significance of the Discriminant Function**

Differences in the means of two groups for individual discriminator variable are tested using univariate Wilks'  $\Lambda$  test statistic in Section 2.1.4. In case of more than one discriminator variable the differences between two groups for all variables are tested jointly or simultaneously. This test has following null and alternative hypothesis:

$$H_0 : \begin{pmatrix} \mu_1^0 = \mu_2^0 \\ \mu_1^1 = \mu_2^1 \end{pmatrix}$$

$H_1 : H_0$  is not true

The test for this multivariate hypothesis is a direct generalization of the univariate Wilks'  $\Lambda$  statistic is given as,

$$\Lambda = \frac{|SSCP_w|}{|SSCP_t|} \dots (2.17)$$

where  $\Lambda$  represents the determinant of ratio of within group sum of square cross product matrix and total sum of square cross product matrix. Wilks'  $\Lambda$  is approximated as a Chi square statistic using the following transformation (where  $g$  is the number of groups and  $p$  is the number of variables)

$$t^2 = -[n - 1 - (p + g) / 2] \ln \Lambda \dots (2.18)$$

The  $t^2$  statistic is distributed as a Chi-square with  $p \times (g-1)$  degrees of freedom. Since discriminant function is a linear combination of the discriminator variables, it is concluded that discriminant function is statistically significant. That is the

means of discriminant scores of two groups are significantly different.

**Yield Forecast Model Using Discriminant Scores**

Yield forecast models have been developed for using discriminant scores calculated from discriminant function as independent variable and cane yield as dependent variable.

**RESULTS AND DISCUSSION**

In the present study two groups are identified namely 'years with lower yield' (group I:  $n_1=9$ ) and 'years with higher yield' (group II:  $n_2=10$ ) as dependent variables for developing discriminant function. Results of the discriminant analysis are presented below. Mean values of explanatory variables belonging to lower and higher yield groups are presented in Table 1 Out of the total period taken for study, nine years are identified as years having lower yield and remaining ten years as years having higher yield. Table 2 shows the results of test of equality for group means using F test. Among seven variables used for study, dry bulb measurements are found to be significant at 5% level. The canonical discriminant function is fitted and given in equation 3.1.

Table 1. Group Mean Score

Explanatory variables	Mean Value	
	Years with Lower yield (Gr.I) ( $n_1=9$ )	Years with Higher yield (Gr.II) ( $n_2=10$ )
$X_1$	32.952	32.738
$X_2$	22.822	22.879
$X_3$	48.728	51.594
$X_4$	32.098	31.575

Explanatory Variables	Mean Value	
	Years with Lower yield (Gr.I) ( $n_1=9$ )	Years with Higher yield (Gr.II) ( $n_2=10$ )
$X_5$	22.293	22.417
$X_6$	6.318	6.277
$X_7$	270.902	282.993

**Calculation of Discriminant Score**

$$Y = 48.521 - 0.133X_1 + 0.728X_2 + 0.403X_3 - 2.99X_4 - 0.495X_5 + 3.536X_6 + 0.011X_7 \dots (3.1)$$

**Test Functions**

- Eigen value: 2.072
- Percentage of variation explained: 100
- Wilks Lambda: 0.326
- Chi-square: 15.15; DF= 7;  $p = 0.03$
- Canonical Correlation: 0.82

Table 2. Test for Equality of Group Means

Explanatory variables	Wilks Lambda	F	Sig
		(df=1,18)	
X <sub>1</sub>	0.984	0.281	0.603
X <sub>2</sub>	0.998	0.042	0.839
X <sub>3</sub>	0.868	2.595	0.126
X <sub>4</sub>	0.759	5.393*	0.033
X <sub>5</sub>	0.994	0.108	0.746
X <sub>6</sub>	0.999	0.025	0.875
X <sub>7</sub>	0.994	0.100	0.756

(Univariate ANOVA's)

\*Significant at 5% level

The results of test function indicate that chi-square test is significant at 1% level. Further the Wilks Lambda and Canonical Correlation values obtained are satisfactory. The discriminant function fitted is able to explain 100% of variation produced by dependant variable.

#### Classification of Individual

Using the discriminant function fitted and observed predictor variables of yield, yield is classified and correct percentage of classification is presented below.

Table 3. Determination of Percentage of correct classification by using Discriminant function on the data.

Yield	Using the Dis.Func. Fitted observations are classified as		Total
	Years with lower yield	Years with higher yield	
Years with lower	8	1	9
Years with higher	2	8	10

From Table 3 it is observed that out of 9 years with lower yield, 8 years (88.8%) are correctly classified; out of 10 years with higher yield, 8 years (80%) are correctly classified. Thus out of total 19 years, 16 years are correctly classified. Hence the percentage of correct classification is 84.2%. The percent of correct classification of yield using observed data clearly indicates adequacy of model in discriminating between two groups.

#### Relative Importance of Predictor Variable

The relative importance of each predictor variable in discriminating between two groups is obtained and the results are presented in Table 4 as given below.

Table 4. Relative Importance of Ratios in Discriminating Between Groups

Variables	Importance value of the Variable	Relative Importance	Rank
X <sub>1</sub>	0.03	1.05	7
X <sub>2</sub>	0.04	1.51	6
X <sub>3</sub>	1.16	42.36	2
X <sub>4</sub>	1.57	57.42	1
X <sub>5</sub>	0.06	2.24	5
X <sub>6</sub>	0.14	5.28	3
X <sub>7</sub>	0.14	5.06	4

Among the variables under study, dry bulb measurements, relative humidity and evaporation are substantially important variables in discriminating between groups namely years with lower yield and years with higher yield.

#### Yield Forecast Model

The yield forecast model is developed using discriminant scores (X<sub>i</sub>) as independent variable and yield (Y) as a dependant variable. Table 5 provides the different forecast models fitted along with their F values. Three models namely linear, quadratic and cubic models are fitted. For all the three models, F values are significant at 1% level. Both the parameter of quadratic model are significant at 1% level. Moreover for the quadratic model, F values, which denote over all adequacy of model are also significant at 1% level.

Table 5. Prediction Equations

Model	F-value
$Y = 106.79 + 3.76 X_1^{**}$	11.430**
$Y = 112.33 + 5.068 X_1^{**} - 2.017 X_1^{2**}$	12.696**
$Y = 112.11 + 5.590 X_1^{**} - 1.858 X_1^{2**} - 0.125 X_1^3$	7.990**

\*\* Significant at 1% level.

The goodness of fit values are presented in Table 6. The results indicate that R<sup>2</sup> values for quadratic model is higher in comparison with linear model. For the cubic model there is only a marginal increase in R<sup>2</sup> value. The MAE, MSE and RMSE values are much lower for quadratic model in comparison with other two models.

Table 6. Goodness of Fit

Model	R <sup>2</sup>	MAE	MSE	RMSE
Linear	0.402	5.80	61.23	7.62
Quadratic	0.613	5.14	41.91	6.12
Cubic	0.615	5.14	44.34	6.11

Based on results of Table 5 and Table 6 it is concluded that quadratic model is the best fit for the present data set.

Performance of the quadratic model is validated by comparing with actual values. Table 7 below presents percentage of deviation of predicted values from the actual values.

Table 7. Percentage of Deviation

Year	Observed Values	Predicted Values	% of deviation ( $\pm$ )
2001	112	115.34	2.9
2002	113	101.44	-10.2
2003	102	97.66	-4.2
2004	116	115.41	-0.5

For the year 2002, percentage of deviation value is slightly high compared to other years. Most of the deviation values are negative denoting that predicted values are lesser than

actual values. Table 7 shows that the percentage deviation values are in  $\pm 10$  range. This shows that the performance of developed model is satisfactory.

#### CONCLUSION

The newly developed quadratic model using discriminant scores can be successfully used to forecast sugarcane yield for subsequent years. Using the forecast model, pre-harvest estimates of sugarcane yield for Coimbatore district could be computed successfully very much in advance before the actual harvest. As the data used for developing this model is of high degree of accuracy, its reliability is also high. Further, this model will produce more accurate results depending on the accuracy of input data provided.

The district government authorities also can make use of the forecast model developed using weather variables, in this study, for obtaining accurate pre-harvest estimates of sugarcane crop.

Till the final production of crops becomes known, decisions have to be made on the basis of informed predictions or scientific forecasts. The main beneficiaries are farmers (decide their procurement prices), traders, exporters and importers (for planning their logistics, inventories and contracts). The processing companies can also plan in advance about the capacity, manpower and marketing strategy.

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## Scope of pheromone technology for sugarcane borer management in South India

C THAMARAICHELVI<sup>1</sup>, S SITHANANTHAM<sup>2</sup> and S JUDI<sup>2</sup>

<sup>1</sup>Main Biocontrol Research Laboratory, Unit of Tamil Nadu Cooperative Sugar Federation, Venpakkam, Chengalpattu.603111, Tamil Nadu.

<sup>2</sup>Sun Agro Biotech Research Centre, Mathananthapuram, Porur, Chennai, Tamil Nadu

### ABSTRACT

Pheromone traps were installed in five sugar mills in Tamil Nadu, three sugar mills in Andhra Pradesh and three sugar mills in Karnataka. In each sugar factory, two sex pheromones traps were installed, one each for monitoring the abundance of adults of internode borer (INB) and another one for comparing with early shoot borer (ESB). The trap consisted of a plastic basin, mounted on wooden stick and a plastic holder for the sex pheromone lure. The lures (rubber septa) containing synthetic pheromone for slow release, were replaced after every two weeks. There was significant correlation between trap catches and Maximum Temperature, Minimum Temperature and Relative humidity for INB, while it was positive correlated with trap catches factor. During the 12 month period (July-June, 2013-2014) the catches of both INB and ESB were higher in the former quarter and much less in the other quarter.

**Key words:** Sugarcane, internode borer, early shoot borer, pheromone traps

The use of insect sex pheromone in monitoring and mass trapping has gained considerable importance as component of eco-friendly insect pest management. The scope for pheromone trapping systems in surveillance and population suppression in the management of sugarcane borers has been well recognised globally (Eswaramoorthy *et al.*, 2003, Judy *et al.*, 2015). In South India, the two borers which cause significant yield loss are the early shoot borer (ESB) *Chilo infuscatellus* and Internode borer *Chilo sacchariphagus indicus*. Pheromone based trap systems can be used for monitoring and mass trapping of the adult stage of the borers (David *et al.*, 1986, Sithanantham *et al.*, 2014, Manikandan *et al.*, 2014). The scope for selecting effective sex pheromone lure dispensers for improving the trap catches of adult males of the sugarcane borers has been pointed out by Mukunthan, 1986. Stakeholders perception studies have confirmed the adoption potential for combining the release of the biocontrol agent (*Trichogramma*) and pheromone traps as components in IPM of sugarcane borers in South India (Sithanantham and Kandasamy, 2011). In this paper we assess the scope for use of sex pheromone traps as component of IPM of sugarcane borers in Tamil Nadu, Andhra Pradesh and Karnataka, so as to extend the possibility of extending the strategy to other borers or regions in India and elsewhere in the tropics.

### MATERIALS AND METHODS

In each sugar factory, two sex pheromones traps were installed, one each for monitoring the abundance of adults of internode borer (INB) and comparing with early shoot borer (ESB). The trap consisted of a plastic basin, mounted on wooden stick and a plastic holder for the sex pheromone lure.

The lures (rubber septa) containing synthetic pheromone for slow release, were replaced after every two weeks. For each factory the lures were sent from Sun Agro Biotech Research centre (SABRC) Chennai at quarterly (3 month) periods. They also supplied the trap catch record sheet. The factories were also encouraged to collect weather data for each quarter, for use in correlation study with the weekly trap catches.

### RESULTS AND DISCUSSION

The data collected from the different participating sugar factories is summarised in Table 1.

The factories assembled data on ESB and INB for durations ranging from 3 to 12 months in year 1 and year 2. The quarterly maximum catch of INB in year 1 was in Chamundeeswari sugars (270), while in year 2 it was in Vijayanagar sugars (135). On the other hand, the maximum catch of ESB was in Vijayanagar Sugar factory in both year 1 (250) and year 2 (170). Adult moth catches recorded in Salem cooperative sugar mill shown in fig 1.

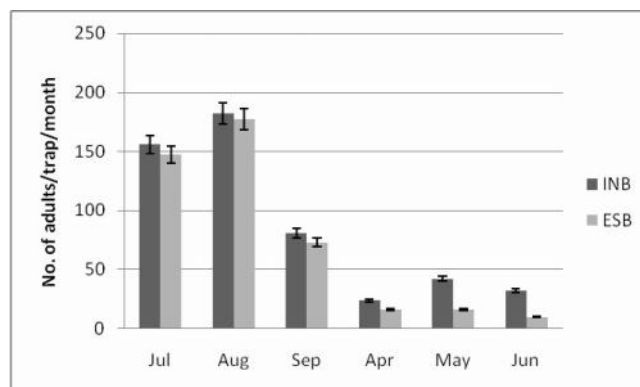


Fig 1

Table.1. Summary of pheromone catches of borer adults in two years

Factory	Monthly trap catches-summary for two years					
	I year			II year		
	Months	INB Max. (3 M)	ESB Max. (3 M)	Months	INB Max. (3 M)	ESB Max. (3 M)
Thiru Arooran Sugars	3	122	118	-	-	-
Salem Co-operative sugars	6	180	175	-	-	-
Cheyyar Co-operative Sugars	-	-	-	12	56	46
Chengalrayan Co-operative Sugars	-	-	-	6	5	4
Vellore Co-operative sugar	-	-	-	9	62	60
Thiruthani Co-operative sugars	-	-	-	9	28	25
Nava Barath Sugars	9	14	4	-	-	-
KCP Sugars	9	32	22	-	-	-
Sudalagunta Sugars	9	8	18	9	8	7
Sri Chamundeeswari Sugars	9	270	175	9	82	12
Bannari Amman Sugars	6	48	25	12	4	47
Vijayanagar Sugars	9	120	250	3	135	170

During the 6 months observation in July 2012 to September 2012, and April 2013 to June 2013, the monthly numbers of adult INB and ESB caught were in the range of 25 to 175 and 25 to 180, respectively, the maximum for both was observed in July in the trap per month ranged mostly between 180 and 175. INB adults were found in all months (maximum: 180). ESB adults were found in all months (maximum: 175). In general the INB moths were slightly more than ESB moths in all six months. The peaks for both INB and ESB were in August. Correlation with weather factors was analysed. There was significant correlation between trap catches and Maximum Temperature, Minimum Temperature and Relative humidity for INB, while it was positively correlated with trap catches factor. Adult moth catches recorded in Cheyyar cooperative sugar mill shown in fig 2.

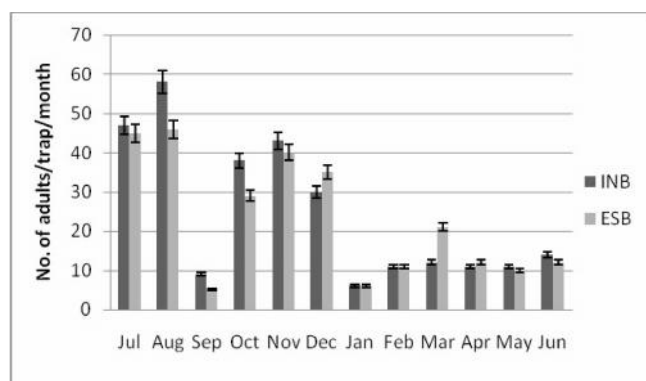


Fig 2

During the 12 months observation (July 2013 to June 2014), the numbers adult of INB and ESB caught in the trap per month ranged from 58 to 5 and 46 to 3, respectively, mostly between 58 and 46. The peaks for both the borers were in August. INB adults were found in all 12 months (max: 58). ESB adults were

found in all 12 months (max: 46). In general, the INB moths were more than ESB moths in eight months. During the 12 month period (July 2013-June 2014) the catches of both INB and ESB were higher in the former quarter and much less in the other quarter. Correlation with weather factors was analysed. Significant correlation was observed between trap catches and Maximum temperature, Minimum temperature and Relative humidity for INB, while it was negatively correlated with trap catches factor. Adult moth catches recorded in Chengalrayan cooperative sugar mill shown in fig 3.

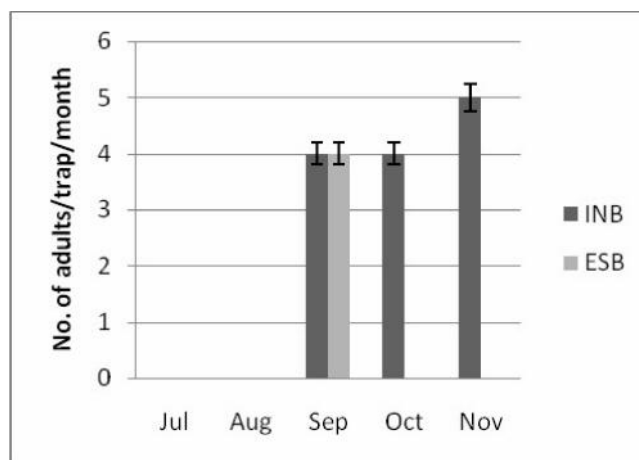


Fig 3

During the 5 months observation in July to November 2013, the numbers adult of INB and ESB caught in the trap per month ranged mostly between 5 and 4. In the case of July to August month there were no moth catches. Correlation with weather factors was analysed. INB adults were found in all three months (maximum:5). ESB adults were found in one month (max: 4). In general, the INB moths are more than ESB moths. There was significant correlation between trap catches and Maximum



temperature, Minimum temperature and Relative humidity for INB, while it was negative correlated with trap catches factor.

Adult moth catches recorded in Vellore cooperative sugar mill shown in fig 4.

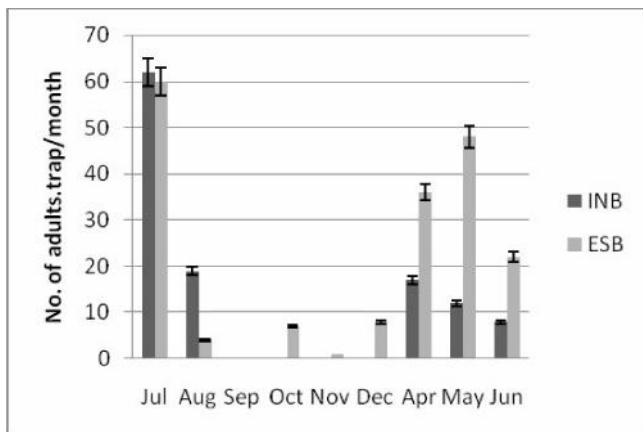


Fig 4

During the 9 months observation in July-2013 to June, 2014), the numbers of adults of INB and ESB caught in the trap per month ranged from 62 to 1 and 60 to 3 respectively. In the case of September, October, November and December no INB moth catches. INB adults were found in five out of nine months (maximum: 62). ESB adults were found in all nine months (maximum: 60). In general the INB moths were more July-August but less than ESB in other months.

Adult moth catches recorded in Thiruthani cooperative sugar mill shown in fig 5.

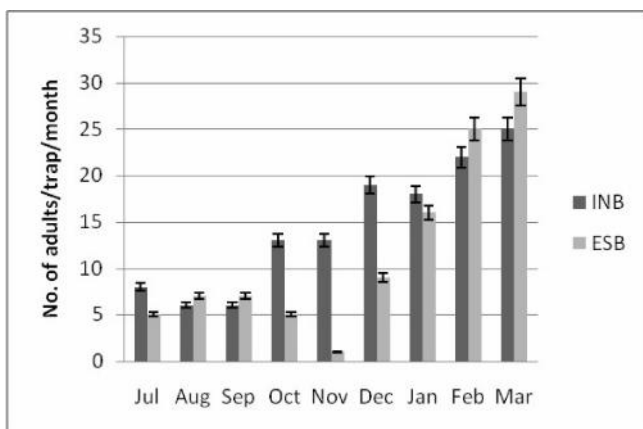


Fig 5

During the 9 months observation (in July-2013 to March, 2014), the numbers adult of INB and ESB caught in the trap per month ranged from 28 to 6 and 25 to 1. INB adults were found in all nine months (max: 28). ESB adults were found in all nine months (maximum: 25). In general the INB moths were more in July and October to January and less than ESB moths in other months. INB adults were found in all nine months (maximum: 28). Correlation with weather factors was analyzed. There was significant correlation between trap catches and Maximum

temperature, Minimum temperature and Relative humidity for INB, while it was negative correlated with trap catches factor.

Adult moth catches recorded in Nava Bharath Sugars shown in fig 6.

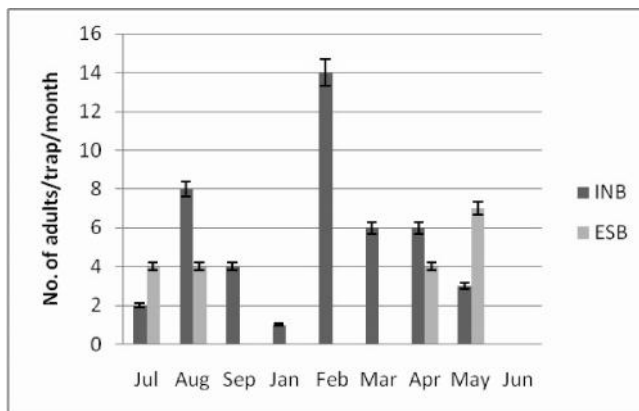


Fig 6

During the 12 months observation in July to September , the numbers adult of INB and ESB caught in the trap per month ranged from 14 to 3 and 7 to respectively. INB adults were found in all nine months (maximum: 14). ESB adults were found in four out of 9 months (maximum: 7). In general, the INB moths were more than ESB moths in August, February to April. Adult moth catches recorded in Sudalagunda Sugars during the 9 months observation in July-Sep; 2013 is shown in fig.7.

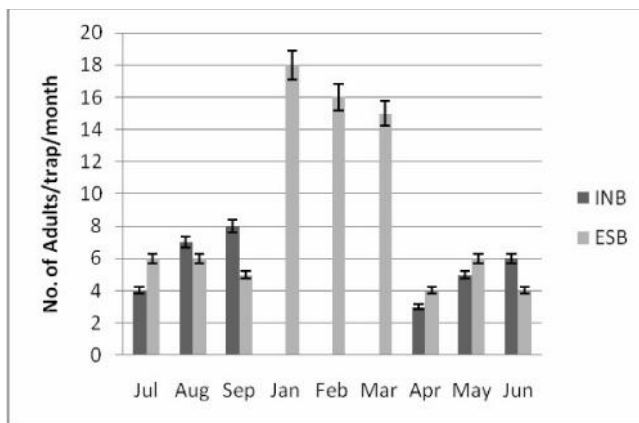


Fig 7

The numbers adult of INB and ESB caught in the trap per month ranged from 8 to 4 and 18 to 4 respectively. INB adults were found six out of nine months (maximum: 8). ESB adults were found in all nine months (maximum: 18). In general, the INB moths were more in June-September and less than ESB in other months. Adult moth catches recorded in Sudalagunda Sugars during January –June 2014 is shown in fig 8.

INB adults were found all months (maximum: 8). ESB adults were found in all months (maximum: 7). In general the INB moths were more in July, October -December while less than ESB moths in other months. Correlation with weather factor

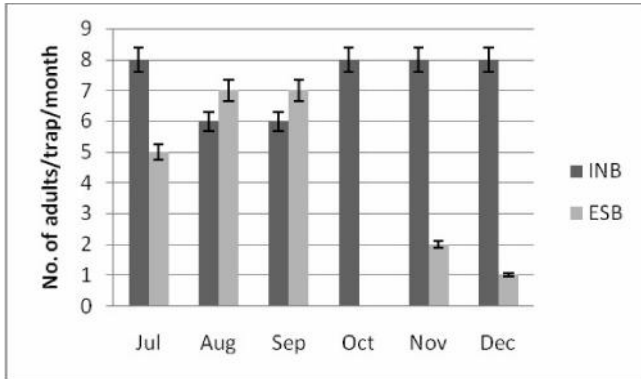


Fig 8

was analysed. There was significant correlation between trap catches and Maximum Temp, Minimum Temp and Relative humidity for INB, while it was negative correlated with trap catches factor. Adult moth catches recorded in KCP sugars during the 12 months observation in July-December 2013 is shown in fig 9.

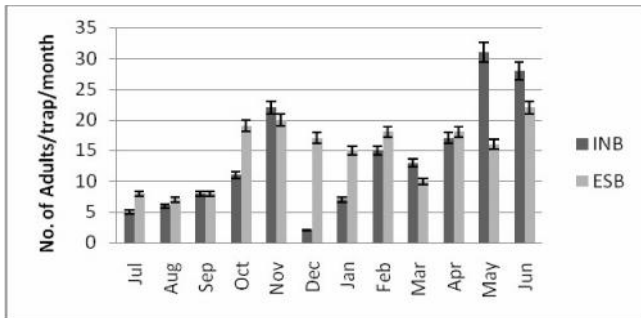


Fig 9

The numbers adult of INB and ESB caught in the trap per month ranged from 32 to 2 and 22 to 6, respectively. INB adults were found in all nine months (maximum: 32). ESB adults were found in all nine months (maximum: 22). In general, the INB moths were more in March-June and less in July-September. Correlation with weather factor was analyzed. There was significant correlation between trap catches and Maximum Temperature, Minimum Temperature and Relative humidity for INB, while it was negative correlated with trap catches factor. Adult moth catches recorded in Vijayanagar Sugars during the 9 months observation from July to September is shown in fig 10.

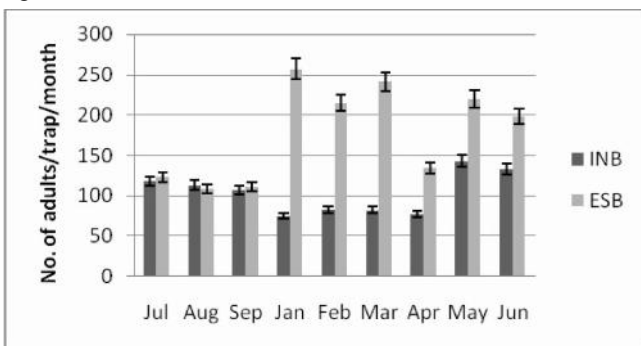


Fig 10

The numbers adult of INB and ESB caught in the trap per month ranged from 120 to 65 and 250 to 100 respectively. INB adults were found in all nine months (maximum: 120). ESB adults were found in all nine months (maximum: 250). In general, the INB moths were more in August, but less than ESB moths in other months. Adult moth catches recorded during July to September 2013 is shown in fig.11.

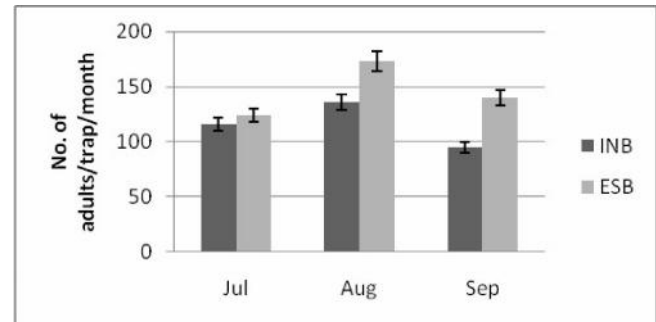


Fig 11

INB adults were found in all three months (maximum: 135). ESB adults were found in all three months (170). In general the INB moths were less than ESB moths in the three months.

Adult moth catches recorded in Chamundeeswari Sugars during the 9 months observation from during July to September is shown in fig 12.

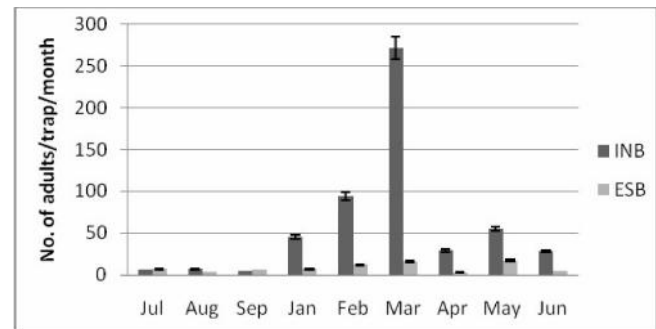


Fig 12

The numbers adult of INB and ESB caught in the trap per month ranged from 270 to 10 and 20 to 5 respectively. INB adults were found in all months, generally low in during July to September high in January-March (maximum: 270). INB adults were found in all months, generally low in during July to September and high in April to June (maximum:20). In general the INB moths are more than ESB moths. Adult moth catches recorded during 2012 and January –June 2013 is shown in fig 13.

INB adults were found in all months, high in July (maximum: 82). ESB adults were found in all months, higher in February to March (maximum:12). In general the INB moths were more in number than ESB moths. Adult moth catches recorded in Bannari amman sugars during the 6 months observation in July-September 2012 is shown in fig 14.

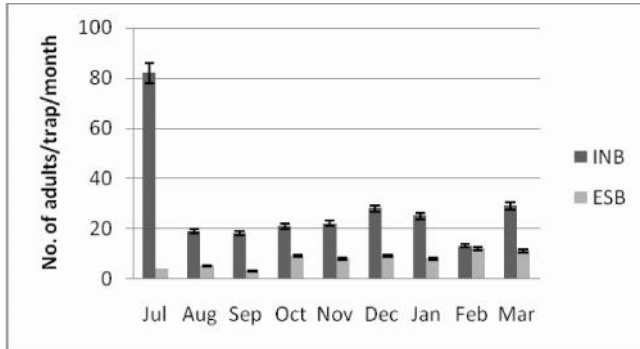


Fig 13

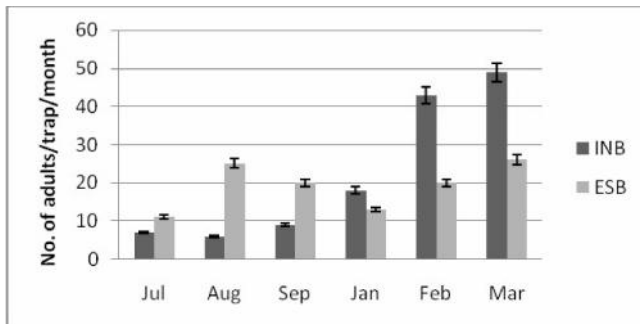


Fig 14

The numbers adult of INB and ESB caught in the trap per month ranged from 48 to 5 and 25 to 22 respectively. INB adults were found in all the months (maximum: 48). ESB adults were found in all the months (max: 25). In general, the INB moths were more in January to March and less in July to September than ESB moths. During January to March, to expect more INB damage, while July to September less than ESB. Correlation of trap catches with weather data is shown in table 8. There was significant correlation between trap catches and Maximum temperature, Minimum temperature and Relative humidity for INB, while it was positive correlated with trap catches factor. Adult moth catches recorded during and January to March 2013 is shown in fig 15.

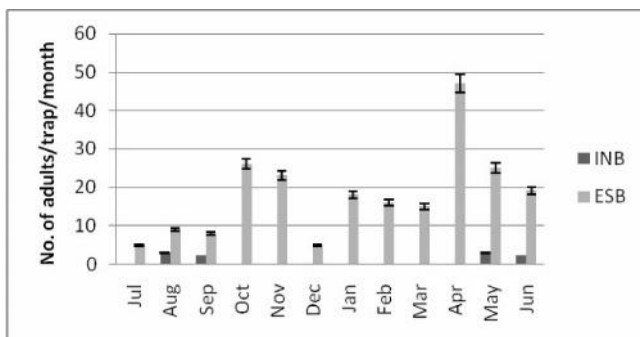


Fig 15

INB adults were found in only four months (maximum: 4). ESB adults were found in all the months (maximum: 47). In general, the ESB moths were more in all the months than INB moths. Expect more infestation in October to November and April to June by ESB.

## CONCLUSION

The deployment of sex pheromone traps would be very useful tool for monitoring and mass trapping of borer adults depending on the number of traps kept per unit area. Mass trapping of borer adults could lead to reduced number of eggs laid per unit area of crop have indicated the trend of monthly sex pheromone trap catches in the network sugar factories in South India and indicates the scope to utilise the local weather data for predicting the severity of the borer.

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