ISSN 0970-3233 Volume 26 June 2011

Indian Journal of Sugarcane Technology

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

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INDIAN JOURNAL OF SUGARCANE TECHNOLOGY

Frequency of Publication	:	Half Yearly (June, December)
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ISSN 0970-3233

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Earthing up and nitrogen levels in sugarcane ratoon under subtropical Indian condition

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ABSTRACT

A field experiment was carried out during the spring seasons of 2008-09 and 2009-10 at Varanasi, Uttar Pradesh to find out exact time of earthing up and level of earthing up with optimum dose of nitrogen for getting higher growth, yield and quality of ratoon crop of sugarcane (*Saccharum spp. hybrid* L.). 25th June earthed crop being comparable with 25th May and 25th June and produced significantly higher number of tillers ha^{-1} by (4.17, 2.30%). However, number of millable canes ha^{-1} were not affected by time of earthing up but higher number of millable canes ha^{-1} (1.09, 1.31%) were recorded under 25th June earthed crop. April earthed crop produced (percentage increased over other treatments) higher weight of millable cane (6.55, 13.91%), cane length (5.41 unit, 8.26%), green tops yield (6.68 unit, 9.47%), number of internodes cane^{-1} (12.99 ,8.22%), cane girth of top (4.83, 3.81%), middle (4.52, 5.66%) and bottom (8.22, 4.76%), cane yield (8.70, 8.40%) and juice sucrose (7.51, 9.58%) except than purity coefficient (which was not significantly affected by time of earthing up) of ratoon crops as compared to 25th May and 25th June respectively. Similarly 20 cm height of earthing up from the ridge also significantly increased all the above parameters such as weight of millable cane (3.09, 8.86%), cane length (4.07, 5.52%), green tops yield (9.56, 6.99%), number of internodes cane^{-1} (5.69, 7.98%), cane girth of top (4.09, 4.27%), middle (6.08, 2.51%) and bottom (7.09, 3.23%) cane yield (6.15, 5.63%) and juice sucrose (4.40, 7.89%) than that of 10 cm earthed crop in both the ratoon crops except number of tillers ha^{-1} and number of millable canes ha^{-1} where 10 cm earthing up recorded comparatively higher values (6.45, 11.34%) and (5.62, 6.43%) than 20 cm earthed crops. Purity coefficients were not influenced by level of earthing up. Application of 210 kg N ha^{-1} linearly and significantly increased number of tillers ha^{-1} (4.16, 5.48%), number of millable canes ha^{-1} (1.08, 1.12%), weight of millable cane (6.59, 5.85%), cane length (3.07, 2.59%), green tops yield (7.59, 4.89%), number of internodes cane^{-1} (8.79, 7.59%), cane girth of top (2.78, 4.52%), middle (2.23, 1.22%) and bottom (1.40, 2.77%) and cane yield (4.38, 5.93%) followed by 180 kg N ha^{-1}. Ratoon crop showed increased values of juice sucrose (6.06, 8.04%) under lower levels of nitrogen i.e., 150 kg N ha^{-1} as compared to relatively higher levels of nitrogen with 180 and 210 kg N ha^{-1} respectively except than purity coefficient did not affected by nitrogen levels.

Key words : Earthing up, Juice quality, Nitrogen levels, Ratoon sugarcane

Sugarcane (*Saccharum spp. hybrids*) is an important agro-industrial commercial crop which plays vital role in national economy by contributing 0.67 per cent to GDP because of its wider adaptability over varying agro-climatic condition and also unique among agricultural crop in the sense that a number of succeeding cane crops are raised from a single planting which is an integral component of sugarcane production system. In India more than 50 to 55% of sugarcane acreage is occupied by ratoons, which are often poor yielder than the plant cane due to non adoption of improved agricultural technologies. Therefore, even a small improvement in ratoon, productivity would add considerably to overall sugarcane production in the country and benefit cane growers by vacating the fields earlier for sowing of wheat and other *rabi* crops timely and mill owner's by providing mature cane in early crushing period. Thus the ratoon crop often gives better yield, quality and sugar recovery than plant cane. Excessive tillering in ratoon crop is a desired character but all tillers may not be productive with proper amount of juice. In order to reduce the number of excessive tillers and converting them into millable cane, earthing up plays an important role in maintaining the growth, yield and juice quality of the sugarcane plant and as well as ratoon. Besides, it has added advantages in terms of pruning/ cutting of old roots, moisture conservation, addition of organic matter, enhanced availability and uptake of plant nutrients, efficient utilization of solar radiation, suppression of weeds and preventing canes from lodging (Yadav and Shukla, 2008). Cane crops as well as ratoons both are highly exhaustive crop having higher demand for nitrogenous fertilizer because of shallow root system, decaying of old roots, sprouting of stubble buds and immobilization of nitrogen (Lal and Singh, 2008). It is, therefore, 20-25 per cent more nitrogeneous fertilizer was recommended over 150 kg N ha^{-1} (recommended dose of nitrogen for ratoon crop). In general, nitrogen plays a vital role in all living plant tissues and reduced the number of unwanted tillers and brought into constant number of millable canes ha^{-1}. Hence, considering all the above mentioned factors, this experiment was designed to study the effect of different time and level of earthing up along with different levels of nitrogen fertilizers for higher growth, yield and juice quality of ratoon sugarcane in Gangetic alluvial soils of Uttar Pradesh.

MATERIALS AND METHODS

The field experiment was carried out during spring seasons of 2008-09 and 2009-10 at Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, (U.P.). The experimental soil was sandy clay loam with pH 7.94, with organic carbon 0.33%, low available N (185.62 kg ha^{-1}), low available P (24.45 kg ha^{-1}) and medium available K (235.37 kg ha^{-1}). Eighteen treatments comprising of 3 time of earthing up i.e., on 25th April, 25th May and 25th June with two levels (i.e., 10 cm height and 20 cm height) of earthing up were assigned in main plots and three nitrogen levels (viz., 150, 180 and 210 kg N ha^{-1}) were taken in sub plot in split plot design and replicated thrice. The cane crop was already existed in a row spacing of 90 cm apart in an experimental field. The crop was harvested and then irrigated. After one or two days of irrigation, basal doses of fertilizers were applied. Thereafter, the field was designed in such a way that our experimental plans have to be accommodated properly. To adjust experiment in already planted sugarcane field, stubbles of fifth rows were uprooted to make irrigation channels as well as boundary wall for the experimental plots. Similarly, stubbles from the rows of sugarcane plants were also uprooted after a measured length of a plot size so as to bifurcate the plot from one plot to another. Thus, all the uprooted stubbles of canes were shifted to vacant places (gap filling) so as to get desired plant population to optimize the yields of ratoon sugarcane. Full dose of P @ 80 kg P_2O_5 ha^{-1}, K @ 80 kg K_2O ha^{-1} and 1/3rd of N as per treatment were applied at the time of ratooning. Rest 2/3rd of N in the form urea was top dressed in two equal splits before earthing up in the month of April and May as per treatments.

Sugarcane ratoon crops were harvested after the completion of 12 month *i.e.,* 15th February or March. Various growth parameters viz. number of tillers ha^{-1}, height of tillers, LAI, dry matter accumulation and number of millable canes were recorded at standing crop. Similarly yield and yield attributes like cane length, cane diameter, cane weight, green tops yield and cane yield were noted after the harvest of ratoon crop. Economic analysis was done based on the prevailing market price of the inputs and produce i.e. fertilizer N @ Rs 11.30 kg^{-1}, P@ Rs 21.25 kg^{-1}, K @ Rs 8.00 kg^{-1} and cost of sugarcane @ Rs 2932.50 t^{-1} (Sugarcane Corporation of India) during 2009-10 as its rate was Rs 293.25 $quintal^{-1}$). The plant canes were crushed to study the juice sucrose and purity coefficient.

RESULTS AND DISCUSSION

Effect of time of earthing up

The earthing time showed significant variations in the number of tillers ha^{-1} as May and June recorded significantly higher number of tillers ha^{-1} as compared to April earthed crop in both first and second ratoon. The number of tillers ha^{-1} increased by 4.17, 2.30% and 8.32, 9.70% over April earthed crop which cleared that higher number of tillers were produced as the earthing up was delayed and less number of tiller were recorded when the crops were earthed earlier i.e., mortality of tillers (%) were more in earlier earthed crop. This might be due to fact that earlier earthing up were successful in reducing the excessive tillers and converting the existing numbers into millable canes by utilizing nutrients and soil moisture by checking aeration in new emerging buds and late tillering (Struben,1911). Time and level of earthing up did not cause significant variations in the number of millable canes in both first and second ratoon crops. However, higher numbers of millable canes ha^{-1} were recorded with June and May earthed crop and was at par with each other as compared to April earthed crop. The percentage increase in number of millable canes ha^{-1} were higher (5.62, 6.43) in May as compared to June (1.09, 1.31) over April earthed crop. April earthed crop recorded significantly higher millable cane weights (6.55, 13.91%) and cane length (5.41, 8.26%) than May (2.71, 6.60%) and (0.50, 2.22%) over June because earlier earthing up makes the cane more bold (width) and strong by providing proper soil moistures, higher soil volumes for root proliferation and earlier reducing of excessive tillers reduced the competition for nutrient and soil aeration (Singh *et al*. 2008). 25th April earthed up crop also exhibited significantly higher green tops yield (6.68, 9.47%) and number of internodes per cane (12.99, 8.22%) as compared to May (6.73, 8.17%) and (9.35, 6.88%) and June earthed crop because of superior growth attributing character (shoot/cane height, number of leaves, leaf area, LAI, dry matter accumulation $cane^{-1}$) and yield attributing character (viz. number of millable cane ha^{-1}, cane length, number of internodes $cane^{-1}$, length of internodes, cane diameter, weight of millable cane, biological yield and harvest index). The time of earhting up i.e., on 25th April earthed crop produced significantly higher cane girth of top (4.83, 3.81%), middle (4.52, 5.66%) and bottom (8.27, 4.76%) than May (1.27, 1.76%), (1.97, 1.71%) (1.87, 1.25%) and June and highest cane girth was obtained from bottom of cane during both the years of ratoon crops which might be due to higher growth of the cane by accumulating more stored food materials at basal part of cane. Higher cane yield was also recorded with 25th April earthed crop in comparison to 25th May and 25th June earthed crop. The increased yield of sugarcane in April was found (8.70, 8.40%) superior over May (5.47, 2.52%) than June earthed crop. This might be due to fact that earlier earthen crop realized better plant growth and development as evidenced by greater values for growth parameters viz. shoot height, number of physiologically active leaves plant^{-1}, LAI, fresh weight and dry matter tiller^{-1}. The earlier earthen crop on 25th April showed significantly higher juice sucrose (7.51, 9.58%) as compared to over delayed earthen crops at 25th May (3.30, 5.13%) and 25th June because of higher yields and yield attributing character obtained under earlier earthen crops (Yadav, 1983). However, purity coefficient did not affected by time and level of earthing up in both first and second ratoon crops of sugarcane.

Effect of level of earthing up

Levels of earthing up influenced the growth, yield and quality characters of ratoon sugarcane as light earthed crop recorded comparatively higher number of tillers ha^{-1} (6.45, 11.34%) and number of millable canes ha^{-1} (5.16, 4.80%) as compared to heavy earthed crop during both the ratoon crops. However, number of millable canes ha^{-1} were found non-significant which might be due to less mortality of tillers in light earthed crop (10 cm height) as it did not check the late tillering as it was done in heavy earthed crop resulted in increased number of millable cane with lower yield. Heavy earthed crop (20 cm) produced significantly higher weight of millable cane (3.09, 8.86%), cane length (4.07,5.52%), green tops yield (9.56, 6.99%), number of internodes cane^{-1}(5.69, 7.98%), girth of cane of top (4.09, 4.27%), middle (6.08, 2.51%) and bottom (7.09, 3.23%), cane yield (6.15, 5.63%) and juice sucrose (4.40, 7.89%) as compared to light earthed crop except than purity coefficient in per cent (Table 1 & 2) during both the years of ratoon crop which might be due to higher soil volume availed the proper growth environment for the crops, provided constant soil moisture, aeration and high anchorage for sugarcane to prevent from lodging which ultimately increased the cane yield and juice sucrose in per cent ((Pandey and Shukla, 2001).

Effect of nitrogen levels

The ratoon crop fertilized with 210 kg N ha^{-1} recorded significantly higher number of tillers ha^{-1} (4.16, 5.48%) and was found at par with 180 kg N ha^{-1} (7.71, 17.56%) as compared to lower doses of nitrogen (150 kg N ha^{-1}) which might be due to continuous uptake of nutrient under different levels of

Table 1. Effect of time, level of earthing up and nitrogen levels on number of tillers ha^{-1}, number of millable cane ha^{-1}, weight of millable cane, cane length, green tops yield and number of internodes cane^{-1} of ratoon sugarcane

Treatment	No. of tillers ('000 ha^{-1})		No. of millable canes ha^{-1}		Weight of millable cane (g)		Cane length (cm)		Green tops yield (t ha^{-1})		No. of internodes cane^{-1}	
	2008- 09	2009- 10	2008- 09	2009- 10	2008- 09	2009- 10	2008- 09	2009- 10	2008- 09	2009- 10	2008- 09	2009- 10
Time of earthing up												
M_1 - 25th April	121.09	110.10	105.17	101.11	1502.75	1416.62	383.78	331.06	24.83	24.06	40.80	37.06
M_2 - 25th May	132.07	121.94	111.44	108.06	1404.20	1219.44	363.00	303.71	23.17	21.78	35.50	34.01
M_3 - 25th June	137.82	124.80	112.67	109.50	1366.03	1138.89	361.17	296.96	21.61	20.00	32.18	31.67
SEm ±	3.04	3.71	2.54	3.35	17.21	16.85	5.30	4.43	0.74	0.42	0.72	0.90
CD (P = 0.05)	9.59	11.68	NS	NS	54.23	53.09	16.70	13.97	2.35	1.32	2.25	2.84
Level of earthing up												
L_1 - Light (10 cm height)	134.68	126.10	112.67	108.93	1401.95	1200.00	361.63	301.76	22.04	21.15	35.10	32.82
L_2 - Heavy (20 cm height)	125.98	111.80	106.85	103.70	1446.71	1316.67	377.00	319.40	24.37	22.74	37.22	35.67
SEm ±	2.49	3.03	2.08	2.73	14.05	13.76	4.33	3.62	0.61	0.34	0.58	0.74
CD (P = 0.05)	7.83	9.53	NS	NS	44.28	43.35	13.63	11.41	1.92	1.08	1.84	2.32
Nitrogen levels (kg ha^{-1})												
N_1 - 150	121.64	102.06	105.28	100.56	1258.64	1105.56	348.83	294.21	18.94	19.56	30.47	28.22
N_2 - 180	131.81	123.80	111.39	108.44	1455.77	1294.44	381.50	314.57	24.33	22.56	37.21	35.78
N_3 - 210	137.54	130.99	112.61	109.67	1558.58	1375.00	393.61	322.96	26.33	23.72	40.80	38.72
SEm ±	0.33	3.87	1.01	1.38	6.74	6.61	4.05	2.37	0.65	0.18	0.20	0.19
CD (P = 0.05)	0.96	11.29	2.94	4.03	19.67	19.30	11.83	6.92	1.91	0.52	0.58	0.56

Table 2. Effect of time, level of earthing up and nitrogen levels on cane girth, cane yield, juice sucrose and purity coefficient of ratoon sugarcane

Treatment	Girth of cane (cm)						Cane yield t ha^{-1}		Juice sucrose (%)		Purity coefficient (%)	
	Top of cane		Middle of cane		Bottom of cane							
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Time of earthing up												
M_1 - 25th April	2.48	2.36	2.65	2.47	2.90	2.52	173.50	144.17	17.03	16.38	87.37	81.61
M_2 - 25th May	2.36	2.27	2.53	2.33	2.66	2.40	158.39	132.06	15.75	14.81	83.17	76.83
M_3 - 25th June	2.33	2.23	2.48	2.29	2.61	2.37	149.72	128.72	15.23	14.05	81.28	74.50
SEm ±	0.03	0.03	0.03	0.02	0.06	0.03	3.01	1.65	0.27	0.30	2.04	2.05
CD (P = 0.05)	0.11	0.10	0.10	0.07	0.19	0.09	9.47	5.20	0.84	0.96	NS	NS
Level of earthing up												
L_1 - Light (10 cm height)	2.34	2.24	2.47	2.33	2.62	2.39	155.44	131.07	15.66	14.46	83.74	77.37
L_2 - Heavy (20 cm height)	2.44	2.34	2.63	2.39	2.82	2.47	165.63	138.89	16.35	15.70	84.14	77.93
SEm ±	0.03	0.02	0.03	0.02	0.05	0.02	2.45	1.35	0.22	0.25	1.67	1.67
CD (P = 0.05)	0.09	0.08	0.08	0.06	0.16	0.08	7.73	4.25	0.68	0.78	NS	NS
Nitrogen levels (kg ha^{-1})												
N_1 - 150	2.23	2.11	2.36	2.24	2.53	2.31	137.11	112.67	16.82	16.17	85.78	79.89
N_2 - 180	2.44	2.32	2.62	2.41	2.80	2.45	168.39	141.67	15.80	14.87	83.63	77.28
N_3 - 210	2.51	2.43	2.68	2.44	2.84	2.52	176.11	150.61	15.40	14.19	82.41	75.78
SEm ±	0.02	0.01	0.01	0.02	0.04	0.03	1.34	0.90	0.30	0.22	1.12	1.14
CD (P = 0.05)	0.06	0.03	0.04	0.07	0.10	0.07	3.90	2.64	0.86	0.65	NS	NS

nitrogen led to more sprouting of tillers and proper growth and development of cane (Shukla, 2005). Application of 210 kg N ha^{-1} significantly recorded higher number of millable canes ha^{-1}, weight of millable cane, cane length, green tops yield, number of internodes $cane^{-1}$, cane girth and cane yield as compared to lower doses of nitrogen. The per cent increase in number of millable cane ha^{-1} due to nitrogen application of extra 30 kg over the 180 kg N ha^{-1} was (1.08, 1.12%), weight of millable cane (6.59, 5.85), cane length (3.07, 2.59%), green tops yield (7.59, 4.89%), number of internodes $cane^{-1}$ (8.79, 7.59%), cane girth of top, middle and bottom (2.78, 4.52%), (2.23, 1.22%) and (1.40, 2.77%), cane yield (4.38, 5.93%). However, 180 kg N ha^{-1} also produced higher number of millable canes ha^{-1}(5.48, 7.26%), weight of millable cane (13.54, 14.59%), cane length (8.56, 6.47%), green tops yield (22.15, 13.29%), number of internodes $cane^{-1}$(18.11, 21.12%), cane girth of top, middle and bottom (8.60, 9.05%), (12.21, 7.05%) and (9.64, 5.71%) and cane yield (18.57, 20.47%) over 150 kg N ha^{-1} during both the of ratoon crops. This might be due to application of higher doses of nitrogen checked late tillers, converted canes in to number of millable canes, increased protein synthesis promoted root development resulted in increased nutrient uptake enhanced the growth and yield attributes except than number of millable canes ha^{-1} (Inoue *et al.* 2009).

On increasing nitrogen levels, decreasing trend of juice sucrose and purity coefficient were recorded in both the first and second ratoon crops of sugarcane because sucrose (%) was markedly influenced by nitrogen doses as higher doses of nitrogen lowered down the sucrose per cent. Lower doses of nitrogen produced significantly higher juice sucrose (6.06, 8.04%) as compared to some what higher doses of nitrogen lowered down the juice quality with each increment of nitrogen doses from 180 to 210 kg N ha^{-1} (Prammanee *et al.* 1999). Nitrogen application did not influence the purity coefficient of sugarcane and with the application of nitrogenous fertilizer it started decreasing till the highest levels of nitrogen were used. However, lower doses of nitrogen (150 kg N ha^{-1}) recorded higher purity coefficient (2.50, 3.26%) as compared to 180 kg N ha^{-1} (1.45, 1.94%) and 210 kg N ha^{-1}. Thus the purity coefficient was statistically and negatively influenced by increasing nitrogen levels (Nassar *et al.* 2005).

CONCLUSION

Considering the importance of ratoon crops in sugarcane cultivation (planting once and harvesting thrice in tropics and sub-tropics) it was concluded that both first and second ratoon crops raised from a single plant cane proved beneficial for farmers when crop was earthed up at 25th April with 20 cm height along with 210 kg N ha^{-1} for better yield and ratoonability of sugarcane but ealier earthen with heavy earthed up crop with lowest dose *i.e.,* 150 kg N ha^{-1} found superior over rest of higher doses of nitrogen for juice sucrose and all treatments were found non significant for purity coefficient of sugarcane juice.

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Agronomic performance of new sugarcane genotypes under different planting geometries and N levels

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ABSTRACT

A field experiment was conducted during spring seasons of 2006-07 to 2008-09 to study the effect of row spacing and nitrogen levels on growth, yield and quality of plant and ratoon crops of new sugarcane (*Saccharum spp. hybrid*) genotypes *viz.* CoLk 94184 and CoLk 97147 on clay-loam soils at Indian Institute of Sugarcane Research, Lucknow falling in sub-tropical belt. The experimental results revealed that significantly higher germination (44.4 %), number of tillers (221.7 thousand /ha), NMC (112.7 thousand/ha) and cane yield (70.5 t/ha) as well as sugar yield (9.45 t/ha) were recorded by the genotype CoLk 94184 than that of Colk 97147. Highest number of tillers (235.8 thousand/ha) and millable canes (110.7 thousand/ha) were counted in sugarcane planted at 60 cm row spacing. The nitrogen level of 225 kg N/ha recorded significantly highest tiller count and number of millable canes. The nitrogen use efficiency was found highest at 150 kg N/ha (167.9 kg cane /kg N applied). The ^{0}Brix (23.2) and pol % juice (19.8) was found higher in the genotype CoLk 94184. Significantly highest sugar yield (10.81 t/ha) was recorded with the application of 225 Kg N /ha, which was however, closely followed by 150 Kg N /ha. The performance of ratoon of genotype CoLk 94184 was found better as compared to CoLk 97147. The number of miilable cane (121.6 thousand/ha) and yield (60.2 t/ha) of ratoon cane was higher at 60 cm row spacing. Higher yield of ratoon (74.3 t/ha) was recorded at 225 kg N / ha, however, NUE was observed higher at 150 kg N/ha for both the genotypes.

Key words : Agronomy, New genotypes, Nitrogen nutrition, Planting geometry, Ratoon performacne index

Sugarcane is the most important sugar crop contributing more than 75% to the world's sugar production. With increasing human population in the world, sugar demand has also gone up, and by the end of first decade of 21st century its requirement is projected to be around 150 million tones. In plant cludistics, it is said that only the high – sugared ones would survive any aberrance in the ecosystem – and this giant grass has survival through several millennia. Now has come to stay as one of the most important crops supporting an agro-based industry in the world. Though the primary product of sugarcane is sugar but, it also provides boifuel, fibre and fertilizer and a myriad by-products besides ensuring ecological sustainability (Hunsigi and Singlachor, 1994). India would need to produce 415 mt of sugarcane with a recovery of 11 per cent to meet per capita requirement of 35 kg sweeteners per year including 20.0 kg sugar and 15.0 kg *gur* and khandsari by 2020 A.D. (Singh *et. al.,* 2002). These projections assume that cane productivity is to be increased by increasing the area under high sugar early maturing sugarcane genotypes. In subtropical belt, the availability of sugarcane varieties with higher sugar content early in the crushing season is an important strategy to fetch high sugar recovery in the mills. To achieve this goal development of early maturing high sugar genotypes is under progress. The genotypes developed showed variable response to different agronomic practices. Row spacing has a direct effect on plant population and plays distinct role in amount of solar radiation interception. More over, the genotypes having high or low tiller dynamics shows variable response to change in planting density/row spacing. The second most important factor is the ability of genotypes is efficient utilization of applied nutrient especially nitrogen because Indian soils are universally deficient in N except some part of eastern region (Lal and Singh 2002). More so, modern cane production package concerned with yield, quality and environmental impact therefore efficient use of fertilizer N is become more crucial. In this context, the present investigation was thus taken up to assess the performance of new genotypes and their requirement for spacing and nitrogen nutrition.

MATERIALS AND METHODS

Field experiments were conducted for three years (two consecutive plant and ratoon cycles) from 2006-07 to 2008-09 at Indian Institute of Sugarcane Research, Lucknow. The experiment was laid out in split-plot design keeping combinations of 2 genotypes (CoLk 94084 and CoLk 97147) in main plot and 4 nitrogen levels (0, 75, 150, 225 kg/ha) and three spacings (60, 75 and 90 cm) in sub plots replicated thrice. The soil of the experimental site was clay loan with pH 7.4, organic carbon 0.28%, available N, P and K were 137.6, 16.5 and 235.0 kg/ha, respectively. Planting of sugarcane was done during third week of February in both the years. Ratoons were initiated during 3rd week of January in both the years. In addition to treatmental nitrogen, 60 kg P_2O_5 and 60 kg K_2O/ha was applied as basal fertilizer dose at planting/ratoon initiation. Nitrogen was applied in 3 equal splits at planting, tillering and late tillering stage in the plant crop. In ratoon, two splits of N was given at initiation and late tillering stage. Trash mulching was done uniformly in successive ratoons. All the recommended plant protection measures were undertaken during the course of investigation. The Ratoon Performance Index was calculated as per Shaw (1988) by the formula given as below :

$$RPI = 100\left[1 - \frac{P_y - R_y}{P_y}\right]$$

P_y = Reference plant crop yield (t/ha)

R_y = Ratoon cane yield (t/ha)

RESULTS AND DISCUSSION

Growth yield and NUE

Significantly higher germination percentage at 45 days after planting (42.3 and 44.4%), tiller count in July (221.7 adn 205.2 thousand/ha), number of millable canes (112.7 and 103.7 thousand/ha) and cane yield (70.5 adn 68.8 t/ha) were recorded by the genotype CoLk 9484 during both the years of experimentation (Table 1). The growth, yield attributes and yield of genotype CoLk 97147 was significantly reduced. Germination count was not affected by row spacing and N levels, however, increase in planting density and nitrogen levels significantly increased the tiller count and number of millable canes during both the years. The highest tiller count (235.8 and 219.4 thousand/ha) and number of millable canes (110.7 and 101.1 thousand/ha) were recorded by planting sugarcane at 60 cm row spacing. However, this increase was not reflected in yield. Application of nitrogen at 225 kg N/ha yielded significantly higher in both the years. The inter row distances depends on tillering capacity of a variety. The genotype CoLk 94184 being a high tillering variety compensated the yield at 90 cm spacing. A row spacing of 90 cm under timely planting condition is also recommended by Verma (2004). The response of N application up to 225 kg N/ha might be due to low availability of nitrogen in the soil and in build characterized of genotype to respond high level of fertilizer N. The results are in conformity with the findings of Singh *et. al.* (2002) and Anonymous (2010).

The nitrogen use efficiency of both the genotypes were found higher at 150 kg N application during both the years. Genotype CoLk 94184 recorded the highest NUE of 165.7 and 167.9 kg cane/kg N applied at 150 kg N/ha in 2006-07 and 2007-08 respectively. Similar to CoLk 94184, genotype CoLk 94147 also showed highest NUE (196.1 and 189.4 kg cane/kg N applied at 150 kg N/ha during both the years. Varietal response in terms of NUE at varying levels of nitrogen was also reported by Singh *et. al.* (2010) and Singh *et. al.* (2011).

Table 1. Effect of spacing and nitrogen levels on growth and yield of new sugarcane genotypes

Treatment	Germination (%)		No. of tillers in July (000/ha)		NMC (000/ha)		Yield (t/ha)		NUE (kg cane/kg N)			
									CoLk 94184		COLk 97147	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Genotypes												
CoLk 94184	42.3	44.4	221.7	205.2	112.7	103.7	70.5	68.8	-	-	-	-
CoLk 97147	33.0	33.6	182.8	173.1	95.5	95.5	59.2	57.4	-	-	-	-
CD (P=0.05)	3.46	4.21	7.83	10.61	5.20	6.31	6.56	5.96	-	-	-	-
Spacing												
60 cm	37.1	39.6	235.8	219.4	110.7	101.1	67.3	65.3	-	-	-	-
75 cm	39.5	39.7	198.5	181.0	102.9	93.5	63.8	62.3	-	-	-	-
90 cm	36.4	37.7	172.5	152.0	98.7	87.6	63.6	61.8	-	-	-	-
CD (P=0.05)	NS	NS	9.59	13.23	6.35	8.36	NS	NS	-	-	-	-
N levels (kg/ha)												
0	36.9	39.4	112.8	99.6	86.7	89.3	45.7	43.5	-	-	-	-
75	36.0	37.3	200.8	186.1	93.8	90.6	58.1	56.9	128.1	154.8	199.3	203.7
150	39.1	40.1	237.4	221.2	112.2	109.7	72.8	70.3	165.7	167.9	196.1	189.4
225	38.7	39.2	258.1	249.7	123.7	113.7	83.0	81.7	151.4	158.8	180.7	180.7
CD (P=0.05)	NS	NS	11.61	16.30	8.58	10.21	3.67	7.54	-	-	-	-

NMC : Number of malleable canes

Quality parameters and sugar yield

The quality traits *viz.,* °Brix, pol, purity and CCS percentage under different agronomic practices did not undergo significant changes. However, among the genotypes, significantly highest °Brix (23.2 and 22.9), pol (19.8%), purity (85.0 adn 86.3%) and CCS (13.41 and 13.50%) were recorded by genotype CoLk 94184 (Table 2). The sugar yield which is mainly the function of CCS % and cane yield under different treatments showed significant variations due to nitrogen nutrition. Among the genotypes, CoLk 94184 yielded significantly higher (9.45 adn 9.30 t/ha) in respective years to the genotype CoLk 94147. Higher dose of nitrogen (225 kg N/ ha) significantly produced higher sugar yield of 10.87 and 10.65 t/ha in two consecutive years respectively.

Performance of ratoon

The data on performance of ratoon, *viz.,* number of millable canes, yield, NUE and ratoon performance Index of the genotypes clearly indicated the superiority of CoLk 94184 over CoLk 97148. Significantly highest number of millable canes (125.5 and 122.4 thousand/ha), ratoon cane yield (64.0 and 62.8 t/ha) and RPI (90.8 and 91.3) were recorded with the genotype CoLk 94184 during both the years (Table 3). Although narrow spacing (60 cm) significantly triggred for higher NMC (121.6 and 118.7 thousand/ha) and yield (58.7 and 60.2 t/ha), however, ratoon performance index was found better (87.7 and 95.2) at 75 cm row spacing. Significantly highest NMC (132.3 and 128.0 thousand/ha) and yield (69.5 and 74.3 t/ha) were recorded at higher dose of nitrogen (225.0

Table 2. Effect of spacing and nitrogen levels on quality of new sugarcane genotypes

Treatment	°Brix		Pol (%)		Purity (%)		CCS (%)		CCS (t/ha)	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Genotypes										
CoLk 94184	23.2	22.9	19.8	19.8	85.0	86.3	13.41	13.50	9.45	9.30
CoLk 97147	21.1	21.5	18.3	18.4	86.8	85.5	12.56	12.52	7.42	7.17
CD (P=0.05)	0.89	0.67	0.80	0.72	NS	NS	0.68	0.57	0.58	1.35
Spacing										
60 cm	22.1	22.2	18.9	18.9	85.7	86.1	12.88	13.28	8.68	8.97
75 cm	22.3	22.4	19.3	19.4	86.6	96.6	13.18	13.27	8.40	8.26
90 cm	22.2	22.1	18.9	18.9	85.5	85.9	12.89	12.92	8.22	8.05
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N levels (kg/ha)										
0	22.3	22.3	19.2	19.2	86.2	86.2	13.13	13.13	6.02	5.74
75	22.2	22.4	19.0	19.0	85.6	84.9	12.94	12.89	7.51	7.36
150	22.1	22.1	18.9	19.1	85.7	86.5	12.87	13.04	9.40	9.19
225	22.1	22.1	19.0	19.0	86.2	86.1	13.00	13.00	10.81	10.65
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.56	2.36

CCS : Commercial cane sugar

Table 3. Effect of different agronomic practices on performance of ratoon of new sugarcane genotypes (2007-08)

Treatment	NMC (000/ha)		Yield (t/ha)		NUE (kg cane/kg N)				Ratoon performance index (RPI)	
	2007-08	2008-09	2007-08	2008-09	CoLk 94184		CoLk 97147			
					2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Genotypes										
CoLk 94184	125.5	122.4	64.0	62.8	-	-	-	-	90.8	91.3
CoLk 97147	102.4	99.1	48.0	55.0	-	-	-	-	81.0	95.8
CD (P=0.05)	6.27	5.26	5.63	4.32	-	-	-	-	3.32	NS
Spacing										
60 cm	121.6	118.7	58.7	60.2	-	-	-	-	86.9	92.4
75 cm	112.3	109.6	56.1	59.1	-	-	-	-	87.7	95.2
90 cm	109.3	105.1	53.3	57.5	-	-	-	-	83.1	93.2
CD (P=0.05)	7.15	6.27	3.46	2.21	-	-	-	-	2.86	NS
N levels (kg/ha)										
0	95.5	93.0	40.4	40.7	-	-	-	-	87.4	93.6
75	104.3	101.5	50.7	54.7	112.6	161.1	161.9	210.8	86.9	96.0
150	123.7	120.4	63.6	65.9	141.1	145.0	168.2	191.3	87.0	93.8
225	132.3	128.0	69.5	74.3	124.9	128.0	133.8	170.8	83.4	90.9
CD (P=0.05)	9.26	8.25	7.39	6.35	-	-	-	-	2.52	NS

NMC : Number of millable canes NUE : Nitrogen use efficiency kg N/ha), but the ration performance index was found higher at 150 kg N/ha. The ratoon performance with respect of number of millable canes yield might be due to positive response of genotypes to higher dose of nitrogen nutrition. On the other hand, lower RPI at higher doses is due to high plant crop under the reference. Genotypic response with respect to ratoon performance Index and higher index at lower doses of fertilizer nitrogen was also reported by Singh *et.al.* (2006).

On the basis of above discussion, it may be concluded that the genotype CoLk 94184 is superior in yield, quality and its ratoonability over CoLk 97147. The spacing requirement of genotype CoLk 94184 may be 90 cm as no significant difference in yield was observed by planting it at narrow spacing. Although the yield of sugarcane plant and ratoon was found higher at 225 kg N/ha, but the highest nitrogen use efficiency (NUE) and RPI was observed at 150 kg N/ha.

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Indian Journal of Sugarcane Technology 2011 26(1) : 10-13

Sugarcane productivity and soil fertility in plant – ratoon system under integrated and organic nutrient management in sub-tropics

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ABSTRACT

A field experiment was conducted during 2006 to 2009 at Indian institute of Sugarcane Research, Lucknow to assess the influence of various nutrient supply systems on sugarcane growth and yield and on soil health in sugarcane plant –ratoon system. Out of all five treatments based on various combinations of organics and fertilizer based nutrient supply, integrated use of organics and fertilizers up to 75% substitution both ways recorded the highest cane yield for plant (82.6 t/ha) and ratoon (78.5 t/ha) crops. However, organic carbon and available nitrogen enrichment (0.65% and 243.8 kg/ha against 0.40% and 192.4 kg/ha initial) were found highest in treatments involving total supply of recommended nitrogen through organics only. Improvement in soil physical properties such as bulk density and water infiltration rate was also recorded under organic and integrated nutrient supply systems.

Key words : Integrated nutrient management, Organic nutrient management, Plant-ratoon system, Sugarcane, Soil fertility

Sugarcane, the most important and remunerative cash crop of sub-tropical India, is fast losing its sheen owing to substantial increase in cost of cultivation and stagnant productivity. Declining soil health and soaring prices of market purchased inputs are the major factors responsible for this. Further, intensive cropping and imbalanced use of essential plant nutrients have rendered the alluvial soils of sub-tropics to be poor in organic carbon content and deterioration in physical properties (Speir *et al*., 2004) lead to restricted growth and development of the crop. In such a scenario it is essential to find agro-techniques which on one hand can ensure balanced supply of nutrients for the crop and on the other effectively restore the soil health and also save on the cost of inputs. Being nutrient exhaustive crop sugarcane removes about 205 kg N, 55 kg P_2O_5 and 275 kg K_2O from the soil for cane yield of 100 t/ha. Replenishing soil regularly with such huge quantity of nutrients through chemical fertilizers alone often results in hampering of soil physical, physico-chemical and microbiological properties leading to decline in soil productivity. Use of farm generated organic resources such as crop residues, vermi-compost, farmyard manure and microbial fertilizers are being increasingly used to arrest the decline in soil fertility and also to restore the soil physical properties. Integration of organic sources with fertilizers has also been found to enhance the nutrient use efficiency of the crop as the efficiency of sugarcane to utilize applied N ranges from 16 to 45% owing to leaching of a large quantity of applied N down through the soil layers along with irrigation water (Yadav and Prasad, 1992). The application of organic matter from such resources as animal manure, crop residues and green manuring has been shown to replenish soil organic C and improve soil fertility (Saviozzi *et al*., 2002; Srivastava *et al*., 2009). Moreover several kind of microbial agents capable of fixing N or mobilizing P and others nutrients are becoming an integral component of Integrated Nutrient Management system of crops. The present study was, thus, carried out to evaluate the different nutrient management modules on soil fertility and cane productivity in a plant-ratoon system under sub-tropics.

MATERIALS AND METHODS

A field trial was conducted during 2006 to 2009 involving three cycles of sugarcane plant and ratoon crops at the Indian Institute of Sugarcane Research, Lucknow situated at 26^0 $56^{'}$N, 80^0 $52^{'}$E and 111 m above mean sea level. The soil was sandy loam in texture with pH 7.5, organic carbon 0.40%, available N 192.4, P 22.1 and K 189.2 kg/ha. In all 5 treatments (Table 1) comprising different levels of integration of organic and inorganic sources of nutrients and crop protection measures were laid out in randomized block design with 4 replications. Sugarcane (CoS 94257) was planted in furrows 75 cm apart using 6 tonnes of seed cane/ha consecutively in March 2006, 2007 and 2008 (3 years) and harvested in February 2007, 2008 and 2009, respectively. All the treatments were applied and adopted following standard package of practices. For treatments with fertilizers half of N and full doses of P_2O_5 and K_2O were applied as basal and remaining N was top-dressed within 85 days after planting. Other practices were followed uniformly as per recommendation for the crop. Subsequent ratoons were initiated every year on 1st March with same treatments as in plant crop. Observations were recorded using standard procedure. The processed samples (soil) from each plot were collected at the end of every plant –ratoon cycle and analysed separately for organic carbon by oxidizing with potassium dichromate, and available N following alkaline permanganate method. Available soil phosphorus was extracted with 0.5 M sodium bio-carbonate solution (pH 8.5) and determined in the extract colorimetrically with neutral normal blue colour method. Exchangeable potassium was extracted with ammonium acetate solution and determined by flame photometer.

RESULTS AND DISCUSSION

Growth and yield attributes and yield

A good crop stand ensures remunerative yield of both the plant and ratoon crops of sugarcane. As far as germination of sugarcane plant crop is concerned, it is evident from the data that all the treatments had similar effect on emergence of buds that ranged from 33.5 to 35.5%. Interestingly germination under treatments with organics had an edge over that under recommended application of NP and K only through fertilizers. Similarly no significant variation in tillering behaviour of plant or ratoon crop was recorded under various treatments at active tillering and grand growth stages of the crops (Table 1). These findings corroborates the results obtained by Singh *et al*. (2007) and also it may be attributed to the improved physical properties of the soil as evident from reduced bulk density and enhanced infiltration rate (5.4 mm/hr against initial 4.1) under treatments involving recommended N supply through organics, bio-fertilizers and intercropped legumes (Table 3). No improvement in these parameters was recorded under NPK treatment. The findings, therefore, indicate that supply of nutrients through organics in sugarcane supports the crop growth equally well as that with recommended dose of nutrients supplied solely through chemical fertilizers.

Economic yield of sugarcane plant and ratoon crops is a function of number of millable canes and the average cane length and thickness at the time of harvest. The pooled data of 3 years revealed that the highest number of millable canes in plant (131000/ha) and ratoon (99300/ha) crops were recorded with the application of recommended N through organics + bio-fertilizers + inter cropping of legumes and control of pests and diseases with chemicals (T2). Similar number of millable canes were recorded where along with organics bio-pesticides were used for control of pests and diseases and dry leaves were de-trashed (T3) or organics were used for supply of 75% recommended N + bio-fertilizers + 25% recommended N through fertilizers + bio-pesticides (T4). Application of recommended N, P and K either solely (T1) or up to 75% through fertilizers (T5) and control of pests and diseases chemically or through bio-pesticides produced significantly less number of millable canes as compared to totally organic based management (T3) or organic nutrient supply combined with chemical pest control (T2). Further, for ratoon crop there was significant increase in number of millable canes under organic nutrient supply combined either

Table 1. Sugarcane germination, initial ratoon stand and tillering behaviour ('000/ha) as influenced by different treatments (pooled data of 3 crop cycles)

Treatment	Initial crop stand		Active tillering stage		Grand growth stage	
	Plant (Germ. %)	Tillers at 15 DARI	Plant	Ratoon	Plant	Ratoon
T_1	33.5	79.8	200	300	187	170
T_2	34.8	80.7	221	318	190	180
T_3	35.5	81.0	220	315	184	187
T_4	35.0	81.5	215	312	188	180
T_5	33.5	80.5	210	310	175	175
CD (0.05)	NS	NS	NS	NS	NS	NS

DARI, Days after ratoon initiation

T_1 Recommended NPK + micronutrients (iron, copper and zinc) through inorganics + control of pests/diseases through chemical mode as per recommendation.

T_2 Recommended N through organic (*vermicompost*)+*biofertilizers*+ intercropping of legumes (*Rhizobium* inoculated) with sugarcane + control of pests) diseases through chemical mode.

T_3 Recommended N through organics (*vermicompost*) 10 t/ha containing 1.5% N, 0.5% P and 0.5% K + *Gluconacetobactor* + intercropping of legume with rhizobium + bio-pesticides (*Trichoderma/ Pseudomonas*/ neem cake) + cultural mode + detrashing of dry leaves September onwards.

T_4 75% of Recommended N through organics + *Gluconacetobactor* + 25% of recommended NPK through inorganics + biopesticides (neem oil and cake at planting).

T_5 75% recommended NPK through inorganics + 25% through organic manures + biofertilizers + biopesticides (*Pseudomonas* + *Trichoderma/neemcake*) as per recommendation.

Table 2. Yield attributing characters and cane yield as influenced by different treatments (pooled data of 3 crop cycles)

Treatment	Cane length (cm)		Cane thickness (cm)		NMC (000/ha)		Cane yield (t/ha)	
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
T_1	216.5	200.0	2.3	2.23	101.0	93.0	77.70	72.0
T_2	218.0	197.4	2.4	2.32	131.0	98.8	76.9	74.8
T_3	218.3	196.9	2.4	2.32	127.0	99.3	78.0	75.0
T_4	227.3	202.1	2.4	2.30	122.0	96.2	82.6	78.5
T_5	224.2	200.0	2.4	2.30	114.0	95.4	80.3	77.5
CD (0.05)	-	-	-	-	11.00	5.67	2.71	3.24

with biopesticides or chemicals for crop protection over that obtained with recommended application of nutrients through fertilizers or supply of 75% N through organics. However, various treatments did not affect the length or thickness of cane in plant as well as ratoon crops.

The highest cane yield (82.6 t/ha for plant cane and 78.5 t/ha for ratoon) was obtained with 75% N supplied through organics + biofertilizers + 25% NPK through fertilizers + biopesticide for control of pests and diseases (Table 2). Statistically similar yields in plant (80.3 t/ha) and ratoon (77.5 t/ha) were recorded under the nutrient supply system where 75% of recommended N was given through fertilizers. Supply of 100% recommended NPK solely through fertilizers produced 77.7 t/ha in plant and 72 t/ha in ratoon crop. As evident integrated nutrient management involving organic resources and chemical fertilizers substantially enhanced the cane yield over the systems totally based on chemical fertilizers or organics. This may be attributed to the balanced availability of nutrients over a longer duration under integrated system as compared to that with solely chemical or organic based systems. Yadav and Prasad (1992) have also reported similar results.

Table 3. Physico-chemical and physical properties of soil at harvest of ratoon (pooled data of 3 crop cycles)

Treatment	Soil pH	Electrical conductivty (dS/m)	Bulk density (Mg/m3)	Water infiltration rate (mm/hr)
T_1	7.68	0.24	1.40	4.2
T_2	7.62	0.24	1.38	5.3
T_3	7.61	0.24	1.37	5.4
T_4	7.65	0.24	1.39	5.2
T_5	7.68	0.24	1.38	5.1
Initial	7.68	0.24	1.40	4.1
CD (P=0.05)	NS	NS	NS	0.23

Effect on soil health

Application of 100% N through organics brought about substantial increase in organic carbon content of the soil (Table 4). The highest enhancement in organic carbon content (0.65 over initial 0.40%)) at ratoon harvest was recorded in the treatment receiving 100% N through organic + biofertilizers + inter cropping of legume with *rhizobium* + pests/diseases control by either synthetic pesticides or bio-pesticides. It was closely followed by 75% N through organics + bio-fertilizers + 25% NPK through inorganic + biopesticides (0.64%). Application of recommended NPK through fertilizers however enriched the soil organic carbon only to 0.55%. Soil enrichment for available nitrogen recorded the similar trend as that of organic carbon. Soil phosphorus content at the end of plant-ratoon cycle however, was found highest (28.5 kg/ha) under treatment receiving recommended NPK through fertilizers only against the value (21 kg/ha) recorded for organic system of nutrient supply. This may have happened owing to greater phosphorus fixation under fertilizer applied plots whereas organics are known to solubilise the unavailable form into available forms. Enrichment of soil for exchangeable potassium was recorded under all the systems of nutrient supply.

Table 4. Soil fertility status at harvest of ratoon crops (pooled data of 3 crop cycles)

Treatment	Soil organic C (%)	Available nutrient (kg/ha)		
		N	P	K
T_1	0.55	243.8	28.5	280.2
T_2	0.65	248.6	20.8	261.7
T_3	0.65	246.7	21.0	257.7
T_4	0.64	240.7	27.9	250.0
T_5	0.62	246.1	28.9	292.0
Initial	0.40	192.4	22.1	189.2
CD (P=0.05)	NS	NS	NS	17.51

It may therefore, be concluded that supply of nutrients in sugarcane plant ratoon system through integrated use of organic resources and fertilizers brought about a significant increase in cane yield over that obtained with sole dependence on either of the sources. Such nutrient supply system also adds to the soil enrichment of organic carbon and available nitrogen and soil physical properties in terms of bulk density and water infiltration rate too become favourable for crop growth and development.

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Indian Journal of Sugarcane Technology 2011 26(1) : 14-15

Enhancing sugarcane (*Saccharum* spp. Hybrid) productivity by integrating organic, inorganic and biological sources of N in sub-tropical India

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ABSTRACT

Field experiments were conducted at the research farm of U.P. Council of Sugarcane Research, Shahjahanpur (India) during 2000-01 to 2002-03 to study the effect of organic, inorganic and biological sources of nitrogen on the growth and yield of sugarcane. It was observed that integration of 25 and 37.5% N through sulphitation press mud cake (SPMC) and rest through inorganic nitrogen (T_4 and T_3), the inorganic N could be saved from 12.5 to 25% with no loss in cane yield as obtained against the total N application (150 Kg/ha) as inorganic source (T_1). However, 50% N through SPMC + 50% through inorganic sources (T_2) increased the cane yield significantly being 12.05% higher than that of treatment fertilized with 150 kg N/ha as inorganic source alone. Results further indicated that inoculation of *Azospirillum brasilense* @ 5 kg/ha along with various sources of nitrogen (T_5, T_6 and T_7) proved amply advantageous, and accordingly improved the cane yield to the tune of 5.72, 3.34 and 5.62% as compared to T_2, T_3 and T_4 treatments, respectively. CCS% cane did not differ significantly due to different treatments of sources of nitrogen application. Thus, organic and biological sources of nutrition would help us to minimize the expenditure on costly inorganic N fertilizers.

Key words : Azospirillum brasilense, Organic, Fertilizer N, Sulphitation

Sugarcane is one of the most efficient converters of solar energy into sugars and other renewable forms of energy. Being a long duration and heavy feeder of nutrients it uptakes considerable amount of plant nutrients from soil. As a result, the nutrient ability of soil to supply plant nutrients is declining day by day which leads to decline productivity of sugarcane till recently. To overcome with this situation, and also to enhance the productivity of sugarcane, it is being felt now-a-days to apply more nitrogen fertilizer than that of its recommended dose (150 kg/ha) in sub-tropical India. But, continuous use of high analysis fertilizers has resulted in imbalance of nutrients in soil, poor growth and decline in sugarcane productivity. Results of a large number of experiments on manures and fertilizers conducted in the country reveal that neither the chemical fertilizers alone nor the organic sources exclusively can achieve the production sustainability of soils as well as crops under a highly intensive cropping system. The integrated nutrient supply has proved superior to the use of its components separately (Singh and Yadav, 1992). It has also been reported that biofertilizers application led to a saving of nearly 25% chemical fertilizers for sugarcane crop (Muthukumarasamy *et.al*., 1994). Keeping the above factors into consideration, an experiment was conducted to study the effect of organic, inorganic and biological sources of N on growth yield and quality of plant crop of sugarcane.

MATERIALS AND METHODS

The field experiments were conducted at the research farm of U.P. Council of Sugarcane Research, Shahjahanpur (India) consecutely during the years 2000-01 to 2002-03. The soil of experimental site at Shahjahanpur was silty loam having low available N (263 kg/ha), medium in available phosphorus (19.8 kg/ha) and higher in potassium (294.6 kg/ha) with pH 7.3. Seven treatment combinations *viz*., T_1 : 100% recommended dose of N (150 kg/ha) as inorganic fertilizer, T_2 : 50% N through organic (Sulphitation press mud cake – SPMC) + 50% N through inorganic, T_3 : 37.5% N through organic SPMC + 50% N through inorganic, T_4 : 25% N through organic (SPMC)+50% N through inorganic, T_5: T_2+*Azospirillum brasilense* @ 5 kg/ha, T_6 : T_3+*Azospirillum brasilense* @ 5 kg/ha and T_7 : T_4+*Azospirillum brasilense* @ 5 kg/ha were evaluated in randomized block design with four replications. Organic manure was applied in the farm of sulphitation press mud cake (SPMC) after treating with *Trichoderma viride* and *Pleurotus* sp. while inorganic N was applied through urea (46.4% N). The doses of P and K were applied @ 60 and 40 kg/ha, respectively to all the plots uniformly. Mean value for N, P and K contents, in enriched SPMC, were 1.2, 1.9 and 1.7 percent, respectively. Sugarcane

Table 1. Effect of organic, inorganic and biological sources of N on growth, yield and quality of sugarcane (*Saccharum* spp. Hybrid)

Treatment	Germination %				Shoots (000/ha)				Millable canes (000/ha)				Cane yield (t/ha)				CCS % cane			
	2000-01	2001-02	2002-03	Mean	2000-01	2001-02	2002-03	Mean	2000-01	2001-02	2002-03	Mean	2000-01	2001-02	2002-03	Mean	2000-01	2001-02	2002-03	Mean
T_1	43.24	37.54	39.03	39.94	160	131	158	150	112	106	97	105	76.02	88.89	82.56	82.49	11.91	10.80	10.16	10.96
T_2	42.94	40.87	44.05	42.62	173	140	171	161	121	111	107	113	84.24	100.00	93.06	92.43	12.61	11.16	10.76	11.51
T_3	43.39	37.17	42.59	41.23	177	138	166	160	125	110	118	118	83.04	96.45	91.12	90.20	12.04	11.04	10.88	11.32
T_4	44.29	34.26	45.77	41.44	169	135	160	155	115	107	102	108	79.37	90.12	84.41	84.63	12.03	10.77	10.58	11.13
T_5	43.54	42.72	43.78	43.35	179	146	177	167	136	119	110	122	88.54	105.56	99.07	97.72	11.79	10.97	10.41	11.06
T_6	42.04	41.53	42.33	41.97	184	142	170	165	127	113	106	115	85.54	100.15	94.14	93.28	11.52	11.30	10.36	11.06
T_7	42.49	34.39	41.53	39.47	175	138	164	159	122	110	103	112	82.54	96.91	88.73	89.39	12.07	10.94	10.68	11.23
CD (P=0.05)	NS	NS	NS	-	NS	NS	NS	-	10.94	12.99	4.56	-	7.37	11.45	10.39	-	NS	NS	NS	-

Treatment details : T_1 : 100 % N (150 kg/ha) inorganic; T_2 : 50 % N (SPMC) + 50% N (inorganic); T_3 : 37.5% N (SPMC) + 50% N (inorganic); T_4 : 25% N (SPMC) + 50% N (inorganic); T_5 : T_2 + *Azospirillum brasilense* @ 5 kg/ha; T_6 : T_3 + *Azospirillum brasilense* @ 5 kg/ha; T_7 : T_4 + *Azospirillum brasilense* @ 5 kg/ha.

variety CoSe 92423 was planted at 90 cm row to row spacing in the second week of February and harvested in the second week of March during all the three years of experimentation. Microbial culture of *Azospirillum brasilense* was arranged from the Division of Microbiology at IARI, New Delhi, and respective treatment plots were inoculated @ 5 kg/ha as side dressing at 45 days after planting. Data on growth, yield and quality of sugarcane were recorded at the appropriate time. The data recorded were thus analysed statistically year wise, and presented and discussed in this paper.

RESULTS AND DISCUSSION

The data presented in Table 1 vividly indicated that germination percent of cane buds and number of shoots per ha did not differ significantly due to different treatments in the study during all the three years of experimentation. However, the T_5 treatment (50% N through SPMC + 50% N as inorganic + soil inoculation of *Azospirillum brasilense* @ 5 kg/ha) being statistically at par with T_2, T_3, T_4, T_6 and T_7 treatments, produced significantly higher number of millable canes than that obtained with the application of 100% N through inorganic N. It clearly indicates the importance of supplementing organic source of N with inorganic nitrogen application, and it thus proves its worthy to apply in sugarcane growing for better results. The data further revealed that by integrating 25 and 37.5% N through SPMC (T_4 and T_3) and rest through as inorganic nitrogen, the dose of inorganic N could be saved from 12.5% to 25% with no loss in cane yield as obtained against the recommended dose of N application (150 kg N/ha) as inorganic source (T_1). However, 50% N through SPMC + 50% through inorganic sources (T_2) increased the cane yield significantly being 12.05% higher than that of treatment fertilized with 150 kg N/ha as inorganic source alone. Soil inoculation with *Azospirillum brasilense* at T_5, T_6 and T_7 treatments proved amply advantageous, and accordingly improved the cane yield, although marginal, to the tune of 5.72, 3.34 and 5.62% as compared to T_2, T_3 and T_4 treatments, respectively. Shankariah and Hunsigi (2000) and Kumar *et al.* (2002) also reported that integration of organic manure and bio-agents such as *Azospirillum brasilense* with inorganic fertilizer significantly increased cane yield and net profit compared to their individual application. CCS% cane did not differ significantly due to different treatments of sources of nitrogen application. Thus, organic and biological sources of nutrition would not only help us to minimise the expenditure on costly inorganic N fertilizers but also sustainable production of field crops.

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Indian Journal of Sugarcane Technology 2011 26(1) : 16-19

Variability Trends for ºBrix Content in General Cross Combinations of Sugarcane (*Saccharum* spp. hybrids)

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ABSTRACT

The study was undertaken to determine the potential of general cross combinations in sugarcane, obtained by open pollinating female parents, to generate variants for ºBrix (percent total soluble solids) content and frequency distribution pattern of variants, hence generated. Using ºBrix (an indicator of sucrose content) as selection criterion, 819 ratooned seedlings raised from five general cross combinations, comprising high sugared commercial varieties of North West zone as female parents, *viz.,* CoS 8436, Co 1148, Co Pant 97222, Co 0238 and Co 0239, were investigated. The corrected ºBrix values of test genotypes, evaluated in augmented incomplete block design, inferred the generation of highly variable population with significant differences in test genotypes. Further cross wise evaluation revealed that progeny means of three GC's raised from female parents CoS 8436, Co 1148, Co Pant 97222 were significantly higher than respective parental means, whereas, the progeny obtained from high sugared female parents Co 0238 and Co 0239 has significantly lower mean ºBrix value than parental means, thereby signifying that determining the combining ability of parents is important to generate elite segregants since some parental combinations may not be able to transfer their potential economic values (traits) to next generation. Highly significant negatively skewed leptokurtic distribution of the progeny for ºBrix content in GCs obtained Co Pant 97222 and Co1148 indicated that the *tail* on the left side of probability density function was *longer* than the right side and the bulk of the values (including the median) lie to the right of the mean. This indicated that Co Pant 97222 and Co 1148 are potential female parents to generate high frequency of elite seedlings for Brix. The evaluation of elite clones from each GC in the next clonal Stage (Settling I) led to a higher selection rate in Co Pant 97222 and Co 1148 as compared to other GCs. The study suggested the scope of general cross combinations, which are less laborious, cost effective and generally yield more fuzz, to generate elite segregants for qualitative traits like sucrose content in sugarcane. The influence of female parents on frequency distribution pattern of elite segregants has been discussed.

Key words: Biparental, ºBrix, Frequency distribution, Kurtosis, Skewness, Sugarcane ratoon

Modern sugarcane (*Saccharum* spp. hybrids) is an important grass that contributes 60% of the raw sugar produced worldwide and has a high biofuel production potential. It was created about a century ago from the combination of the polyploid species *S. officinarum*, the domesticated sugar-producing species with x = 10 and 2n =8x = 80, and *S. spontaneum*, a vigorous wild species with x = 8 and 2n =5x =40 to16x = 128 and many aneuploid forms (D'Hont *et al.,* 1995). Proper exploitation of variability in a crop like sugarcane with a complex ploidy and a high level of heterozygosity is a complicated process (Babu *et al.,* 2009). Breeding for higher yield and quality traits requires basic information on the extent of genetic variation in a population and its response to selection. Improvement in genetic potential for stalk and sugar yields is the most important objective in sugarcane breeding programme. The main difficulty in improvement of sugarcane is selection at seedling stage. Further, it is a vital stage of selection because it provides the base population for remaining and more effective stages of selection (Ram, 2009). New sugarcane cultivars are developed through the selection of vegetatively propagated genotypes, obtained from true seed after hybridization of superior parents. Selection is applied in all breeding stages: the choice of parents, cross combinations and the plant population originating from the crosses made. Selection at early stages in sugarcane breeding programmes is generally based on refractometer ºBrix as the only juice quality characteristic. Many breeders indicated that heritability of juice quality in sugarcane, including ºBrix, is moderate to high and therefore can be improved with the correct selection pressure. ºBrix was highly correlated with sucrose and selection for high sucrose could begin as early as the single stool stage and most of the genetic variation for ºBrix could be attributed to additive effects.

Recognising ratoonability as an important trait in sugarcane varieties, selection in ratoon seedlings is warranted, particularly in sub-tropical countries where seedlings remain immature at the time of next season's planting and hence, may not express their full potential (Ram *et al.,* 1997). Seedling selection in the ratoon crops is practised in many countries, *e.g.,* Argentina, Barbados and Guyana, the USA, and South Africa. After several cycles of crossing and selection in a generation-wise crossing programme, gain in performance becomes smaller and more difficult to detect. Therefore, improving the efficiency of selection that generates genetic gains is important. The selection percentage is a measure of the overall merit of the cross which represents all the aspects of desirability considered in these stages and the weight given to each component character by the selector. Brix was highly correlated with sucrose and selection for high sucrose could begin as early as the single stool stage and moreover, most of the genetic variation for ºBrix could be attributed to additive effects. The main objective of the experiment was to investigate the potential of general cross combinations which are not laborious to execute like biparental crosses in sugarcane, and to estimate the influence of maternal parent on frequency of elite segregates in the population for brix value, a trait of high heritability and an indicator of sugarcane quality.

MATERIALS AND METHODS

Five general cross combinations were effected from five open pollinated sub-tropical female parents sown in same block at National Hybridization Garden NGH, Sugarcane Breeding Institute, Coimbatore, India in 2007. The subtropical or tropical parents refer to variety/clone/cultivar adapted to respective zone. In general cross combinations, female parents were allowed to open pollinate and fuzz (true seed) was collected from female arrows. The seedling stage refers to a selection stage where clones are grown from fuzz after hybridization and the subsequent stage that develops from regeneration of the seedling clumps after harvest, is referred to as ratooned seedling stage. After germination tests, the fuzz was sown under polytunnels with high humidity in April, 2008. Three-month-old seedlings were transplanted during July, 2008 in the ground nursery at an equal distance of 60 cm between the seedlings in each of a 6 m row length, spaced at 75 cm. The experiment was established as an augmented incomplete block design along with one-month old settlings of four checks *viz.,* CoJ 64, CoJ 83, CoJ 88 and CoJ 89 (commercial varieties) along with maternal parent clones in each block. The seedlings were harvested under cold conditions after 300 days of transplanting and the crop was ratooned using standard cultural practises followed in the Punjab state of India in 2009. Eight hundred and nineteen ratooned seedlings derived from different crosses were evaluated for ºBrix using a hand refractrometer after 270 days of ratooning. The ºBrix was recorded from two shoots of a clone and the average ºBrix from the two sub-samples was used for all statistical analysis. The individual ratooned seedlings (test genotypes) were evaluated on small-unreplicated plots in an augmented design because of the paucity of cane material in each clone. Descriptive statistics were worked out for each cross and hence, the class intervals were constituted for ºBrix. The frequency distribution of progeny for ºBrix content for each general cross combination was determined and represented graphically. The elite clones from each GC were promoted to Stage I based on ºBrix content and other cane traits in 2010 and data on per cent selection has been discussed briefly.

RESULTS AND DISCUSSION

The ratooned seedlings were evaluated in an augmented design using adjusted values of ºBrix as the selection criterion. The critical differences and standard error of deviation for a total of 819 test genotypes (irrespective of type of crosses) within blocks, between blocks and between control and test treatment were presented in Table 1.

The heterogeneity was observed within blocks. The treatments were, therefore adjusted, and compared using respective critical differences. Highly significant differences in the test genotypes for ºBrix content indicated the generation of highly variable population from general cross combinations in sugarcane. In augmented design, the standard varieties were planted in each block and thus replicated, while the test entries were not. Because the design is unreplicated for the test clones, the repeated checks were used to estimate the error mean square and the block effects. The estimated block effects were used to adjust the observed values of the test entries. The comparative utility and efficiency of augmented randomised block design over incomplete block designs, namely the rectangular lattice and cubic lattice in the clonal evaluation trials in sugarcane inferred that the top 10% selection based on statistical analysis remained almost the same in both the designs. The augmented design, though not equal to lattice design in statistical efficiency, is quite useful to sugarcane breeders who have to evaluate a large number of clones as precisely as possible. Though the analysis of augmented design provided for elimination of block effects in respect of each genotype, there seemed to be no possibility of further reduction of error variance as in lattice design. The higher values of L.S.D. and C.V. are usually recorded in case of augmented design (Bhagyalakhsmi and Somarajan, 1999). The adjusted brix values were used further for cross wise progeny evaluation.

Table 2 described the comparison of parental mean with the respective progenies originated for each GC. In GC I, II and III originated from CoS 8436, Co Pant 97222 and Co 1148, the mean value of the progenies were significantly higher than the parental means, thus inferring the potential to generate good segregants for °Brix. As expected, the variance was higher in the progeny as compared to parents in all GCs. GC IV and GC V were originated from high sugared elite varieties, *viz.,* Co 0238 and Co 0239 having mean values 19.09 and 19.07, respectively. Their progenies were recorded with significantly lower mean values for Brix in comparison to parental mean, *i.e.,* 17.09 and 17.88, respectively.

The general statistics for each type of general cross combination *viz.,* CoS 8436 (GC I), Co1148 (GC II), Co Pant 97222 (GC III), Co 0238 (GC VI), and Co 239 (GC V) were described in Table 3. The mean Brix was 17.98 in progeny of GC V followed closely by that of GC IV and GC III with a °Brix value of 17.77 and 17.63, respectively. In GC I, IV and V, none of the seedling has Brix value lower than 10.0 whereas in GC II and III, the lower limits of the variants were 9.0 and 7.4, respectively. Not much difference were observed in coefficient of variance in all general cross combinations (13.09 in GC II to 13.20 in GC V) except in GC I (11.38). To assess the distribution of progeny and its deviation from a normal distribution, skewness and kurtosis in progeny of each GC, has been worked out.

Left skewed distribution (Skewness <0) was observed in all GCs though the value was statistically significant in only GC I, II and III, thereby indicating that most values are concentrated on the right of the mean (Table 3). Graphically, the frequency distribution in the progeny of each GC was also analysed. Significant leptokurtic distributions in progeny of GC II and GC III, derived from Co Pant 97222 and Co 1148

Table 2. Comparison of Mean and Variance in the Female Parental Clones and Respective Progenies originated in General Cross Combinations of Sugarcane

	°Brix in female parent	°Brix in progeny originated
GC I	CoS 8436	CoS 8436 GC
Mean (t-value)	16.52	17.14 (2.51*)
Variance	0.42	3.78
GC II	Co Pant 97222	Co Pant 97222 GC
Mean (t-value)	16.87	17.42 (2.23*)
Variance	0.49	5.25
GC III	Co 1148	Co 1148 GC
Mean (t-value)	16.40	17.63 (5.43**)
Variance	0.35	5.87
GC IV	Co 0238	Co 0238 GC
Mean (t-value)	19.09	17.09 (-3.19**)
Variance	1.64	6.67
GC V	Co 0239	Co 0239 GC
Mean (t-value)	19.07	17.88 (-2.45*)
Variance	1.76	7.28

* and ** refer to significant at 1% and 5% level of probability, respectively.

Table 1. Analysis of Variance for °Brix value of the Progenies based on augmented design

Source	Df	SS	MS	F	Prob>F
Block	40	34.85	0.871	1.501	0.048
Treatments (adjusted)	819	4041.76	4.935	8.506	0.000
Error	120	69.62	0.580		
Total	979	4831.82			

Parameters	Standard error of deviation (SEd)	Critical difference (5%)
Two Control Treatments	0.168229	0.333093
Two Test Treatments (Same Block)	1.077190	2.132837
Two Test Treatments (Different Blocks)	1.204335	2.384584
A Test Treatment and A Control Treatment	0.857802	1.698448

Table 3. Descriptive Statistics for HR °Brix in Progeny of Different General Cross Combinations

General cross combination	Total no. of seedlings evaluated	Mean	Minimum	Maximum	Median	Coefficient of Variance	Skewness	Kurtosis
CoS 8436 GC	148	17.14	11.0	22.0	17.4	11.38	-0.48*	0.74
CoPant 97222 GC	209	17.42	9.0	23.0	17.6	13.19	-0.92*	1.57*
Co 1148 GC	265	17.63	7.40	23.0	18.0	13.77	-0.45*	0.67*
Co 0238 GC	118	17.77	10.0	23.0	17.8	13.09	-0.15	0.29
Co 0239 GC	93	17.98	12.0	23.0	18.0	13.20	-0.11	-0.19

Table 4. Performance of Progeny in Different General Cross Combinations

	Percent poor seedlings /population (<16.0 HR Brix)	% Average seedlings/population (16.1 -20.0 HR Brix)	% Elite seedlings/population (>20.1 HR Brix)
CoS 8436 GC	18.18	74.83	6.99
Co Pant 97222 GC	16.75	68.90	14.35
Co 1148 GC	20.83	57.58	21.59
Co 0238 GC	31.36	59.32	9.32
Co 0239 GC	48.39	44.09	7.53

inferred that distribution of progeny presented higher peaks around the mean compared to normal distributions, which leads to thick tails on both sides. This signified that the most of the seedlings from Co Pant 97222 and Co 1148 performed superior to the population mean and in the direction of higher scale and hence, surfaced as potential female parents to generate high frequency of elite seedlings for °Brix content . Where as the non significant skewness was observed in the progeny of Co 0238 and Co 0239 with the low percentage of extreme segregants.

Based on °Brix value, the categorization of seedlings in three classes *viz.,* poor (<16.0 °Brix content), average (16.1-20.0 °Brix content) and elite (>20.1.0 °Brix content), was done (Table 4). Co1148 GC generated the highest per cent of elite (21.59) seedlings followed by Co Pant 97222 GC (14.35). CoS 8436 , Co 0238 and Co 0239 generated 6.99, 9.32 and 7.53 per cent elite seedlings having °Brix content >20 per cent. Under average category, Cos 8436GC genrated highested seedlings / population (74.83) followed by CoPant 97222 GC (68.9%).

In sugarcane breeding, the number of superior individuals in a cross are very important because thousands of progenies are available for testing. Parents are chosen for further crossing on the basis of high sample mean and or high sample variance in the progeny for the traits under consideration (Shanthi *et al.,* 2005). The °Brix was taken as selection criterion as this trait has high repeatability over generations. °Brix cane juice presented high repeatability values between stages I and II and also between plant-cane and first-ratoon crops. Particularly for this trait, individual selection can be intensified in stage I. The availability of objective data on progeny performance present the opportunity to generate robust estimates of the breeding value of parents involved in crosses. The evaluation at ratooned seedling stage has added advantage of selection for ratoonability as well. Better ratoonability, when harvested during winter months, is an important trait of sugarcane clones in sub-tropical zone and this would be improved by increasing the selection intensity in seedling ratoon nursery.

ACKNOWLEDGEMENT

The support and guidance rendered by the Director, Sugarcane Breeding Institute, Coimbatore in hybridization work is deeply acknowledged.

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Indian Journal of Sugarcane Technology 2011 26(1) : 20-23

Co A 05323 – A Promising Mid Late Clone for Andhra Pradesh

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ABSTRACT

A promising midlate clone Co A 05323 was developed from Co 85002 PC at Regional Agricultural Research Station, Anakapalle. It was tested against the popular checks CoV92102 Co 7219 and Co 86249 for its performance under AICRP yield trials from 2008-09 to 2009 – 200 in two plant and one ratoon crops. The pre release clone Co A 05323 recorded an average cane yield of 116.20 t/ha and sugar yield of 14.95 t/ha and thus found superior to the checks 83 V 15 (95.23 / 12.85 t/ha) Co 7219 (101.56 and 12.67 t/ha) and Co 86249 (84.10 / 10.52 t/ha) for cane and sugar yields, respectively. The percent increase for cane yield in Co A 05323 over checksCo V 92102, Co 7219 and Co 86249 was 22.02, 14.42 and 38.17 respectively. Similarly for sugar yield also the percent increase in Co A 05323 over checks ranged from 16.34 to 42.11. Percent juice sucrose in Co A 05323 was on par with 83 V 15 but superior to Co 7219 and Co 86249. Number of millable canes, length of millable canes, diameter of cane and single cane weight were also high in Co A 05323. The improved clone Co A 05323 was resistant to red rot under natural and artificially inoculated conditions. It is a medium thick cane with erect growing habit and non lodging nature. The clone can be distinguished by greenish yellow cane with black waxy coating dark green foliage, greenish pink, blotches present on leaf sheath, easily trashable, possesses excellent ratoonability.

Key words : Mid late, Tropial India, Andhra Pradesh

Sugarcane is one of the important commercial crops of the tropical and sub tropical, Sugarcane is grown is an area of 4.39 million hectares. Producing 271.2 m tons of cane with national average yield of 61.70 t/ha (2008-09). In Andhra Pradesh, it is grown in area of 1.96 lakh ha, producing 153.22 lakh tons with an average yield of 78.0 t/ha (2008-09).

Choice of suitable cultivar for a particular agro ecological situation play a decisive role in augmenting sugarcane productivity. Since the commercially released sugarcane cultivars are exposed to diversified climati logical situations, their gentle potentiality of the cultivar is the prime management and aberrant weather conditions etc. The sugarcane yield levels over the years have remained stagnant or in some years decreased resulting in economic losses to sugarcane farmers and sugar industry. The industry and farmers are looking for new varieties , which will improve cane yield and sugar productivity in the state .To ensure genetic diversity among the cultivated varieties , Its is essential to identify a few more midlate maturing high yielding and high sugar varieties so that vulnerability to diseases & pests to planting of some varieties in extensive arrears can be avoided .It is in this content the release of new varieties assumes importance (Jalaja ctal ,2006)

Production and productivity of sugarcane is governed by varieties, season and agronomic package of practices besides balanced nutrition. Reduction in production perhaps may be due to lack of any of them and badly affects both the cane growers and sugar mills and ultimately has an adverse impact on national economy.

There is an urgent need to increase the productivity by adopting midlate varieties since most of the factory areas who occupied by early varieties and a very few midlate varieties were under cultivation might be one of the reasons for low productivity in the state . To meet requirement of both the farmers and industries, 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 provide quality cane to be factories throughout the crushing period.

MATERIALS AND METHODS

The clone CoA05323 is a selection from Co 85002 Pc. It was tested in advanced yield trials from 2008-09 to 2009-10 under two plant crops and one ratoon crop at Regional Agricultural Research Station, Anakapalle (AICRP Annual report, 2008 and 2009). Each clone was grown in eight rows of six meters row length. The experiment was laid out in Randomiged Block Design with three replications. All the recommended package of practices are adapted for raising a good and healthy crop. Data were recorded on morphological characters, number of millable canes at harvest, length of millable canes, single cane weight and diameter of cane, juice quality (brix sucrose, purity and CCS%) were determined as per the standard procedure (Meade and chen, 1971). Cane yield was recorded at harvest on plot basis and expressed in tons / hectare, sugar yield was estimated based on cane yield and CCS percent. Reaction to diseases viz., red rot and smut both under natural and artificial conditions was recorded against the mixed inoculum of three predominant pathotypes (Cf 419, Cf 671 and Cf 997) of red rot in Andhra Pradesh. Statistical analysis of data was carried out as per panse and sukhatme (1978). The chief morphological characters are presented in table 1

RESULTS AND DISCUSSION

The data on cane yield, yield components, juice quality parameters and reaction to red rot and smut are furnished in table 2(a) to 3 respectively.

Cane yield (t/ha)

The promising clone Co A 05323 has recorded a higher mean yield of 116.20 t/ha in two plant crops and one ratoon crop compared to the checks CoV 92102(95.23 t/ha), Co 7219 (101.56 t/ha) and Co 86249 (84.10 t/ha). The clone Co A 05323 gave significantly higher cane yield over the three checks. The percent increase for cane yield in Co A 05323 over two plant crops and ratoon against checks was 22.02 was 14.42 and 38.17 respectively over Co V 92102, Co 7219 and Co 86249 (Table 2a)

Sugar yield (t/ha)

The improved clone Co A 05323gave an average sugar yield of 14.95 t/ha over two plant and one ratoon crops while the checks Co V 92102 , Co 7219 and Co 86249 recorded a

Table 1. Description of morphological characters of Co A 05323(2000A225)

S.No.	Name of the description		Descriptor status
1.	Clone number	:	Co A 05323(2000A225)
2.	Stool habit	:	Erect
3.	Stem colour (exposed)	:	Yellowish green
4.	Stem colour (undexposed)	:	Greenish yellow
5.	Ivory marks	:	Absent
6.	Weather marks (Corky patches)	:	Absent
7.	Internode shape	:	Cylindrical
8.	Internode alignment	:	Straight
9.	Pithiness	:	Absent
10.	Splits on internode	:	Absent
11.	Wax on internode	:	Black waxy coating
12.	Node swelling	:	Absent
13.	Bud size	:	Small
14.	Bud shape	:	Oval
15.	Bud cushion	:	Absent
16.	Bud groove	:	Absent
17.	Growth ring colour	:	Yellowish white
18.	Leaf length	:	Medium
19.	Leaf width	:	Medium
20.	Lamina colour	:	Green
21.	Leaf carriage shape	:	Open tip drooping
22.	Leaf sheath colour	:	Greenish with greenish pink blotches
23.	Leaf sheath waxiness	:	Medium
24.	Leaf sheath spines	:	Absent
25.	Leaf sheath clasping	:	Loose
26.	Dewlap colour	:	Yellow
27.	Presence / absence of ligular process	:	Absent
28.	Shape of the ligule	:	Asyndetically steeply sloping
29.	Percent flowering	:	Absent

sugar yield of 12.85 t/ha, 12,69 t/ha and 10.52 t/ha respectively (Table 2b). The percent increase in sugar yield of Co A 05323 over two plant and one ratoon crops over checks was 16.34 (CoV 92102), 17.81 (Co 7219) and 42.11 (Co 86249).

Yield components

The clone Co A 05323 has recorded maximum number of millable canes, length of millable cane, and diameter of cane at harvest compared to all checks tested in plant and ratoon crops. For single cane weight, Co A 05323(1.49) was superior to Co 7219 (1.22) and Co 86249(1.18) but on par with Co V 92102 (1.60) (Table 2c).

Juice quality parameters

Data on percent brix, sucrose, purity and CCS in juice is presented in Table 2(d). The clone Co A 05323 (20.35) was found on par with the best standard CoV92102 (21.21)but superior to Co 7219 (19.77) and Co86249 (19.69) for percent brix. It has recorded a mean juice sucrose percent and CCS percent (17.98 and 12.84) and was found on par with standards, Cov92102 (18.86 and 13.44) followed by Co7219 (18.00and 12.97) and superior over Co86249 (17.54 and12.51) respectively.

Reaction to red rot and smut.

Reaction of Co A 05323 and checks for red rot and smut was studied under artificially inoculated conditions (Table 3). The Clone Co A 05323 resistant reaction under nodal and plug methods, respectively against individual pathotypes Cf 671, Cf 997 and Cf 419 and mixed inoculam of these three

Table 2a. Performance of Co A 05323 in Advance Varietal Trials for cane yield (t / ha) (2008 -09 to 2009-10).

S.No.	Clone	Cane yield (t/ha) Plant I	Plant II	Ratoon	Mean	% over cheeks
1	Co A 05323	128.00	123.00	97.60	116.20	
2	Co V 92102 (C)	94.00	117.67	74.03	95.23	22.02
3	Co7219 (C)	110.00	122.67	72.00	101.56	14.42
4	Co 86249 (C)	108	92.00	52.30	84.10	38.17
	CD at 5%	13.24	6.66	9.93	-	
	C.V. (%)	8.60	10.44	7.91	-	

Table 2b. Performance of Co A 05323 in Advance Varietal Trials for Sugar yield (t/he) (2008 -09 to 2009-10).

S. No.	Clone	Sugar yield (t/ha) Plant I	Plant II	Ratoon	Mean	% over Cheeks % over Cheeks
1	Co A 05323	16.41	16.20	12.23	14.95	
2	Co V 92102 (C)	12.07	16.59	9.88	12.85	16.34
3	Co7219 (C)	13.90	15.13	9.04	12.69	17.81
4	Co 86249 (C)	13.65	11.34	6.57	10.52s	42.11
	CD at 5%	2.21	3.18	2.58	-	
	C.V. (%)	6.90	13.02	14.04	-	

Table 2c. Performance in Advance Varietal Trials for yield components (2008-09 to 2009-10) over two plant and one ratoon crop

S. No.	Clone	NMC at harvest '000 /ha	Length of millable cane (m)	Single cane weight (kg)	Diameter of cane (cm)
1.	Co A 05323	114.60	3.63	1.49	3.25
2.	Co V 92102 (C)	99.00	3.13	1.60	3.05
3.	Co 7219 (C)	103.30	3.26	1.22	2.72
4.	Co86249 (C)	88.00	3.53	1.18	2.44
	CD at 5%	19.81	0.59	0.23	0.32
	C.V. (%)	11.11	10.04	9.80	6.36

Table 2d. Performance of Co A 05323, in Advance Varietal Trials for juice quality parameters (2008-09 to2009-10)

S. No.	Clone	Brix percent				Sucrose percent				Purity percent				CCS percent			
		P1	P2	Ratoon	Mean	P1	P2	Ratoon	Mean	P1	P2	Ratoon	Mean	P1	P2	Ratoon	Mean
1.	Co A 05323	20.26	19.56	21.23	20.35	18.00	17.95	18.00	17.98	88.84	87.72	86.87	87.84	12.82	13.17	12.53	12.84
2.	CoV92102(C)	19.80	21.60	22.23	21.21	17.90	19.60	19.07	18.86	90.40	90.74	90.78	90.64	12.86	14.10	13.35	13.44
3.	Co 7219 (C)	19.67	19.47	20.18	19.77	17.80	18.00	18.20	18.00	90.49	89.27	89.24	89.67	12.80	13.06	13.06	12.97
4.	Co 86249 (C)	20.00	19.80	19.26	19.69	17.75	17.40	17.46	17.54	88.75	87.88	89.04	88.56	12.64	12.33	12.56	12.51
	CD at 5%	0.66	0.64	0.56		0.46	0.41	0.41		2.61	4.59	1.45		0.77	11.20	13.17	
	C.V. (%)	1.80	1.88	1.73		1.56	1.29	1.29		1.70	2.93	0.66		3.40	0.63	0.55	

Table 3. Reaction of Co A 05323, a millable clone against red rot and smut

S. No.	Clone	Red rot								Smut
		Nodal				Plug method				
		Cf 419	Cf 671	Cf 997	Mixture	Cf 419	Cf 671	Cf 997	Mixture	
1.	Co A 05323	R	R	R	R	R	R	R	R	MS
2.	Co V 92102(C)	R	R	R	R	R	R	R	R	MS
3.	Co 7219(C)	R	R	R	R	R	S	S	S	MS
4.	Co 86249(C)	R	R	R	R	R	R	R	R	R

pathotypes of red rot . The clone Co 7219 showed field resistance to red rot under plug method. The clone Co A 05323, Co V92102 are moderately while Co 86249 recorded resistant reaction to smut under artificially inoculated conditions.

CONCLUSION

The promising midlate clone Co A 05323 with erect and non lodging growth habit, desirable morphological characters, higher cane, sugar yield and resistance to red rot can be recommended for commercial cultivation in Andhra Pradesh under different sugar factory operational zones.

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Indian Journal of Sugarcane Technology 2011 26(1) : 24-27

Impact of different vernalization treatments on flowering and seed production in sugar beet (*Beta vulgaris* L.)

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ABSTRACT

Seed production is the most important limitation to sugar beet (*Beta vulgaris* L.) production in the India which is dependent on usually insufficient cold climate except foot hill of Himalaya. Sole dependence on a particular area is not the answer to the problem. An economically and environmentally desirable solution is to develop a technique to sustain seed production in area where cold climate is no longer persisting. The objectives of this study were to study the effect of direct Seeded, transplanting and cold treatment on seed yield and component characters of sugar beet. Already stable varieties for Indian conditions were taken for experiment *viz.* (Variety-1 = LS-06 and Variety-2 = IISR Comp-1). Four treatments were given : T1-Steckling, T2-*In situ* (Direct seeded), T3-In pit at Mukteshwar transplanted at Mukteshwar in march, T4-Cold treatment at Lucknow and transplanting at Mukteshwar in March. Days to bolting, days to stalk formation, date of first flowering, number of sub branches, stalk length (cm), test weight (100 seed), yield/plant and germination % were measured over two growing seasons during 2006–2008. Study revealed that the T2 were significantly higher for days to bolting for both variety (250.33 for V2 and 250.00 for V1) which was at par with other treatments T3 and T4 in both variety. Overall T2 in V2 showed significant response to other attributing characters *viz.* days to bolting, days to stalk formation, date days to first flowering, number of sub branches, stalk length (cm), test weight (100 seed), germination % and highly effective for yield/plant (g) *i.e.,* 125.32 g. Resultantly, variety IISR Comp-1 performed well in each treatment while variety LS-6 performed satisfactory only in the second treatment.

Key words: Sugar beet, Vernalization, Treatment

Sugar beet (*Beta vulgaris* L.) has its origin in early nineteenth century from feral and fodder beets (Achard, 1979; Marggraf, 1979). Sugar beet has been specially selected and bred for sucrose production over the past two centuries (Winner 1993). Its ability of sugar manufacture is determined by the stability of yield and the quality (saccharose content) of sugar beet. It is a biennial plant and during the first growing season it produces large succulent roots. In the second growing season a vernalization period (normally 10-14 weeks at 4^0-8^0C) as well as certain requirements of light must be fulfilled before flowering. This switches the plant from vegetative to reproductive growth. The range and duration of low temperature, the genotypes, day length and plant age will also influence the generative phase (Lexander, 1980). The biennial beet requires that the steckling be removed from the ground for protection against freezing. They are then replanted in the spring for seed production in the fall.

Agronomical factors such as planting density, steckling weight, harvesting date and method as well as application of chemical materials affect qualitative characteristics of sugar beet seed – bearing plants through affecting plants ripening uniformity (Bordei and Tapus, 1981). Because of the importance of the effect of steckling weight and planting density on sugar beet seed production, a number of experiments have been conducted but the effect of different treatments, *viz.,* direct sowing, transplanting and cold treatment and varietal response to these treatments still needs attention under Indian conditions. Considering these an attempt has been made to study the relationships between these factors with quantitative characters contributing production of sugar beet seed in India.

MATERIALS AND METHODS

This research was conducted to study the effect of direct seeded, transplanting and cold treatment on seed yield and component characters of sugar beet. Field trials and glass house experiment were carried out in I.I.S.R, Lucknow and Regional station at Mukteshwar, Nainital in two successive seasons of 2006/2007 and 2007/2008 in 3 replications. Already stable varieties for Indian condition were taken for experiment, *viz.,* LS-06 and IISR Comp-1, which were most suitable for studying effect of different treatments without or minimal error.

In order to study the genetic and seed yield attributes against effect of different treatments a two-year field examination was conducted using complete randomized block design with three replications during 2006 to 2008. Sugarbeet were sown in line, 50 cm apart, on flat beds or on ridges which were kept 10-12 cm high and 20 cm wide. The seed bed was prepared in the same manner as for sowing (Theurer and Doney, 1980). The land was prepared to a good tilth.

Field trials were carried out in I.I.S.R, Lucknow and trial station at Mukteshwar, Nainital in two successive seasons of 2006 and 2008. The climate of first experimental site mukteshwar Station was 29º 23' N, 79º 30' E with 2286 meter altitude, classified as "cool temperate"; the monthly maximum and minimum temperature of the town ranged between 28.06 ^{0}C and 7.06 ^{0}C," with an average annual precipitation of 380 mm. The soil texture of the location was sandy clay with neutral pH reaction. Second experimental site Lucknow (80º 45'–53' E, 26º 40'–45' N) has soil texture - sandy, loam and clay. 120 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha were applied. Potassium and phosphorous were applied on the basis of soil test values, at three stages including once at sowing date, once at thinning and the last one immediately after earthling–up in December.

Each trial included four treatments representing the T1-Steckling, T2-*In situ* (Direct seeded), T3-In pit at Mukteshwar transplanted at Mukteshwar in March, T4-Cold treatment at Lucknow and transplanting at Mukteshwar in March. The two varieties were seeded October, 2006-2008 into soil in Lucknow, 3 cm in diameter X10 cm deep. The plants were watered daily. Seedlings were 4 weeks old (4- to 6- leaf stage) when they were transplanted to the field in December, 2006–2008.

Days to bolting, days to stalk formation, days to first flowering, number of sub branches, stalk length (cm), test weight (100 seed), yield/plant and germination % were measured over two growing seasons during 2006–2008. Data were recorded for 20 plants that had been randomly chosen from the middle rows in each plot days to bolting, days to stalk formation, date to first flowering were recorded after first emergence. Number of sub branches and stalk length (cm) were recorded for each plot and at the full maturity. Test weight (100 seed), yield/plant and germination % were recorded just after the harvesting.

RESULTS AND DISCUSSION

For sugar beet breeding, several physiological and agronomic traits with varying complexity are of utmost economic relevance (Draycott 2006). This makes sugar beet as an attractive model crop for genetic studies.

Seed yield attributing characters as influenced by different treatments

For the better seed yield performance of different treatments were studied and result revealed that the treatment -2 was highly significant for days to bolting for both variety (250.33 for V2 and 250.00 for V1) which was *at par* with treatment- 3 and treatment -4 in both the varieties (table-1). Similarly Abo-Elwafa et al. (2006) in Egypt found that extending vernalization duration led to an increase in the percentage of bolting% in both seasons. Treatment-1 was not satisfactory for the days to bolting in both the varieties. Overall treatment-2 in V2 showed significant response to other attributing characters *viz.* days to bolting, days to stalk formation, date to first flowering, number of sub branches, stalk length (cm), test weight (100 seed), germination % and highly effective for yield/plant (g), *i.e.,* 125.32 g. Similarly, Atia (2000), in Kaliobia, Egypt, reported that vernalization

Table 1. Seed yield attributing characters as influenced by different treatments

Treatments	Days to bolting	Days to stalk formation	Date to Ist flowering	Number of sub branches	Stalk Length (cm.)	Test weight (100 seed)	Yield per plant	Germination %
T1V1	106.33	145.00	167.33	19.33	127.00	2.36	7.54	90.00
T1V2	105.33	136.00	167.00	27.93	146.20	19.19	59.70	90.37
T2V1	250.00	321.33	342.33	22.80	159.73	2.99	27.83	87.97
T2V2	250.33	311.33	311.33	28.47	183.53	4.41	125.32	90.53
T3V1	158.67	159.67	190.67	14.07	127.40	1.75	2.92	88.07
T3V2	150.67	161.67	191.00	21.80	158.73	4.09	52.46	86.13
T4V1	182.67	188.00	231.00	16.00	149.44	1.99	2.41	68.47
T4V2	185.33	221.00	251.67	15.33	140.44	3.54	23.93	62.57
CD	11.74	14.33	11.39	4.61	12.58	0.87	5.84	3.95
CV	3.69	4.01	2.81	13.81	5.23	14.38	12.9	2.78

T1-Steckling, T2-In-situ, T3-In pit transplanted at Mukteshwar in March, T4-Cold treatment at Lucknow and transplanting at Mukteshwar in March, V1-LS6, V2- IISR-Comp1

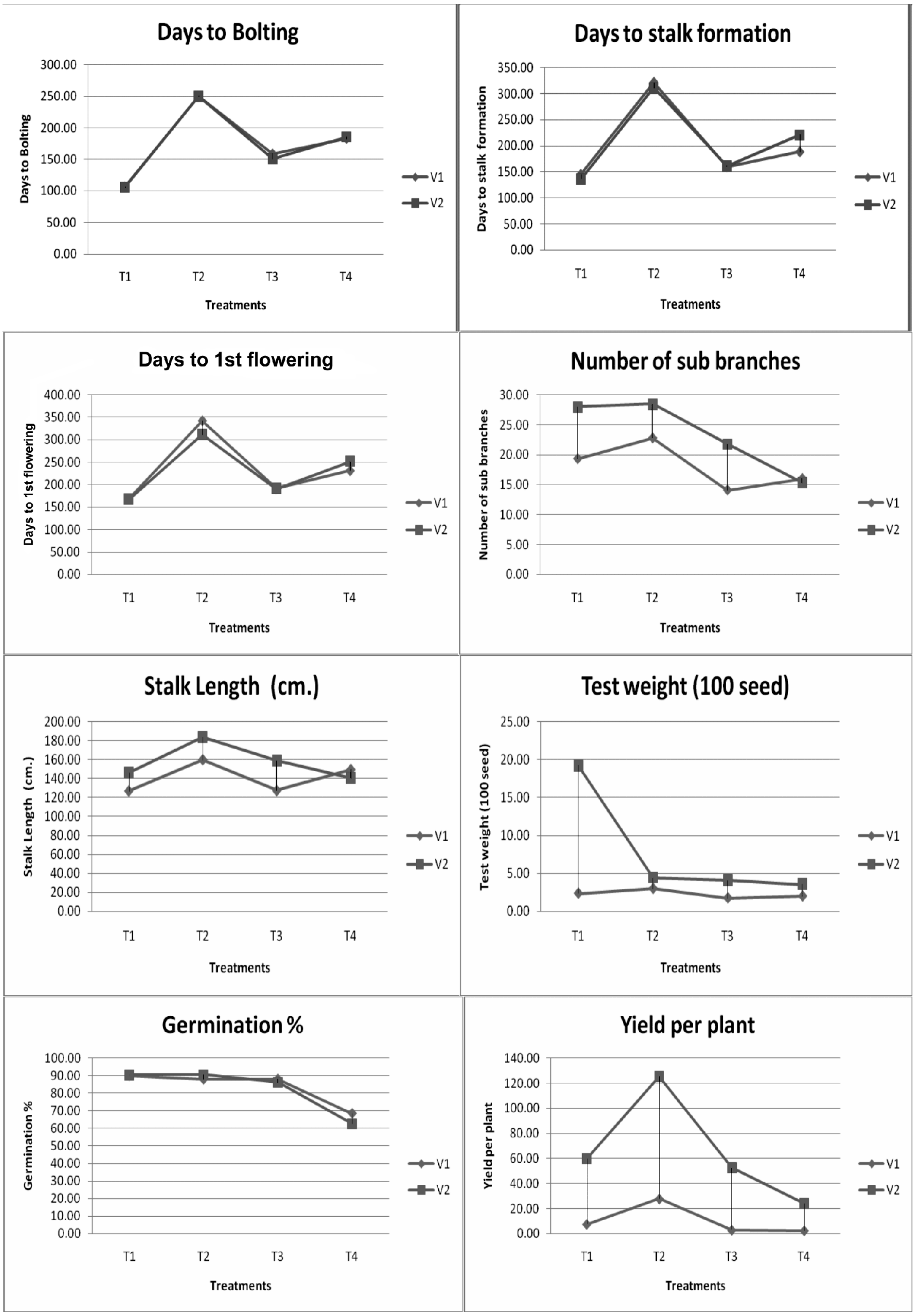

Fig. 1. T1-Steckling, T2-*In-situ*, T3-In pit transplanted at Mukteshwar in March, T4-Cold treatment at Lucknow and transplanting at Mukteshwar in March; V1-LS-6, V2- IISR Comp-1

Table 2. Estimation of genetic parameters for seed yield and its components in sugar beet

S.No.	Characters	CD	CV	Vg	Vp	H^2bs
1	Days to bolting	3.33	1.02	3082.10	3086.73	1.00
2	Days to stalk formation	5.05	1.30	5371.86	5382.51	1.00
3	Date to I[st] flowering	4.68	1.07	4363.04	4372.21	1.00
4	No. of sub branches/plant	2.52	6.32	34.09	36.75	0.93
5	Stalk Length (cm.)	3.71	1.32	291.35	297.11	0.98
6	Test weight (100 seed)	0.11	1.87	1.14	1.15	1.00
7	Yield /plant	2.37	3.22	1708.26	1710.61	1.00
8	Germination %	3.68	2.34	119.39	125.04	0.95
9	Days to Maturity	3.84	0.64	4058.31	4064.47	1.00

Table 3. Correlation coefficients of seed yield and component characters in sugar beet

	Yield per plant	Days to bolting	Days to stalk formation	Date to Ist flowring	Number of sub branches	Stalk Length (cm.)	Test weight (100 seed)	Germination %
Yield per plant	1							
Days to bolting	0.3910	1						
Days to stalk formation	0.6812	0.925805	1					
Date to I[st] flowring	0.6156	0.946582	0.994189	1				
Number of sub branches/plant	0.9248	0.077067	0.432509	0.34908	1			
Stalk Length (cm.)	0.756	0.300376	0.515786	0.490979	0.653226	1		
Test weight (100 seed)	0.4417	-0.59201	-0.24453	-0.30965	0.720849	0.357276	1	
Germination %	0.5256	-0.15461	0.038625	-0.05008	0.61731	-0.0623	0.436016	1

had a significant effect on yield attributing characters and in Netherlands, Smith (1982) reported that the cold temperature duration influences the flowering proportion of plants. Subsequently, other treatments T1V2 and T3V2 were also effective for yield in positive direction with 59.70 g, and 52.46 g. whereas, T3V1 and T1V1 showed negative effect on yield. In our study also long duration of vernalization in treatment-2 on both varieties produced high seed yield.

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Indian Journal of Sugarcane Technology 2011 26(1) : 28-30

Impact of age and type of planting materials on the incidence of shoot borer *Chilo infuscatellus* (Snellen), yield and quality under late summer planted sugarcane

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ABSTRACT

Field experiment was conducted at Sugarcane Research Station, Melalathur, Tamil Nadu Agricultural University during 2005-2008 in Randomized Block Design with three replications. The thirty days old raised bed seedlings and polybags seedling were transplanted on the same day of single bud setts planted directly in the field. The seedlings were transplanted in the main field on 30 days after shoot borer observation taken. The intercrops were sown 3rd day after planting / transplanting and incorporated insitu in the field on 90th day at the time of earthing up. The incidence of was shoot borer recorded on 30th, 60th and 90th days on the basis of number of shoot affected with respect to total number of shoots and cumulative shoot borer incidence was worked out. Single bud setts directly planted on one side of ridges + black gram on the other side, recorded the lowest cumulative shoot borer incidence of 21.35 per cent. The raised bed seedlings were more susceptible to shoot borer (33.41%) than polybag seedling (31.06 %) and single budded direct planting (22.10%). Sugarcane intercropped with blackgram reduced the shoot borer incidence in all the treatments due to changes in the micro climate developed by the intercrops and non host crops acted as physical barrier. The highest sugar yield of 13.62 t/ha was obtained from cane yield of 101.55 t/ha with CCS% of 13.41 in single budded direct planted on one side of the ridges+ blackgram on the other side.

Key word: Shoot borer, cane yield, single budded direct planting, Type of planting material

Sugarcane is one of the most important commercial crops in India. Globally, India ranks second in area (20.4%) and production (18.6%) among sugarcane growing countries of world. In India, sugarcane is cultivated in an area of 4.2 million ha with total production of 281 million tones of cane with average productivity of 66.7 t/ha (Mahesh *et al*., 2010).

In Tamil Nadu, sugarcane is cultivated in 3.2 lakh ha with an average productivity of 100 t/ ha. More than 200 species of insects causing damage to sugarcane crop during the course of its germination, growth and maturity. Among these, shoot borer *Chilo infuscatellus (*Snellen) assuming serious pest status in subtropical situation where because of availability of a conducive environment for their population build up, the field and factory losses are substantially high because important sugarcane varieties have invariably been found to be more susceptible to shoot borer which is not even effectively controlled with pesticides, because of their concealed habitat (Jaipal and Singh, 2010)

The type of planting material, its age and spatial arrangement in the field plays major role to maintain the micro climate in the cropping area. Farmers mostly use the conventional method of planting with two bud setts in ridges and furrows. Recently, the interest of farmers and researchers have changed their focus to various methods of planting with seedlings and varied plant geometry in the field. Because of this, the interest of cultivator have increase in planting of sugarcane with various method of planting using polybag seedling, raised bed seedling, single bud, spaced transplanting method and direct planting of single bud in addition to conventional method of planting. Many worker studied the intercropping with legumes might have the effect of population built-up shoot borer because change the relative humidity at canopy level (Misra and Hora, 1982; Sardana, 2000; Thirumurugan *et al*., 2001; Thirumurugan and Koodalingam, 2005). Sikchi *et al.,* (1989) reported the high shoot borer incidence on 45 -50 days old transplanted seedlings under drought situation. However, no information is available on the impact of age and varied planting materials coupled with intercropping on the incidence of shoot borer and yield quality parameters. Hence, the present investigation was taken to study the effect of seedling age and type of planting materials on the incidence of shoot borer, its yield and quality of cane.

MATERIALS AND METHODS

A field experiment was conducted in clay loam soil of Sugarcane Research Station, Melalathur during 2005-2008 with variety CoG 94077 planted in plots measuring 20 m^2 each at 80 cm spacing in Randomized Block Design replicated thrice to study the impact of age and type of planting materials on the incidence of shoot borer *Chilo infuscatellus* (Snellen), yield and quality under late planted summer sugarcane crop.

The treatments includes, T_1 - 30 days old Single bud raised bed seedlings transplanted in furrow; T_2 - 30 days old Single bud polybag seedlings transplanted in furrow; T_3 - 30 days old Single bud raised bed seedlings transplanted on one side of the ridges;T_4 - 30 days old Single bud polybag seedlings transplanted on one side of the ridges; T_5 - 30 days old Single bud raised bed seedlings transplanted in one side of the ridges + black gram on other side; T_6 - 30 days old Single bud polybag seedlings transplanted in one side of the ridges + black gram on other side; T_7 - Single bud setts direct planting in furrows and T_8 - Single bud setts direct planting in furrows on one side of the ridges + black gram on other side of the ridges.

The seedlings were transplanted on 30 day after establishment at the distance of 30 cm in furrows and on ridges after shoot borer incidence observation taken. The shoot borer incidence was recorded on 30th, 60th and 90th days after planting in T_7 and T_8 whereas in T_1 to T_6 the shoot borer incidence was recorded 30th days at nursery, 60th and 90th days in main field and cumulative shoot borer incidence was worked out. The yield parameters were recorded at the time of harvest. The data was analyzed statistical tools (Panse and Sukhatme, 1985).

RESULTS AND DISCUSSION

The shoot borer incidence was recorded on 30th, 60th and 90th days. Cumulative incidence was worked out and presented in Table 1. From the data shown single budded direct planting on one side of the ridges and blackgram on other side recorded lowest shoot borer cumulative incidence of 21.35 % followed by single budded direct planting in furrows 22.84 % as compared to 36.76 % in 30 days old raised bed seedlings planted in furrows and 32.91 % in 30 days old polybag seedling planted in furrow. Thirty days old raised bed seedlings were more susceptible to shoot borer which reflected in higher percent of cumulative shoot borer incidence (33.41%) as compared to 30 days poly bag seedlings (31.07%) and single bud sett direct planting (22.84%) (Fig 1). It might be due to transplanted seedlings are weaker and low vigor during the early establishment stage and ultimately resulted in highly vulnerable for shoot borer attack. This was in conformity with the findings of Sikchi *et al.*(1989) who reported higher incidence of shoot borer in 45-50 days old transplanted seedlings because after transplanting, seedlings were weaker and highly vulnerable for attack as compared to single budded sett direct plantings. Irrespective of type of seedling used for planting the intercrop reduced the incidence of shoot borer (Fig 2) due to changes in micro climate and faster growth, which were unfavorable to shoot borer multiplication. The non host crops might have also acted as physical barrier preventing initial build up of shoot borer population (Sardana, 2000 and Thirumurugan and Koodalingan, 2005).

Data on yield parameters (Table 1) revealed highest number of millable cane (104040 /ha) in single budded setts direct planting on one side of the ridges + blackgram on other side followed by single budded setts direct planting in furrows (103550/ ha) and former recorded the highest cane yield (104.55 t/ha) which was on par with single budded setts direct planted in furrows (98.53 t/ha). Single budded setts direct planting methods recorded higher cane yield (104.55 t/ha) than 30 days old polybags seedlings used (84.08 t/ha) and 30 days old raised bud seedlings (74.57 t/ha) (Fig 1).

Intercropping of blackgram in single budded setts direct planted cane or cane seedlings had increased the sugarcane yield in all the treatment due to nodulation of legume crops and fixation of N in the soil which was available to the cane

Table 1. Impact of age and type of planting materials on the incidence of shoot borer, yield and quality of sugarcane

Treatments	Cumulative shoot borer incidence (%)	% of Shoot borer increased over T8	Tiller population (000/ha)	Millable cane population (000/ha)	Cane yield (t/ha)	CCS (%)	Sugar yield (t/ha)
T_1	36.76	72.18	80.70	81.74	74.57	13.39	9.98
T_2	32.91	54.15	90.76	88.60	84.08	13.36	11.23
T_3	32.40	51.76	78.42	72.69	70.23	13.31	9.35
T_4	32.10	50.35	93.82	94.24	93.19	13.32	12.41
T_5	31.07	45.52	70.50	88.49	81.84	13.51	11.06
T_6	28.17	31.94	92.80	98.27	98.17	13.36	13.11
T_7	22.84	6.98	108.14	103.55	98.53	13.39	13.19
T_8	21.35	-	109.38	104.04	104.55	13.41	13.62
CD (=0.05)	7.05	-	22.39	8.24	8.62	NS	1.50

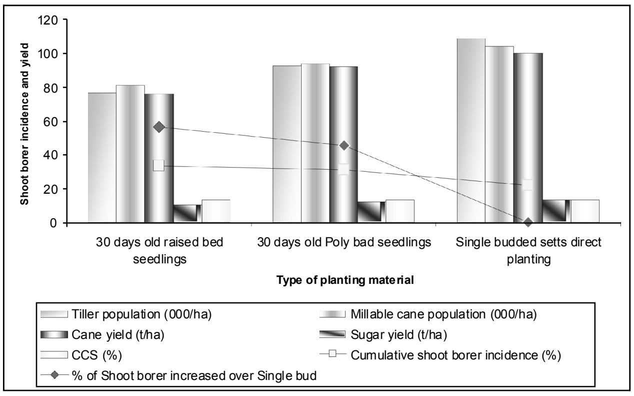

Fig 1. Impact of type of planting material on shoot borer incidence and yield

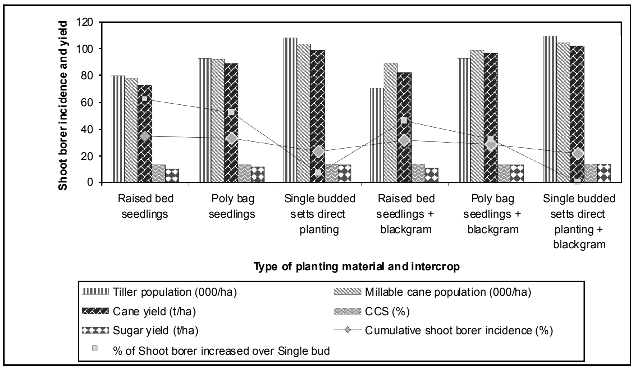

Fig 2. Impact of type of planting material and intercrops on shoot borer incidence and yield

crop over and above the applied N as reported by Maragathamani (1993) in cotton and blackgram and Thirumurugan and Koodalingan (2005) sugarcane with green gram or sunhemp intercropping system. No change in commercial cane sugar (CCS %) was observed due to age of seedlings and different type of planting material used. The single budded setts direct planting on one side of ridge and blackgram on other side recorded the highest sugar yield of 13.62 t/ha.

CONCLUSION

Planting single budded setts direct with or without intercropping could manage shoot borer attack than polybag seedlings and raised bed seedlings. Intercropping with blackgram with sugarcane was helpful in reducing shoot borer incidence in late (summer) planted crops and also increased the cane and sugar yield.

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Assessment of compatability of recommanded insecticides with *Thrichogramma chilonis* Ishii in laboratory conditions

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ABSTRACT

Laboratory studies were carried out to compare the toxicity of the six insecticides, *viz.*; nuvan, imidacloprid, malathion, monocrotophos, endosulfan and chloropyriphos during 2009-10 with respect to adult emergence and per cent parasitization of *Trichogramma chilonis* Ishii. The result reveals that imidacloprid-17.8 SL (@ 0.5 ml/L) was found to be comparatively safe to the parasitoid with least effect on the adult emergence and parasitization of *Chilo tumidicostalis* Ishii. The toxicity of other insecticides in descending order was $T_1 > T_3 > T_4 > T_6 > T_5$ with 19.67 : 18.67; 22.67 : 20.67; 33.00 : 34.33; 40.33; 37.00 and 54.00; 52.57 of per cent adult emergence and parasitization, respectively.

Key words : Compatiability, insectides, Trichogramma chiloris, Parasitoid, Sugarcane.

Sugarcane is an important commercial crop of Bihar, Many factors effect the yield of this important crop including borer complex. Among these borer complex of Sugarcane, Root borer, Shoot borer, Top borer, Stem borer and Plassey borer are considered to be the major problem, which can effect the quality and quantity of cane at harvest. *Trichogramma chilonis* Ishii is widely used natural enemy against these borer complex. *Trichogrammatid* egg parasitoids are considered to be most useful biological control agents for inundative release against lepidopterous pests (Singh and Jalali 1994).

Trichogramma chilonis is important in suppressing insect pest-population. Conservation of these bio-agent is a valuable in integrated pest management approaches in sugarcane. Keeping this view an experiment was formulated and conducted in laboratory to screened for their comparative safe to bio-agents among the locally available insecticides and commonly used in sugarcane under north Bihar sugarcane agro ecosystem. The present study will be focused only on the effect of insecticides on *Trichogramma chilonis* Ishii.

MATERIALS AND METHODS

Present investigation were carried out in the laboratory of Department of Entomology, Sugarcane Research Institute, Rajendra Agricultural University, Bihar, Pusa during 2009-10. The layout-system was CRD with three replications and six insecticides treatment viz. Nuvan 100 EC, Imidacloprid 17.8 SL, Malathion 50 EC, Monocrotophos 36 SL, Endosulfan 35 EC, Chloropyrifos 20 EC excluding control (untreated). *T. chilonis* was mass cultured on the eggs of rice moth *C. cephalonica*. The fresh corcyra eggs were collected and sterilized under UV radiation to avoid the emergence of *C. cepholonica* larvae. The 100 no. of sterilized eggs were than pasted on paper cards. These eggs cards were placed in polythene bags along with a nucleus cards at 6:1 ratio for parasitization and these cards used for conducting the experiment. The cards were sprayed with recommended dose of above mentioned insecticides and untreated (control) cards were sprayed with water. All the treated cards kept separately in glass vial to record the adult emergence, from emerged *T. chilonis* adult, ten mated female were exposed to 100 fresh *C. cephalonices* eggs for 24 hrs. to record the parasitization per cent emergence and parasitization was worked out using the following formula :

$$\text{Per cent of emergence} = \frac{\text{No of wasps emerged}}{\text{Total no of eggs}} \times 100$$

$$\text{Parasitization per cent} = \frac{\text{No of parasitized eggs}}{\text{Total no of corcyra eggs}} \times 100$$

RESULTS AND DISCUSSION

Data on toxicity effect of insecticides with respect to adult emergence and parasitization percentage of *Trichogramma chilonis* Ishii summerised in table 1. The result showed that adult emergence and parasitization percentages were reduce significnalty over control (89%) after sprayed of different doses of insecticides. Among tested insecticides maximum (67%) emergence with imidachloprid was recorded which was significantly higher than other insecticides followed by 54.00 and 40.33 per cent emergence with endosulfan and chloropyrifos, respectively. The emergence per cent (33.00) was recorded with monocrotophos which was at par from endosulfan. The minimum (19.67%) emergence was recorded while nuvan was sprayed which was at par from malathion (22.67%) emergence. Hence, the compatibility of insecticides were found to be in order of their merit in order as $T_1 < T_3 < T_4 < T_6 < T_5 < T_2$ in adult emergence of *Trichogramma chilonis*. Hussain *et al.* (2010) studied *Trichogramma* exposure to insecticides, imidachloprid, abametin, friflumuron, emamectin benzoate, indoxacarb and lufenuron had 70.02, 32.19, 27.62, 25.98, 21.45 and 18.48 per cent survival, respectively, after 4 hours but after 24 hours none of the insecticides was safer for *Trichogramma chilonis* adult emergence at Entomological Research Institute, AARI, Faisalabad, Pakistan during the year 2008-09.

For compatibility with respect to percentage of parasitation by *Trichogramma chilonis* reveals that the maximum (72.00%) parasitization per cent was recorded with imidachloprid which was highly significantly among all the treatments. Next compatibility with endosulfan as per cent parasitization being 52.67 which was at par from chloropyrifos (37.00%) and 34.33 per cent parasitization with monocrotophos. The minimum (18.67%) parasitization was recorded with nuvan showing highly toxic to parasitization of *T. chilonis* as compared to other treatments of insecticides. It was also indicated that per cent parasitization with all treatment of insecticides were significantly reduced over control (84.33%). Similar, Singh and Shenhmar (2008) reportd that five insecticides viz., malathion, endosulfan, imidacloprid, triazophos and chloropyriphos were evaluated for their impact on some biological parameters of egg parasitoid *T. japonium* (Ashmead). Endosulfan (@ 394 g ai/ha) was found to be comparatively safe to the parasitoid with least effect on the emergence and parasitization of parents as well as their progency, while malathion (@ 1250 g ai/ha) and chloropyriphos (@ 175 g ai/ha) were highly deleterious. The toxic effect of imidacloprid (@ 20 g ai/ha) and triazophos (@ 600 g ai/ha) were in between endosulfan and malathion.

Table 1. Effect of insecticides on adult emergence and parasitization of *Trichogramma chilonis*

Treatment	Dose (ml lit.$^{-1}$)	*Per cent adult emergence	*Per cent parasitization
T_1 - Nuvan-100 EC	1.0	19.67	18.67
T_2 - Imidacloprid-17.8 SL	0.5	67.00	72.00
T_3 - Malathion-50 EC	1.0	22.67	20.67
T_4 - Monocrotophos-36 SL	1.0	33.00	34.33
T_5 - Endosulfan-35 EC	1.5	54.00	52.67
T_6 - Chloropyrifos-20 EC	3.0	40.33	37.00
T_7 - Control (Water spray)	-	89.00	84.33
SEm (±)	-	3.54	4.43
CD (p = 0.05)	-	10.71	13.41

*Mean of three replications

This it may be concluded that among six insecticides, imidacloprid-17.8 SL (@ 0.5 ml/litre) was found to be comparatively safe to the parasitoid with least effect on the adult emergence and parasitization of *Chilo tumidicostalis* Ishii. According to Kaur *et al.* (2010) *Trichogramma brasiliensis* Ashmead is a common egg parasitoid of cotton ballworms, but due to indiscriminate use of insecticides, its effectiveness is reduced. The toxicity of insecticides in descending order was endosulfan > monocrotophos > cypermethrin > climethoate > dimethoate > NSKE > Bt had 54.36; 43.30, 32.03, 16.78, 13.27 and 4.75 per cent mortality, respectively. Their persistence was 9, 9, 5, 4, 3 and 0 days after application, respectively.

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Evaluation of insect pest management methods against cane borers of sugarcane in ratoon crop

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ABSTRACT

Field experiments were conducted to evaluate the role of variety and effectiveness of biological control, chemical control and mechanical & cultural intensive methods of insect pest management in sugarcane ratoons for three crop seasons i.e. 2000-01, 2001-02 and 2002-03 at Indian Institute of Sugarcane Research, Lucknow. The experiments were laid out in split plot design with two sugarcane CoLk 8102 (susceptible) and CoS 767 (tolerant) varieties as main treatment and three Insect Pest Management methods viz., bio-control method, chemical control method and mechanical & cultural control method as sub treatments against cane borers (*Chilo auricilius* Dudgeon and [(*Chilo sacchariphagus indicus* (Kapur)]. First ratoon was initiated in February 2000 with harvest of crop planted in February 1999 and the same practice was adopted further for next two ratoons during 2001-2002 and 2002-2003. Bio-control method included field releases of *Trichogramma chilonis* Ishii @ 50,000 ad/ha at 10 days interval from July to October and *Cotesia flavipes* Cameron @ 500 gravid females / ha at weekly interval from July to November. The chemical intensive included foliar spray of monocrotophos @ 0.75 kg a. i./ha in August and September. Mechanical and cultural method included removal of infested canes and water shoots. Infestation of stalk borer in CoLk 8102 varied from 42.73 to 52.28 percent as against 17.16 to 41.81 percent in CoS 767. Incidence of internode borer was varied 14.71 to 27.55 % in CoLk 8102 as against 7.17 to 19.50 % in CoS 767. Apart from high infestation of borer pests CoLk 8102 responded higher cane yield over CoS 767 because CoLk 8102 is a high yielder sugarcane variety.

Key words: Chilo auricilius, Chilo sacchariphagus indicus, Internode borer, Stalk borer, Sugarcane.

In India, ratoon shares about 50-55 percent of total area under sugarcane cultivation. The sugarcane growers take one or more ratoons from one plant crop. In general cane yield in ratoons is low because of pests and low inputs by the marginal farmers. Being a long duration crop (12-18 months) it is attacked by a number of insect pests, out of them about one dozen borers cause an economic loss to the crop right from stubble sprout till harvest. Stalk borer (*Chilo auricilius* Dudgeon) and internode borer [(*Chilo sacchariphagus indicus* (Kapur)] are the major pests and cause an economic loss to the crop from July to November when cane formation starts. Internode borer (*C. sacchariphagus indicus*) damages the ratoon crop and constitutes about 10.7 percent reduction in cane yield while stalk borer (*C. auricilius*) causes 31.8 percent reduction in cane yield and 5.3-20.4 percent reduction in sugar recovery (Singh *et. al.,* 1973). In sugarcane chemical control is most prevalent but it is not adoptive due to high cost and dense canopy of crop. Several workers have advocated the efficacy of biological control of borer pests of sugarcane (Mishra *et al.,* 1986, Varma *et al.,* 1991 and Tiwari *et al.,* 1996). Moreover, chemical pesticides result in the development of resistance in insect to insecticides, loss of bio-diversity, resurgence of pests and secondary pests out breaks apart from environmental contamination. It led to evaluate mechanical & cultural and biological control against borers as alternative and eco friendly pest control methods. Therefore, a field experiment was carried out to evaluate three insect pest management tactics (Chemical control intensive method, mechanical & cultural intensive method and biological control intensive method) against these two borers in ratoon crop for three consequence cropping season (2000-01, 2001-02 and 2002-03) at I.I.S.R. Research farm at Lucknow.

MATERIALS AND METHODS

Field experiments were carried out to evaluate different insect pest management methods in ratoon at IISR Research farm for three crop seasons (2000-01, 2001-02 and 2002-03). First ratoon was initiated in February 2000 with harvest of crop planted in February 1999 and the same practice was adopted further for next two ratoons during 2001-2002 and 2002-2003. The experiment was laid out in split plot design with two main plots i.e. tolerant (CoS 767) and susceptible (CoLk 8102) variety and four sub plots i.e. T_1. Biological control intensive method, T_2.Chemical control intensive method, T_3.Cultural & mechanical control intensive method and T_4. Untreated control. Details of Insect Pest Management methods are given in table 1. Four replications for each treatment were maintained. Plot size was measured 6 m X 7.2 m separated by 1.8 meter path all around the plots. *T. chilonis* @ 50,000 adults /ha (216 gravid female / plot) and *C. flavipes* @ 500 gravid females /ha (Two female / plot) were released during dusky hours of evening in the central place of the experimental plots. Release of parasites was started with the release of *C. flavipes* followed by *T. chilonis* on third day of release of *T. chilonis* to adjust three releases of *T. chilonis* and four releases of *C. flavipes* in one month. Insecticide spray (monocrotophos 0.05%) was done twice at monthly intervals (in August and September) after removing the dry leaves from the cane to facilitate contact toxicity of the insecticides against cane crawling larvae borers. Recommended agronomic practices were given timelyto raise a good crop. Observations infestation of stalk borer and internode borer were recorded in August and September and cane yield was recorded at harvest in January. The results were statistically analyzed.

RESULTS AND DIUSCUSSION

The data on stalk borer infestation during 2000-2001 and 2002-03 indicated that the infestation significantly higher in CoLk8102 than CoS 767. Infestation of stalk borer during 2000-01 in CoLk8102 ranged from 42.73 to 52.28 percent as against 17.16 to 21.29 percent in CoS 767. During 2001-02, infestation of stalk borer was high in both of the varieties. Infestation of stalk borer during 2002-03 was significantly higher in CoLk 8102 (43.35 to 51.57 per cent) over CoS 767 (29.17 to 41.81 percent) (Table 2). Tanwar *et al.,* (2003) reported significantly low incidence of stalk and top borer in CoLk 8102 over CoS 767. Incidence of stalk and internode borer was low in biological control and mechanical control intensive methods during 2000-01 and 2001-02. Saroj, Jaipal (2000) evaluated some IPM modules against insect pests of sugarcane and found that mechanical control and biocontrol based modules helped in reducing the incidence of third brood of top borer and incidence of stalk borer was reduced by innundative releases of *T. chilonis* (egg parasitoid) along with propping of cane stalks.

The data on infestation of internode borer revealed that incidence during 2000-2001 and 2002-03 was significantly higher in CoLk 8102 in comparison to CoS 767. Infestation of internode borer during 2000-01 in CoLk 8102 ranged from 14.71 to 21.53 percent as against 7.17 to 11.67 percent in CoS 767. During 2001-02, incidence was low of pest (6.34 to 7.70 percent). Infestation of internode borer during 2002-03 was significantly higher in CoLk 8102 (24.73 to 27.55 per cent) over CoS 767 (13.02 to 19.50 percent) (Table 2). Incidence of internode borer was low in biological control and mechanical control intensive methods during 2000-01 and 2001-02. Saroj Jaipal (1996) evaluated *T. chilonis* against *Chilo auriclius* and found considerable reduction in borer incidence.

The data on cane yield showed that cane yield during 2000-2001 and 2002-03 was significantly higher in CoLk 8102 than CoS 767 as it is a high yielder variety. Cane yield during 2000-01 in CoLk 8102 ranged from 51.53 to 68.48 t/ ha as against 34.66 to 39.46 t/ha in CoS 767. During 2001-02 cane yield was higher in both of the varieties but difference in cane yield was not significant. Cane yield in CoLk 8102 ranged from 94.74 to 100.67 t/ha and it ranged from 77.49 to 95.42 t/ha in CoS 767. Cane yield during 2002-03 was significantly higher in CoLk 8102 (57.97 to 67.41 t/ha.) over CoS 767 (35.92 to 56.27 t/ha) (Table 2). Tanwar *et al.,* (2003) also reported higher cane yield in CoLk 8102 over CoS 767.

Main treatment (sugarcane varieties) have significant role in cane yield in ratoon while sub treatments and their interaction did not show any significant impact on cane yield.

Table 1. Insect Pest Management methods applied

IPM modules	Components	Time of application	Insect
Biological control intensive method	Release of *Trichogramma chilonis* @ 50,000 adults / ha at 10 days intervals.	July to October	Stalk and internode borer
	Release of *Cotesia flavipes* @ 500 gravid females / ha at weekly intervals	July to November	Stalk and internode borer
Chemical control intensive method	Foliar spray of monocrotophos @ 0.7 kg a. i. / ha twice at monthly intervals	First week of August and September	Stalk borer and internode borer
Cultural and mechanical control intensive method	Removal of dry leaves and clean cultivation. Removal of egg masses of top borer February to June. Removal of water shoots (harboring larvae of cane borers) from November and onwards.	First week of September and October	Stalk and internode borer internode borer
Farmers practice	Sett selection	At planting	Borer pests

Table 2. Effect of different IPM modules on infestation of stalk borer and internode borer of sugarcane

I Year (2000-2001)

Treatment	Percent incidence					
	Stalk borer			Internode borer		
	CoS 767	CoLk8102	Mean	CoS 767	CoLk8102	Mean
Biological control	17.44	42.73	30.08	9.12	21.53	15.32
	(24.37)	(40.62)		(17.55)	(26.93)	
Chemical control	21.29	52.28	36.78	10.22	19.00	14.61
	(27.26)	(46.38)		(18.35)	(25.60)	
Mechanical control	17.16	48.76	32.96	7.17	14.71	10.94
	(24.26)	(44.27)		(15.38)	(26.26)	
Farmers practice	20.24	51.69	35.96	11.67	19.30	15.48
	(26.56)	(45.56)		(19.75)	(25.71)	
CD at 5%	10.34		-	6.96		-

II Year (2001-2002)

Treatment	Percent incidence					
	Stalk borer			Internode borer		
	CoS 767	CoLk8102	Mean	CoS 767	CoLk8102	Mean
Biological control	54.36	64.83	59.59	6.34	7.21	6.77
	(47.50)	(53.88)		(12.64)	(14.93)	
Chemical control	71.99	72.23	72.11	7.52	7.09	7.30
	(58.18)	(58.54)		(15.62)	(15.37)	
Mechanical control	52.93	66.62	59.77	6.93	6.83	6.88
	(46.81)	(54.94)		(14.43)	(15.05)	
Farmers practice	58.76	69.09	63.92	7.70	5.34	6.52
	(50.59)	(56.66)		(16.11)	(12.96)	
CD at 5%	NS			NS		

III Year (2002-2003)

Treatment	Percent incidence					
	Stalk borer			Internode borer		
	CoS 767	CoLk8102	Mean	CoS 767	CoLk8102	Mean
Biological control	29.17	51.57	40.37	16.46	25.39	20.92
	(32.43)	(45.91)		(23.60)	(29.09)	
Chemical control	41.81	48.26	45.03	15.19	24.73	19.96
	(40.25)	(44.00)		(22.12)	(29.55)	
Mechanical control	33.24	43.69	38.46	13.02	26.43	19.72
	(34.88)	(41.34)		(20.89)	(30.59)	
Farmers practice	39.08	43.35	41.21	19.50	27.55	23.52
	(38.67)	(41.11)		(26.03)	(30.86)	
CD at 5%	6.089			6.193		

Figures in parentheses are transformed values

Table 3. Effect of different IPM modules on cane yield

Sugarcane yield (t/ha)	I year (2000-01)			II year (2001-02)			III Year (2002-03)		
Treatment	CoS767	CoLk8102	Mean	CoS767	CoLk8102	Mean	CoS767	CoLk8102	Mean
Biological control	38.89	68.48	53.68	81.42	97.45	89.43	39.99	67.41	53.70
Chemical control	39.46	67.65	53.55	95.42	94.74	95.08	56.27	67.31	61.79
Mechanical control	34.66	51.53	43.09	77.49	100.67	89.08	35.92	57.97	46.94
Farmers practice	37.73	62.47	50.47	90.16	91.32	90.74	36.39	63.61	50.00
CD at 5% level	6.37			NS			4.935		

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Indian Journal of Sugarcane Technology 2011 26(1) : 37-40

Inhibitory effect of spraying electrolyzed water and pine oil on sucrose losses in harvested sugarcane

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ABSTRACT

Spraying of electrolyzed water and pine oil on the harvested cane showed relatively lesser decline in commercial cane sugar compared to water sprayed & trash covered control during late crushing period. The CCS in untreated, EW and Pine oil treated canes after 240 hours of storage was 9.84, 10.84 and 11.10 respectively. A marked increase in acid invertase activity and mannitol formation was noticed with the duration of storage. The treated canes showed appreciable reduction in the invertase activities, dextran and mannitol formation. Deterioration of harvested cane could be minimized to a considerable extent by spraying of electrolyzed water or pine oil followed by covering it with trash, pine oil was more effective than EW treated canes.

Key words: Electrolyzed water, post-harvest losses, commercial cane sugar, mannitol, pine oil.

Sugar industry worldwide suffers from the monetary losses due to inordinate delays in crushing of harvested cane. The delivery of consignments of stale sugarcane to factories can detrimentally affect multiple process units, and pull down sugar recovery. Sugar industry is one of the largest users of biocides and a huge quantity of this chemical is consumed every year in sugar mills to minimize sugar losses during processing. In India, a large spectrum of biocides (QUAT,thiocarbamate,halogen compounds) are used to minimize biological losses in milled juice(s). Now adays, use of chemicals in production and processing of food commodities is being restricted due to environmental and socio-economic concerns. Use of ecofriendly chemicals such as electrolyzed water,pine oil,beta acids,hops etc. could minimize the use of hazardous chemicals in food processing industries. Pine oil is an essential oil obtained from *Pinus sylvestris* is a phenolic disinfectant that is mildly antiseptic and antibacterial (Naturforsch, 2002). It is effective against *Brevibacterium ammoniagenes*, the fungus *Candida albicans*, *Enterobacter aerogenes*, *Escherichia coli*, gram-negative enteric bacteria, household germs (United states environmental protection agency,2006). Eco-friendly chemical i.e. electrolyzed water (EW) is also a biocidal formulation produced through an electrochemical process. It contains a mixture of oxidizing compounds predominantly hypochlorous acid and sodium hypochlorite, has a pH of 5-7 and an oxidation reduction potential (ORP, redox) of around 1000mV. The high redox potential allows for the quick and efficient destruction of microbes. Studies have indicated that the freshly produced electrolyzed water is highly active against *Mycobacterium tuberculosis*, *Mycobacterium avium-intracelulare*, *Mycobacterium chelonae*, *Escherichia coli* , *Enterococcals faecalis*, *Pseudomonas aeruginosa*, *Bacillus subtilis var niger* spores, methicillin-resistant *Staphylococcus aureus*, *Candida albicans*, poliovirus type 2 and human immunodeficiency virus HIV-I. The use of EW is an emerging technology with considerable potential (Al Haq, 2005: Xiaodong *et al*, 2008). Antibacterial effect of electrolyzed water on oral bacteria has also been reported by Lee and Choi (2006). Priyanka and Solomon (2010) has shown its positive effect on the shelf life of harvested sugarcane,under sub-tropical conditions.

MATERIALS AND METHODS

The study was carried out in the month of April (ambient temperature 35-40^{0}C) at IISR, Lucknow. Sugarcane variety CoSe 92423 (a mid- late, medium sugar) was raised under normal cane husbandry practices prevailing in north India. Cane stalks of uniform size were harvested, topped, detrashed and kept in separate bundles in small heaps under natural field conditions in three replicates. First heap was mist sprayed with water and covered with thick layers of trash and used as control(T-1), second heap(T-2) was sprayed with electrolyzed water (Sterisol-C, Faith Biotech, New Delhi, India) and covered with trash. and third heap(T-3) was sprayed with aqueous formulation of pine oil (1:200) and covered with thick layer of trash. Ten canes from each heap were selected and juice was extracted at the interval of 0, 48, 96, 144, 192 and 240 hours in a clean power operated vertical crusher. The deterioration of cane was recorded by observing juice quality parameters.

Commercial Cane Sugar (CCS) in juice was calculated by using equation CCS%= 1.022(pol% juice) – 0.292(brix). Acid invertase activity in the primary expressed juice was assayed by the method described by Rosario and Santisoparsi (2003). Proteins were estimated by the method of Lowry *et al* (1951). Mannitol was estimated by the method of Eggleston et al (2009) using mannitol dehydrogenase (MDH) and nicotinamide- adenine- dinucleotide(NAD). Dextran was estimated by Haze method.

RESULTS AND DISCUSSION

The loss in sugar after harvest has been depicted by CCS content, and is highly correlated with the sucrose content in cane on a fresh weight basis (Muchow, *et al* 1996).The loss in CCS% in water sprayed + trash covered cane (T-1) after 96 and 240 hours on storage was 1.7 and 4.02 units, in EW treated cane+ trash covered (T-2) CCS loss was 0.41 and 3.02 units. In pine oil treated cane + trash covered (T-3) CCS loss was reduced to 0.16 and 2.76 units. These figures indicate the beneficial effect of EW and Pine oil treatment in minimizing post-harvest sugar losses (Fig.4).

Use of EW has been reported in disinfecting vegetables such as cabbage, spinach and lettuce (Wang *et al*., 2004). The antimicrobial activity of essential oils from the family Pinaceae was investigated by many authors (Bagci and Digrak, 1996a; Lis-Balchin *et al.*, 1998 and A. & Todd,1994), essential oils with high monoterpene hydrocarbon levels, such as pine oil, were very active against bacteria. All pine oils are antiseptic, anti-fungal and detoxifying. Initial studies conducted by Solomon and Priyanka (2009,2011) have shown that application of EW on harvested cane had beneficial effects on its keeping quality, a mist spray of EW on cut cane and covering with trash was found to be effective. Unlike pesticides, electrolyzed water and Pine oil are safe,

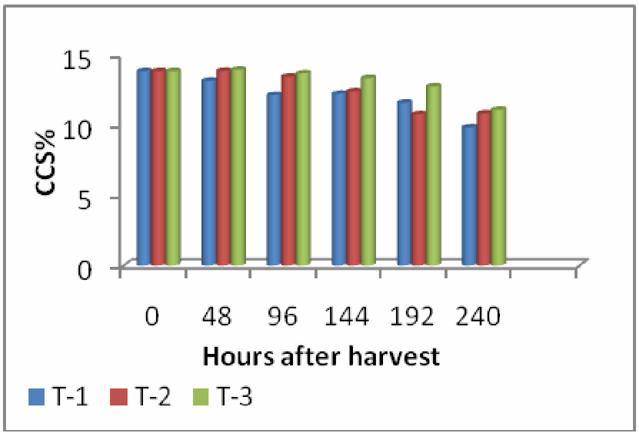

Fig.1. Effect of Pine oil & EW treatment on CCS% in harvested cane juice

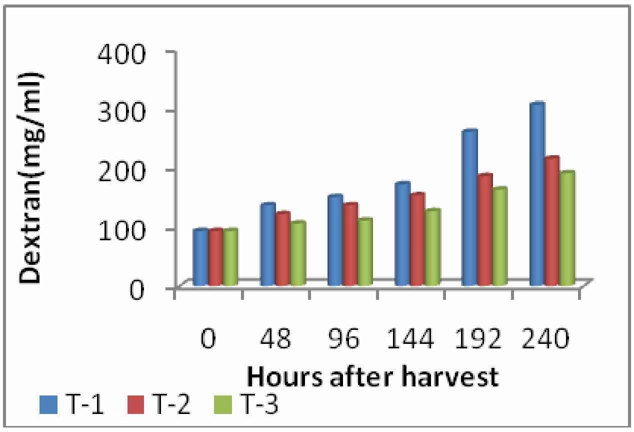

Fig.2. Effect of pine oil and EW on Dextran formation in harvested cane

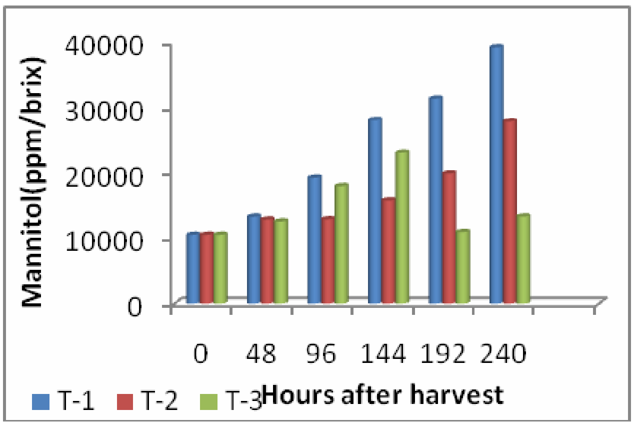

Fig.3. Effect of EW and Pine oil spray on Mannitol formation in harvested cane

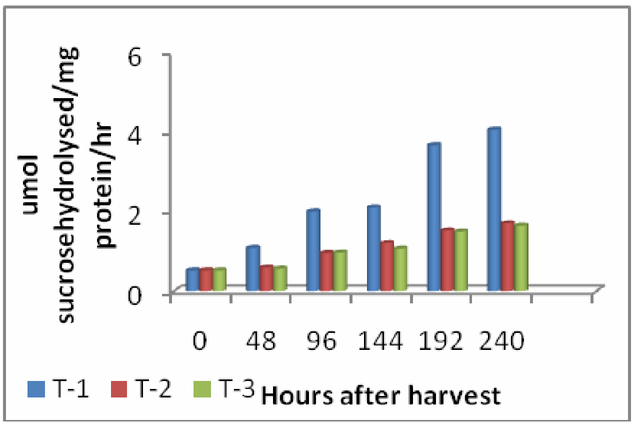

Fig.4. Effect of EW and pine oil treatment on acid invertase activity in harvested cane juice

environment friendly and has a low running cost and therefore they can be easily used, to preserve the quality of raw material after harvest.

Dextran concentration was 93 mg/l,which increased by 1.61,1.46 and 1.19 folds in T-1,T-2 and T-3 canes after 240 hours of harvest. These data also show that formation of dextran was reduced when treated with electrolyzed water and pine oil.(Fig.2).

Long term storage of harvested cane showed appreciable mannitol production, which is a useful indicator of cane deterioration. Mannitol concentration in T-1, T-2 and T-3 canes was 28693.23,17359.83 and 2807.95 ppm/Brix after 240 hours of harvest (Fig. 3). Mannitol is a major degradation product of *Leuconostoc mesenteroides* deterioration of both sugarcane and sugar beet and a sensitive marker that can predict processing problems. Eggleston *et a*l (2002) first reported that mannitol was a major deterioration product in sugarcane. An enzymatic method (Eggleston, 2009) was used to measure mannitol in juice collected from stale cane and our results are also in agreement with their studies(Priyanka & Solomon,2011).Mannitol formation in Pine oil treated cane was low, which probably indicates its antibacterial activity.

Soluble acid invertase activity assayed in the primary extracted juice of harvestd cane increased by 1.48 and 3.7 units after 96 and 240 hours of harvest in untreated cane (T-1). In EW treated (T-2) canes it showed very marginal increase ie; 0.434 and 1.9 units after 96 and 240 hours, in Pine oil treated cane (T-3) the increase was 0.444 and 1.7 units after 96 and 240 hours respectively (Fig.1). A high activity in the harvested cane could be due to combined expression of plant and microbial acid invertases,in untreated cane. This seems to have suppressed due to treatment of EW and Pine oil.. The higher acid invertase activity favored sucrose inversion which is responsible for loss of sucrose in the harvested stored cane (Priyanka *et al*, 2008). The endogenous invertases get activated due to loss of moisture and lack of any physiological and biochemical control mechanism and this situation is further compounded by release of invertases from microbes (Solomon *et al* 1990). A sharp increase in acid invertase leads to increased sucrose inversion and consequently there is a drop in Commercial Cane Sugar (Solomon *et al*., 1997) in harvested cane. Eggleston and Legendre (2003) advocated that the enhanced activity of acid invertases could be due to mobilization of cell invertase, possible synthesis of cut induced invertase and decreased activities of sucrose synthesizing enzymes induced by pH change.

ACKNOWLEDGEMENTS

Authors are grateful to DST, Delhi, India for financial support under Women's Scientist Scheme and Director, Indian Institute of Sugarcane Research, Lucknow for providing facilities to conduct this study.

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Variation in size of apparent free space and assimilatory apparatus in sugarcane varieties with differential sucrose accumulation into the stalks affecting source-sink relationship

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ABSRACT

The size of apparent free space plays a key role in regulating the activity of source and sink in sugarcane varieties differing in sucrose contents. The results have indicated that the ability of storage tissue of six sugarcane varieties to take up sucrose from external medium, particularly in the passive stage ranged from 4.34 to 4.52 mg g^{-1} fwt in high sucrose accumulating varieties than low sucrose accumulating varieties where it ranged from 1.89 to 2.84 mg g^{-1} fwt. The higher size of apparent free space (57%) in CoJ64 favored the accumulation of 50% (0.269 mg g^{-1} fwt h^{-1}) of translocated sucrose in the stalks whereas in a low sucrose accumulating variety BO91, where the apparent free space was only 14%, rate of sucrose accumulation was nearly half of Co J 64 i.e. (0.132 mg g^{-1} fwt h^{-1}). This has possibly led to high sucrose % (18.6) in Co J 64 as compared to only 14.2 % in BO 91. Leaf area ratio, an indicator of assimilatory apparatus in same varieties differed significantly in both by 50% and it was 62 and 31 cm^2g^{-1} in CoJ 64 and BO91, respectively.

Keywords Sugarcane, Apparent free space, Source and sink relationships, Sucrose, Reducing sugars.

Sugarcane is a C_4 crop characterized by its ability to store sucrose at levels up to 0.70 M (Welbaum and Meinzer, 1990). The present varieties under cultivation are not able to store sucrose up to this level (Tejera *et al*., 2007). As sucrose is stored in the parenchyma cells in stalks and not in terminal sink organs, sugarcane represents a complex source-sink system. During the storage of sucrose into vacuoles of parenchyma cells, sucrose is translocated passively from leaf to apparent free space from where it is either as such enters into vacuoles or a part is hydrolyzed into reducing sugars and re-synthesized to sucrose for its storage in the vacuoles (Komor *et al.,* 1996; Vorster and Botha, 1999). This process is mediated by cell wall invertase and sucrose phosphate synthase (SPS) (Lingle and Tew, 2008). SPS is a key regulatory enzyme involved in carbon assimilation and partitioning of photoassimilates between sucrose and starch (Li *et al*., 2003). It plays a crucial role in the production of sucrose in assimilatory cells. The sink demand to store sucrose also enhances the source activity, so that more sucrose could be synthesized (McCormick *et al*., 2008). For this, plant develops a mechanism through which more photoassimilates may be partitioned for sucrose synthesis. This is governed by development of assimilatory apparatus (McCormick *et al*., 2008). In spite of this the current varieties differ in their sucrose accumulation pattern. During this storage of sucrose, size of apparent free space plays crucial role, which determines the amount of sucrose received from the leaf and its further movement to storage space of the parenchyma cell in the stalks.

The term apparent free space (outer space), metabolic compartment and storage compartment were defined by Sacher *et al.* (1963). Apoplast and free space are equivalent terms in some given circumstances (Canny, 1995). Sucrose hydrolysis in the tissue free-space is obligatory and rate limiting for sucrose uptake and sucrose accumulation in sugarcane (Sacher *et al.* 1963). The role of apoplastic enzymes in sugar accumulation in the sugarcane stalks has also been worked out by other worker (Vorster and Botha, 1999; Zhu *et al*., 2000). Sugar uptake by sugarcane storage tissues have been aimed to elucidate the mechanisms of sucrose uptake and storage (Hawker and Hatch, 1965; Glasziou and Gayler, 1972). Bieleski (1960) studied the uptake of sucrose *in vivo* by discs of the storage tissue of a commercial variety *Pind*ar and suggested that laboratory tests might therefore be used to screen genotypes for their potential to store sugar. This was supported by Glasziou (1960) who found that the accumulation into the inner space of tissue was similar whether the source of sugar was photosynthate in the phloem or sucrose contained in a solution bathing the tissue discs.

This work was taken up to compare the size of apparent free space, rate of uptake of sucrose by storage tissue and its relation to source activity in different varieties of sugarcane differing in their sucrose accumulation patterns to establish their source-sink relationship.

MATERIALS AND METHODS

The experiment was conducted at the Indian Institute of Sugarcane Research, Lucknow, India, located at 26° 56' N, 80°52'E and 111 m above sea level, which falls in the Agro-Eco-region 4 (Northern plain and Central Highlands, Hot Semi-arid Eco-region with Alluvial-derived soils (N8D2) (Sehgal, 1990). A field experiment was conducted during 2009-2010 at the farm of the Institute. The local climate is characterized by two distinct seasons, a very hot summer from May to September with maximum temperature up to 42°C and cool winter from October to March with minimum temperatures as low as 4°C. The organic carbon (OC) content of the soil was 0.78 with total nitrogen 0.069%. The available N, P, K were 183.7, 18.7, 192 kg ha^{-1}, respectively in 2009-10. The sugarcane varieties CoJ 64, CoS 95255, CoLk 94184 (high sucrose accumulating, HSA) and CoS 767, CoSe 92423, BO91 (Low sucrose accumulating, LSA) were planted in spring seasons of 2009-2010 by conventional method after keeping the number of three budded sets (60,000 ha^{-1}) constant in a randomized block design.

The three-bud setts of above mentioned varieties along with basal dose of fertilizers were placed in furrows at 75 cm row spacing. The crop was planted in February 2009 and was harvested in March 2010. Ridges and furrows were laid with tractor-mounted furrow opener at 75 cm inter-row spacing and opened furrows were treated with chloropyriphos 20% EC ha^{-1} at the time of planting to control the termites; and N, P and K were applied in the ratio of 150:80:80 kg ha^{-1} in the furrows. The three-bud setts were placed in the furrows in such a way that their ends were overlapping to each other and on an average five setts were planted in each running meter length. The crop was grown under assured irrigation condition with five irrigations up to June and two irrigations after September till harvest of crop. From July to September monsoon rains were sufficient to irrigate the crop.

Abbreviations

AFS	Apparent free space
LAD	Leaf area duration
NAR	Net assimilation rate
Z	Biomass duration
LA	Leaf area
LAI	Leaf area Index
LSA	Less Sucrose accumulating
HSA	High Sucrose accumulating
fwt	Fresh weight

Assimilatory apparatus development (source and its activity)

The growth parameters such as leaf area, leaf area index (LAI), net assimilation rate (NAR), leaf area duration (LAD), leaf area ratio (LAR) and biomass duration (Z) were quantified at 10 months after planting. The area per leaf was calculated by multiplying the result of length by width (at the middle) by a factor 0.7. The factor results from the relationship between the leaf area and product of blade width by blade length (Lerch *et al*., 1977). The total leaf area of the individual stalk was obtained by adding the area of all individual leaves of each stalk. Results were expressed in dm^2 $stalk^{-1}$. Leaf area index (LAI) was calculated by multiplying the mean value of leaf area per stalk by number of stalk present in a known area. The growth parameters were individually calculated using the formulae of Kvìt *et al*. (1971).

Net assimilation rate (NAR mg $cm^{-2}d^{-1}$)

$$= (W_2-W_1) \ln L_2-L_1/[(t_2-t_1)(L_2-L_1)]$$

Leaf area ratio (LAR cm^2g^{-1}) = L/W

Leaf area duration (LAD cm^2day) = $L_2+L_1 (t_2-t_1)/2$

Biomass duration (Z g day) = $W_2+W_1 (t_2-t_1)/2$

where W and L are the mean values of dry weight and leaf area at a specific time. W_1 and W_2 represent initial and final mean values of total dry weight of a stalk and L_1 and L_2 are initial and final mean values of leaf area belonging to a stalk over the period t_2-t_1. All these growth parameters were calculated at a plant age of 10 months after planting. The values obtained at each earlier sampling, were used to compare the above mentioned parameters using respective formulae.

Estimation of sugars

Estimation of reducing sugars was made according to the method adopted from the procedure described by Somogyi (1945). The values are expressed as % cane fresh weight. Sucrose % in juice was carried out by method of Meade and Chen (1977).

The varieties listed in Table 1 were used in assay, which shows their sugar content recorded at maturity after 10 months in the field. Out of these the three varieties, CoJ64, CoS 95255 and CoLk 94184 were high sucrose accumulating (HSA) and CoS 767, CoSe 92423 and BO 91 were grouped as low sucrose accumulating (LSA) cane. The range of sucrose % in juice was from 18.1 to 18.6 and 14.2 to 14.3 % in HSA and LSA cane, respectively (Table 1).

Measurement of apparent free space and sucrose uptake

The assay used for measuring sucrose uptake *in vitro* was similar to that described by Bieleski (1960). All varieties were assayed 8 and 12 months after planting. The tissue was taken from top most fully expanded internodes (young internodes) and from the lower section of cane (old internodes). The nodal tissue and outer rind of the internodes were removed and remaining cores of tissue cut into quarters longitudinally and then into slices of 2-3 mm thickness. The slices were washed in running tap water to remove sugar held in the free space, blotted dry and weighed into sub-samples of 60 g each. Twelve such sub-samples for each internodes were immersed in 200 ml of 2% sucrose solution, which was continuously aerated, the air being humidified to reduce evaporation. The assay was carried out at 25°C. The amount of sucrose taken up by the slices was measured by estimating the changes in dry weight of sucrose of the external solution in three flasks after 0, 12, 24 and 36 h. Each flask plus the contents was weighed initially and at the time of sampling to allow correction for evaporation loss.

Calculation of apparent free space

The density of the tissue slices was estimated and found to be one. Assuming that the concentration of sucrose in the apparent free space after the initial uptake is complete was the same as the concentration in the external medium, the AFS is given as:

[Initial uptake of diffusible sugars (mg g^{-1}fwt) / concentration of external solution at equilibrium (mg ml^{-1})] x 100 (Oworu *et al*., 1977)

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) by the method of Snedecor and Cochran (1967) and correlation coefficient was calculated using MS Excel statistical tools to assess the interrelationships between different parameters estimated. Statistical analysis was performed at a significant level of p=0.05.

RESULTS AND DISCUSSION

Development of assimilatory apparatus

Leaf area and Leaf Area Index

Leaf area increased in all the three HSA varieties than LSA varieties where leaf area ranged from 60 to 70 dm^2 $stalk^{-1}$ in HSA contrary to LSA varieties where it ranged from 34 to 4 0 dm^2 $stalk^{-1}$, respectively (Table 1). Increase in leaf area indicates the availability of leaf surface for photosynthesis and light absorption. Similarly, leaf area index (LAI) showed similar trend as total leaf area and it ranged from 4.5-5.2 in HSA than LSA varieties where it ranged from 3.2-3.6. Variety Co J 64 which had highest leaf area per stalk registered the maximum value of LAI (5.2). There was a positive and significant correlation coefficient (r^2=0.80**) between leaf area of individual stalk and leaf area index. The plants of HSA varieties showed a higher leaf area per stalk than the LSA varieties along with LAI. This result seems to be a direct consequence of its size of apparent free space because leaf area was correlated with apparent free space of the either young or old internodes at 8 or 12 months of age (R^2=0.85, 0.93, 0.95 and 0.95; Table 6). Although, Raji et al.,(1999) have pointed

Table 1. Sucrose % and reducing sugars expressed as percentage of fresh weight of cane of six sugarcane varieties and growth analysis parameters after 10 months of growth

Variety	Type of cane	Sucrose % in juice	Reducing sugars % cane fresh wt	Leaf area (dm^2/stalk)	Leaf area Ratio (cm^2g^{-1})	Leaf area duration (cmday) x10^4	Z(gd) x10^3	NAR mg cm^{-2} d^{-1}	LAI
CoJ 64	HSA	18.6±0.02	0.99±0.01	70±0.63	62±0.67	50±0.12	45±0.45	0.82±0.02	5.2±0.01
CoS 95255	HSA	18.1±0.03	0.95±0.02	65±0.87	58±0.56	48±0.14	42±0.56	0.78±0.03	4.8±0.02
CoLk 94184	HSA	18.5±0.01	1.21±0.02	60±0.45	60±0.46	45±0.11	40±0.49	0.75±0.04	4.5±0.03
CoS 767	LSA	14.3±0.04	2.12±0.01	40±0.37	44±0.76	36±0.13	30±0.43	0.45±0.01	3.5±0.02
CoSe 92423	LSA	14.2±0.03	1.61±0.03	39±0.35	38±0.67	32±0.15	28±0.56	0.44±0.03	3.2±0.03
BO 91	LSA	14.2±0.05	1.68±0.02	34±0.34	31±0.68	28±0.12	26±0.34	0.42±0.02	3.6±0.04
LSD (p=0.05)		0.21	0.02	1.21	2.12	2.20	1.67	0.001	0.120.02

HSA: High sucrose accumulating, LSA: Low sucrose accumulating, In all cases, values are mean ± SE for three observations.

out that plants ultimately depends on green leaf surface for assimilatory out put, HSA varieties with higher LAI values, had larger size of AFS and plant efficiency for light interception. An optimum value of LAI has been proposed as significant for increase in sugarcane growth and development of size of apparent free space at 8 and 12 months of young and old internodes (R^2=0.82, 0.89, 0.95 and 0.95; Table 6).

Leaf area ratio and Net assimilation rate

Leaf area ratio (LAR) which is a measure of relative size of assimilatory apparatus, decreased in LSA (31-44 cm^2g^{-1}) than HSA (58-62 cm^2g^{-1}). Variety Co J 64 registered maximum values of LAR (62 cm^2g^{-1}) which was significantly higher than BO 91 (LSA variety; 31 cm^2g^{-1}) (Table 1). The leaf area ratio (Table 1) which indicates the development of assimilatory apparatus was higher in HSA varieties than LSA by 40% causing sucrose % increase more than LSA varieties by 27%.

Net assimilation rate (NAR) which indicates the ratio of biomass increase per unit leaf area per day, was higher in cultivar CoJ 64, CoSe 95255 and CoLk 94184 at 10 months after planting. These varieties had registered values from 0.75 to 0.82 (mg cm^2 d^{-1}) whereas the LSA varieties this variation was from 0.40 to o.45 (mg cm^{-2} d^{-1}).

The values of LAR and NAR are related with size of assimilatory apparatus and net carbon incoming for biomass formation and development of sink tissues in the stalks and significantly correlated with apparent free space in young and old internodes at 8 and 12 months of age (R^2= 0.94, 0.97, 0.94 and 0.96 with LAR and R^2= 0.88, 0.95, 0.93 and 0.96 with NAR; Table 6). The results showed that LAR seems to play a central role during the early stages of development of parenchyma cells into the stalks and AFS in young and old internodes at 8 and 12 months of age (R^2= 0.94, 0.97, 0.94 and 0.96; Table 6). This type of differences was detected in HSA and LSA varieties. A high NAR suggests high-energy conversion through large foliar apparatus (Shimabuku *et al.*, 1980). Ramesh (2000) related the yield of four sugarcane varieties with high NAR values and optimum LAI. The HSA varieties showed high NAR values than LSA varieties. The high values in HSA varieties could probably maintained because of higher efficiency of light utilization by all leaves in present on the stalk which might contribute to positive balance between photosynthesis and respiration processes in sucrose synthesis and ultimately increasing sucrose accumulation.

Leaf area duration and biomass duration

The leaf area duration (LAD) and biomass duration (Z)

Table 2. Sucrose uptake *in vitro* by storage tissue from old and young internodes of six sugarcane varieties (mg/g fwt)

Varieties	Time (hours)							
	0	12	24	36	0	12	24	36
	Young internode				Old internode			
CoJ 64	4.2±0.01	7.2±0.04	10.3±0.12	12.4±0.23	10.1±0.02	12.2±0.12	14.8±0.23	18.3±0.23
CoS 95255	3.3±0.02	6.3±0.03	7.8±0.14	8.3±0.12	8.2±0.03	10.3±0.11	12. ±30.21	14.9±0.22
CoLk 94184	4.3±0.03	5.2±0.01	6.4±0.11	7.3±0.22	5.8±0.01	6.5±0.13	11.5±0.11	13.8±0.21
CoS 767	2.1±0.01	4.3±0.02	4.8±0.13	5.3±0.15	3.8±0.05	5.2±0.13	5.8±0.10	9.2±0.19
CoSe 92423	1.8±0.02	4.5±0.03	4.9±0.12	6.2±0.08	2.4±0.02	5.3±0.14	6.3±0.09	8.3±0.11
BO 91	2.7±0.03	4.8±0.01	5.2±0.15	6.5±0.07	4.8±0.03	6.3±0.13	7.5±0.08	8.9±0.12
LSD (p=0.05)	0.02	0.03	0.01	0.02	0.32	0.05	0.02	0.21

In all cases, values are mean ± SE for three observations

Table 3. Passive uptake of sucrose (mg g^{-1} fwt) from a 2% sucrose solution by tissue slices from young and old internodes and estimated apparent free space (%) of six sugarcane varieties

Variety	Passive uptake		Apparent free space (%)	
	Young internodes	Old internodes	Young internodes	Old internodes
CoJ 64	4.52±0.01	9.72±0.03	22.7±0.23	57.0±0.34
CoS 95255	4.34±0.03	9.61±0.02	21.2±0.34	56.4±0.56
CoLk 94184	4.48±0.02	9.06±0.03	24.1±0.21	43.3±0.67
CoS 767	2.84±0.01	4.81±0.04	14.9±0.12	26.0±0.34
CoSe 92423	1.89±0.03	2.82±0.01	9.7±0.15	14.8±0.56
BO 91	1.97±0.01	2.69±0.02	10.2±0.14	14.0±0.45
LSD (p=0.05)	0.02	0.03	0.520	0.32

In all cases, values are mean ± SE for three observations.

showed similar trend in all the varieties. Hence the value for biomass duration was higher in HSA than LSA varieties (Table 1). The values range from 40 to 45 in HSA whereas in LSA the values ranged from 26 to 30 (gd x 10^3). The leaf area duration was again higher in HSA varieties than LSA by 8%. The biomass duration ranges from 40-45 in HSA varieties whereas in LSA varieties it ranged from 26-30 gd x 10^3.

Leaf area duration and biomass duration increased in HSA varieties indicating the maintenance of leaf area and biomass for longer time in these varieties. These two parameters i.e. LAD and Z were significantly correlated with AFS of young and old internodes at 8 and 12 months of age (R^2= 0.89, 0.93, 0.96 and 0.95 with LAD and 0.88, 0.94, 0.96 and 0.96 with Z; Table 6). It is clearly indicating that higher source and sink activity in HSA varieties are developed in such a way that it is affecting the size of apparent free space which is higher in these varieties.

Sucrose uptake in differing in accumulation of sucrose

The uptakes of sucrose from external solution by varieties (Table 2; Fig 1) showed a rapid initial uptake (passive uptake) occurred in all varieties followed by a prolonged slow uptake (active accumulation). The amount taken up in the passive stage varied with varieties but was always complete within an hour, while active accumulation proceeded at a slow rate for the duration of the experiment. Passive uptake was always greater in storage tissues from old internodes than young internodes and was more than twice as much in some varieties, but there was no comparable effect of age on the rate of active uptake. The values for passive uptake corrected for active uptake during the first hour and the apparent free space (Table 3). The HSA varieties having consistently higher values for passive uptake than LSA varieties in which differences were significant between varieties. Thus CoJ64, CoS 95255 and CoLk 94184 (HSA varieties) had higher values for passive uptake, while Co S 767, CoSe 92423 and BO 91 (LSA varieties) had lower values. The passive uptake of sucrose ranged from 3.94 to 4.48 (mg/g fwt) in young internodes of HSA varieties but these values for LSA varieties ranged from 1.89-2.84 (mg/g fwt) with a size of AFS ranging from 21.2 -24.1 in HSA than that in LSA was 9.7-14.9%. In old internodes the passive uptake was from 9.06-9.72 (mg/g fwt) in HSA varieties than that in LSA varieties was from 2.82-4.81 (mg/g fwt) with a size of AFS ranging from 43.3 to 57% in HSA varieties than 14-26% in LSA varieties. This is indicating that older internodes are able to take higher % of sucrose from bathing medium than younger internodes due to variation in size of apparent free space. From the passive uptake values, apparent free space was estimated (Table 3). AFS is described as that volume of tissue slices which comes into rapid diffusion equilibrium with external medium (Briggs and Robertson, 1957) and which includes the aqueous phase of the cell walls, cut cells and any intercellular spaces which may have been injected with liquid (Hawker, 1965). The values found for active uptake ranged from 0.269 mg g^{-1} fwt h^{-1} for tissue from old internodes of high sucrose accumulating varieties to 0.0112 mg g^{-1} fwt h^{-1} for low sucrose accumulating varieties. The values for commercial varieties agree with those of Bieleski (1960) who reported a value of 0.245 mg g^{-1} fwt h^{-1} for immature storage tissue and a somewhat lower rate for mature tissue. It appears that values for active uptake in high sucrose accumulating varieties may be higher than in low sucrose accumulating varieties. There was no difference, however, in rate of active uptake between young and old storage tissue of same varieties, despite consistent differences between tissues in rate of passive uptake.

Apparent free space and source and sink activity

In the old internodes values for AFS ranged from 57% in CoJ64 to 14% in BO 91 and in young internodes from 24 in CoLk 94184 to 10.2 % in BO 91 (Table 3). The rate of active uptake showed variation with the varieties of sugarcane. The results indicate a similar trend to that obtained for passive uptake, The HSA varieties tending to have higher values than LSA varieties. The values of passive, active uptake and AFS for varieties that were sampled at different ages in the field are shown in Table 4. The order of varieties was generally the same for passive and active uptake at two stages but passive uptake was higher in eight month-old canes than 12 months old cane. The improvement in growth analysis parameters in HSA varieties also increased sucrose accumulation and development of apparent free space over LSA varieties. The size of apparent free space provides the site for unloading of sucrose from leaf to the stalk for its accumulation into the parenchyma cells of the stalk. It showed that the sink activity was increased in HSA varieties as the source activity was also increased in contrast with LSA varieties where both were decreased. The uptake of sucrose (Table 4) from the bathing medium was higher in HSA than LSA varieties indicating transfer of diffusible sugar was at faster rate in HSA varieties than LSA varieties as the time duration increases the sucrose uptake was reduced. In older

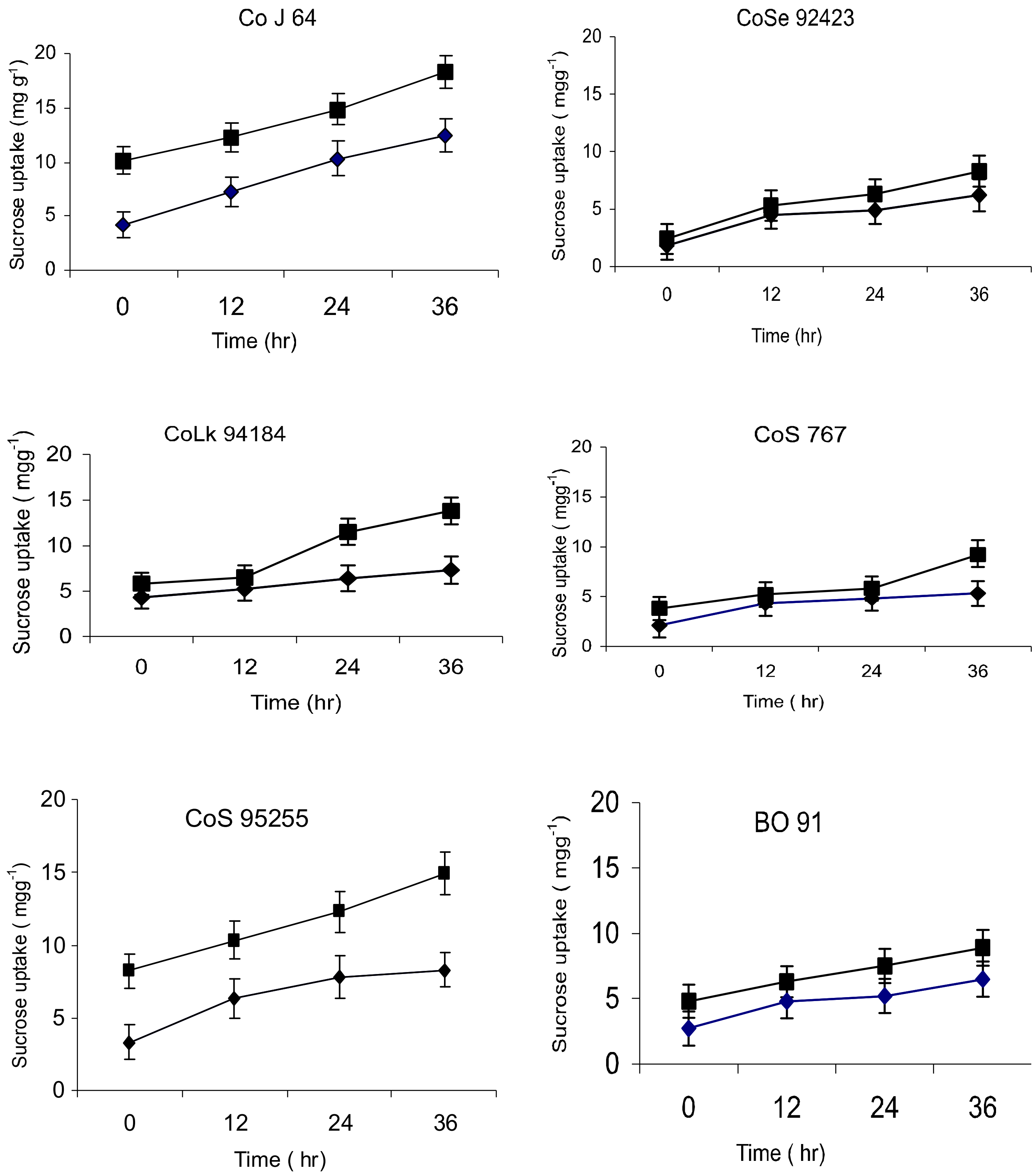

Fig. 1. Sucrose uptake *in vitro* by the storage tissue from young (♦) and old (■) internodes of six sugarcane varieties (mg g^{-1} fwt). In all cases, values are mean ± SE for three observations. The SE is represented by vertical bars (n=3)

Table 4. Rate of uptake of sucrose (mg g^{-1} fwt h^{-1}) from a 2% sucrose solution by tissue slices from young and old internodes of six sugarcane varieties

Varieties	Young internodes	Old internodes
CoJ 64	0.269 ±0.049	0.383 ±0.038
CoS 95255	0.172 ±0.012	0.242 ±0.034
CoLk 94184	0.219 ±0.005	0.298 ±0.017
CoS 767	0.112 ±0.016	0.144 ±0.008
CoSe 92423	0.102 ±0.004	0.166 ±0.030
BO 91	0.132 ±0.005	0.153 ±0.008
LSD (p=0.05)	00.005	0.002

In all cases, values are mean ± SE for three observations

internodes the uptake of sucrose was higher than the younger internodes (Table 5). This was due to poor size of AFS in younger internodes than older ones. The size of apparent free space ranged from 21.2 to 24.1 in young and 43.3 to 57% in old internodes of HSA varieties where in LSA varieties it ranged from 9.7 to 14.9 in young and 14-26 % in old internodes. The passive uptake of sucrose was in the proportion of apparent free space in both parts of the internodes. The sucrose uptake by slices of sugarcane storage tissue follows the patterns of sugar uptake as reported earlier (Bieleski 1960) and Butler (1953). A large initial uptake which was completed within one hr was followed by a long period of slow continuous uptake. There were clear differences between varieties and between old and young internodes of the same varieties in the initial passive uptake but differences in active uptake and correlated with AFS (R^2=0.84, 0.60, 0.95 and 0.89) at 8 months of age where these values were 0.82, 0.54, 0.96 and 0.93 at 12 months of age in young internodes. In old internodes these values were 0.97, 0.94, 0.98 and 0.96 for passive and active uptake of sucrose (Table 6**).** Preliminary experiments in which tissue slices were washed in running water showed that initial sugar lost from different varieties on washing was in agreement with initial uptake of sucrose by these varieties.

The initial rapid uptake is recognized as being result of passive diffusion of solute into the free-space of the tissue and amount of free space can be estimated from the amount of solute taken up passively. Various values of free space have been reported by other investigators. AFS found values ranging from, 24 to34% of tissue volume (Butler 1953). Epstein (1955) found 24% AFS for excised barley roots bathed in radioactivity labeled solutions of potassium sulphate and potassium selenate. Hawker (1965) tried to estimate the AFS of sugarcane variety *Pindar* by taking microphotographs of transverse and longitudinal sections of mature stem and obtained a value of 18.4% although admitted it was not accurate because it was impossible to get a clear print of every cell wall and to cut out the walls accurately.

Some of the values of AFS obtained in the present assay 57% in mature internodes are high compared to many reported values. Glasziou and Gayler (1972) reported values as high as 80% for sugarcane storage tissue using 0.5 mm thicker slices. They attributed this high value to a high proportion of cells being damaged by cutting. With slices 2-3 mm thick cut cells should contribute less to AFS than with slices 0.5 mm thick. In addition slices of all varieties and of both ages of internodes are subjected to the same treatment and it would be unlikely therefore that only the AFS values of old internodes would be inflated because of cell damage, The values found, if not absolute, are at least likely to reflect real differences between

Table 5. Passive and active uptake of sucrose from 2% sucrose solution by tissue slices from young and old internodes of six varieties of sugarcane at different stages of growth

Varieties	Age (months)	Passive uptake (mgg^{-1} fwt)		Active uptake (mg$g^{-1}$$hr^{-1}$)		Apparent free space (%)	
		Young internodes	Old internodes	Young internodes	Old internodes	Young internodes	Old internodes
CoJ 64	8	5.21±0.02	9.81±0.04	0.269±0.01	0.271±0.02	22.7±0.45	54.7±0.78
	12	4.13±0.03	9.75±0.03	0.269±0.02	0.2310.03	22.7±0.34	53.4±0.67
CoS 95255	8	4.48±0.04	9.21±0.05	0.258±0.04	0.269±0.02	21.8±0.46	44.3±0.56
	12	4.44±0.01	9.34±0.03	0.249±0.01	0.248±0.05	21.2±0.42	42.5±0.47
CoLk 94184	8	4.34±0.02	9.13±0.04	0.256±0.02	0.272±0.02	25.3±0.41	41.3±0.58
	12	4.49±0.05	8.69±0.06	0.249±0.03	0.234±0.03	24.8±0.46	50.1±0.47
CoS 767	8	3.74±0.01	5.84±0.01	0.149±0.05	0.151±0.04	19.0±0.32	32.1±0.46
	12	2.84±0.03	4.82±0.02	0.163±0.01	0.198±0.01	14.9±0.31	26.0±0.21
CoSe 92423	8	2.48±0.02	3.52±0.03	0.107±0.02	0.158±0.02	13.9±0.28	18.8±0.31
	12	2.82±0.01	2.82±0.01	0.113±0.03	0.172±0.03	12.8±0.45	16.6±0.41
BO 91	8	3.52±0.03	3.67±0.04	0.133±0.01	0.176±0.06	14.6±0.48	21.3±0.34
	12	4.42±0.05	4.77±0.01	0.114±0.04	0.168±0.04	12.3±0.34	19.3±0.31
LSD (p=0.05)		0.02	0.01	0.002	0.003	0.04	0.02

In all cases, values are mean ± SE for three observations

Table 6. Correlation of apparent free space with physiological attributes and sucrose uptake in young and old internodes of sugarcane at 8th and 12th month during the growth cycle

Correlation coefficients (R^2)	Apparent free space in sugarcane internodes			
	8 th month		12 th month	
	Young	Old	Young	Old
Passive uptake of sucrose (young internodes)	0.84	0.95	0.82	0.98
Active uptake of sucrose (old internodes)	0.60	0.97	0.54	0.96
Passive uptake of sucrose (young internodes)	0.95	0.97	0.96	0.98
Active uptake of sucrose (old internodes)	0.89	0.94	0.93	0.96
Sucrose uptake young internodes	0.80	0.89	0.87	0.94
Sucrose uptake old internodes	0.77	0.89	0.87	0.93
Sucrose %	0.85	0.91	0.94	0.96
Reducing sugar %	-0.61	-0.72	-0.77	-0.78
Leaf area (LA)	0.85	0.95	0.93	0.95
Leaf area ratio (LAR)	0.94	0.94	0.97	0.96
Leaf area duration (LAD)	0.89	0.96	0.93	0.95
Net assimilation rate (NAR)	0.88	0.93	0.95	0.96
Leaf area index (LAI)	0.82	0.95	0.89	0.95
Biomass duration (Z)	0.88	0.96	0.94	0.96

varieties in the AFS. The large differences in AFS between young and old internodes are difficult to explain since in both cases the internodes are fully extended. The differences occurred in all clones but were much greater in the HSA varieties. The AFS of tissue from old internodes was 40% and 52% greater than that from young internodes in low sucrose accumulating varieties whereas in high sucrose accumulating varieties old internodes had 150 and 160% greater than young internodes respectively. In the varieties where AFS was greater the development of assimilatory apparatus was also higher followed by leaf area, leaf area index, and net assimilation rate and biomass duration. It is indicating that larger as the size of apparent free space larger, the sucrose synthesizing sink activity was also higher.

Differences in the AFS of internodes of different ages has been reported for sugarcane storage tissue (Bieleski, 1960), although differences were generally smaller than those found here. Bieleski reported values of 10-155 for immature and 15-20% for mature tissue, respectively. It is likely however that the mature tissue used by Bieleski was from younger internodes than old tissue used here since his immature tissue was taken from internodes which were still expanding.

The apparent free space of stalk parenchyma from HSA varieties was about 25% higher than LSA varieties. The sucrose hydrolysis in the tissue free-space has been found rate limiting for sucrose uptake and sucrose storage (Hawker and Hatch, 1965). Moor (1995) explained the central role of AFS and called "to make a rapid progress in discovering and characterizing the temporal and spatial regulation of sucrose accumulation in sugarcane". The role of apoplastic enzymes in sugar accumulation in sugarcane stalks has been stressed by other scientists (Zhu et al., 2000).

The transport of photoassimilates is regulated by the assimilatory activity (source) and by sink strength (Kaitaniemi and Honkanen, 1996). AFS is relevant in sucrose accumulation as low turgor in the sink tissues, associated to sink apoplastic phloem unloading; increases sink strength and the transport of photoassimilates towards it (Walsh *et al*., 2005).

The present results indicated that varieties showed contrasting growth analysis parameters 300 days after planting. At this stage HSA varieties achieved higher leaf area, an optimum leaf area index, a high and stable net assimilation rate and an elevated leaf area duration and biomass duration. The higher translocation rate of sucrose in these cultivars could support by higher apparent free space of stalk as compared with LSA varieties. Further higher partitioning of sucrose to stem parenchyma is reflected by a higher sucrose% and it was correlated with AFS values at 8 and 12 months of young and old internodes (R^2=0.85, 0.94, 0.91 and 0.96; Table 6**).** The content reducing sugars were negatively correlated with AFS at 8 months and 12 months (R^2= -0.61, -0.77, -0.72 and -0.78; Table 6) indicating it is regulating sucrose contents of the cane. The higher volume of AFS in the canes may favour the accumulation of translocated sucrose in the stalks of HSA varieties, thus reaching a high sucrose % in sugarcane supports the role of free space in sucrose accumulation in sugarcane and could be used as possible yield indicator.

It is concluded that the ability of storage tissue of sugarcane varieties to take up sucrose from external medium, particularly in the passive stage, may be related to their potential sucrose content *in vivo*. The higher volume of apoplast (or free space) in the canes may favour the accumulation of translocated sucrose in the stalks of high quality cultivars, thus reaching a high sucrose % during ripening. The high correlation between apparent free space in the internode parenchyma tissue and sucrose % in sugarcane (r^2=0.98**) supports the role of free space in sucrose accumulation in sugarcane.

ACKNOWLEDGEMENTS

We thank Ram Darash, Namita Arya and Chatrapal for their valuable help and technical assistance in field and laboratory measurements during the experimentation.

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Indian Journal of Sugarcane Technology 2011 26(1) : 51-54

Value Addition in Sugarcane: A critical analysis of various consumables produced in Andhra Pradesh

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ABSTRACT

The present study was an attempt to work-out costs and returns in value added products of Sugarcane *viz.,* sugar, jaggery and sugarcane juice, in order to suggest the sugarcane growers the profitable and sustained way to deal with sugarcane. Multistage sampling technique was adopted in selecting the sampling units at various levels during 2010-11. Analytical tools like tabular analysis and Benefit Cost Ratio (BCR) were employed to achieve the objectives. The results revealed that cost of cultivation of sugarcane is the prime factor in the various value added products. Among the value added products, sugarcane juice production was found more profitable, which needs further study of technical and financial feasibility of keeping quality in order to produce on large scale.

Key words : Value Addition, Jaggery, Benefit Cost Ratio, Sugarcane

As per the provisional estimates for 2010-11, Andhra Pradesh (A.P) slipped to seventh place (from fifth during 2009-10) in sugarcane cropped area in the country. During 2010-11, in A.P sugarcane cultivated area is 0.19 Mha (3.87% of country) and production is 14.98 Mt (4.45% of the country), whereas, in productivity A.P state (78.0 t/ha) is at higher side than the all India average (67.9 t/ha). The estimated jaggery (including khandsari) production in India is 5.92 Mt. AP ranks fourth in production with 0.62 Mt (4% of country). Anakapalli regulated market located in Visakhapatnam district is the second largest jaggery market in India.

Jaggery processing is an important cottage industry in sugarcane growing regions of Andhra Pradesh. It is worth nearly 1,000 crores providing employment to nearly three lakh people in the state. The jaggery manufacturers are mostly small and marginal farmers relying on quick returns from jaggery. Since many years the quantity of sugarcane supplied to sugar factories or crushed for jaggery manufacturing is fluctuating owing to multiple reasons *viz*., price risk, marketing problems and lack of technology support. These lead to poor performance of sugarcane growers in recent years affecting the economic benefits of the rural poor. Naidu (1993) estimated that producers' share in consumers rupee of 80 to 93 per cent. Against this background, it is imperative to take up a comprehensive study with following objectives:

1) To work-out costs and returns of Sugarcane production
2) To compare the costs and returns in value added products of Sugarcane
3) To suggest the sugarcane growers the profitable and sustained way to deal with sugarcane

MATERIALS AND METHODS

Multistage sampling technique was adopted in selecting the sampling units at various levels. North Coastal Zone was selected as it has higher base of sugarcane production in state. North Coastal Zone comprises of three districts *viz.,* Srikakulam, Vizianagaram and Visakhapatnam. These are arranged in descending order and district with highest area *viz.,* Visakhapatnam, was selected purposively. All sugarcane growing mandals in Visakhapatnam district was listed and two mandals with largest area *viz.,* Munagapaka and Kasimkota, under sugarcane cultivation was purposively selected. All the villages in the selected mandals were listed and two villages selected randomly from each mandal. Thus, four villages *viz.,* Nagulapalli, Timmarajupeta, Narsingapalli and Bayavaram were selected. Fifteen sugarcane growers were selected at random from each village. In other words, *in toto,* 60 farmers were selected. The study was conducted during 2010-2011. For calculating costs and returns in sugar production two sugar factories located in the district were selected and worked-out only operational costs.

Analytical Tools

i) Simple averages

Simple averages were used to work out the farm house hold particulars, labour utilization on sample farms, cost of cultivation of sugarcane, cost of production of Sugar, cost of jaggery processing and sugar juice production

ii) Benefit Cost Ratio (BCR)

It was calculated as Gross Returns (GR) accrued divide by Total Cost (TC) incurred on a i^{th} enterprise by j^{th} category of farmers as given below :

$$\mathbf{BCR} = \frac{\sum GR_{ij}}{\sum TC_{ij}}$$

RESULTS AND DISCUSSION

Cost of Cultivation of Sugarcane

The cost of cultivation of sugarcane is a key factor in deciding the price of value added products of sugarcane. Table 1 reveal that the total cost of cultivation of sugarcane per ha was Rs. 1,46,281 with the variable cost Rs.93,891 and fixed cost Rs. 52,390 they accounts for 65 per cent and 35 per cent of the total cost respectively. Further, out of the total operational cost, 72 per cent (Rs.67,602) was incurred on labour charges and 28 per cent (26,289) was spent on materials. This shows the significance of labour charges. Among the operational costs, seed material and planting 18% (Rs.26,175) was highest followed by harvesting charges 17% (Rs.11,700), TT Propping 7% (Rs.10,500) weeding and intercultivation 6% (Rs.8, 125), *etc*. This reiterates the role of labour charges in cost of cultivation,

Ali baba (2005) reported that during 2001-02 total cost of cultivation of sugarcane per ha in Visakhapatnam district was Rs. 53,370 with variable cost of Rs. 39,398 and fixed cost of Rs. 13,972. They accounts for 73.82 per cent and 26.18 per cent respectively. Thus, there was increase of Rs. 92, 911 per hectare ***ie.,*** 174 per cent in 9 years. The major contributor for this increase was labour wages. Among these periods (between 2001-02 to 2010-11) labour wages (Average) increased from Rs. 50, to 150 ***ie.,*** 3 times.

Comparative Economics of Value Added Products of Sugarcane

The sugarcane farmers in this zone alter their decision to supply sugarcane to sugar factory or for jaggery production based on the prevailing prices of cane and jaggery. The profitability of cane supply to sugar factory vis-à-vis jaggery production was worked out on the basis of benefit cost ratio for the study period. The results are presented in tables 2 to 4 along with profitability of sugar juice production.

i) Sugar Production

The cost of raw material *i.e.,* sugar cane was the prime

Table 1. Cost of Cultivation (per hectare) of Sugarcane

S.No	Particulars of Operations		Cost (Rs.)	%
I	**OPERATIONAL COSTS**			
	a. Land Preparation		10,250	7
	b. Seed material and sowing		26,175	18
	c. Fertilizers and Manures and its application		8,500	6
	d. Weeding and intercultivation		8,125	6
	e. Irrigation charges		8,200	6
	f. Earthing-Up		2,000	1
	g. Plant Protection		3,000	2
	h. TT Propping		10,500	7
	i. Harvesting		11,700	8
		Cost A1	88, 363	61
	J. Interest on Working capital		5,528	4
		Cost A	93,891	65
II	**FIXED COSTS**			
	1. Land Revenue		500	0
	2. Imputed (Rental) Value of Own land		44,460	30
	3. Depreciation (@10% per annum)		3,250	2
	4. Interest on fixed capital (@12% per Annum		4,180	3
		Cost B	52,390	35
III		**Cost C (Cost A+ B)**	1,46,281	100
	Yield (tones/ha)		78	
	Total revenue (@ Rs. 1000/Ton)		1,48,000	
	Cost per Ton		1877	
		BCR (On Cost A)	1.58	
		BCR (On Cost C)	1.01	

variable cost accounting for 90.2 per cent of the operating cost of sugar production (Table 2). Therefore, the cost of sugarcane is a important factor in deciding the price of sugar. Benefit cost ratio was 1.13, shows that sugar factories are running at fewer profits. That too if we take the returns from by-products *viz.,* Bagasse, Filter cake (Bio-earth), Molasses (Ethanol) and Co-generation (Power). BCR for only sugar production is 0.96. That indicates factories will incur a loss of four paisa per every rupee of investment if they produce only sugar.

ii) Jaggery Production

Teggi et al., (1998) reported that the cost of raw material ***i.e.,*** sugarcane was the prime variable cost accounting for 88 per cent of the total cost of jaggery production. In the present study sugarcane was the prime variable cost accounting for 71.4 per cent of the total cost of jaggery production (Table 3). Therefore, cost of sugarcane is one of the key factors in deciding the price of jaggery. For preparing jaggery of 100 kgs the total cost incurred was Rs. 2,382, out of which 71.4, 15.2 and 3.4 percents costs were incurred on sugarcane and additives, Machines rent and Labour charges respectively. The BCR was arrived as 1.22. Jaggery farmers are making profits of 22 paisa for one rupee of investment. But, Ali baba (2005)[2] estimated that the BCR for production of jaggery was 1.33 in Visakhapatnam district of Andhra Pradesh. Further, Anjugam *et al* (2007) estimated the net income realized from jaggery production of Rs.14,138 in western zone of Tamilnadu, which was higher than that of the cane produced for sugar factories. But, in present study less profits in jaggery production is mainly owing to increase in cost of cultivation of Sugarcane.

Table 2. Costs and Returns in Sugar production

Particulars	Quantity (Tones)	Unit Rate (Rs./Ton)	Costs	Returns
Sugarcane	1	1800	1800	
Processing Charges			1020	
Sugar	0.1	27,300		2730
Bagasse	0.28	750		210
Filter cake (Bioearth)	0.04	100		4
Molasses (Ethanol)	0.037	3000		111
Power	43.5 W	2.73 (per Watt)		119
		Total	**2820**	**3174**
		BCR	**1.13**	

Table 3. Costs and Returns in Jaggery production

Particulars	Quantity (Tones)	Unit Rate (Rs./Ton)	Costs	Returns
Sugarcane	1	1700	1700	
Materials & Machines			362	
Labour	2+1		320	
Jaggery	0.1	29,000		2900
		Total	**2,382**	**2900**
		BCR	**1.22**	

iii) Sugar Juice Production

The amount spent on machines' rent was the prime variable cost accounting for 63.4 per cent of the total cost of sugar juice production (Table 4). For preparing sugar juice of 550 liters from 1 ton of sugarcane, the total cost incurred was Rs. 5,500, out of which 32.73, 63.4 and 3.87 percents costs were incurred on sugarcane, machines and additives and labour charges respectively. BCR was arrived as 2.5. That is sugar juice makers (farmers) are gaining profits of Rs. 0.73 per rupee of investment.

Rama rao (2010) reported that BCR for sugar juice production was 1.73 in north coastal zone of Andhra Pradesh during 2007-08. But, in the present study BCR for sugar juice production was higher mainly due to increase in price of sugar juice i.e. Rs. 10 /- per litre to 25 /- per litre. But, the major constraint is seasonal with two to three months of sales apart from its small scale operations. Further, keeping quality of sugar juice is major constraint from technical angle.

Table 4. Costs and Returns in Sugar Juice production

Particulars	Quantity (Tones)	Unit Rate (Rs./Ton)	Costs	Returns
Sugarcane	1	1,800	1,800	
Materials & Machines			3,500	
Labour	two	100	200	
Juice	550 liters	Rs. 5/ Glass (200 ml)		13,750
		Total	**5500**	**13,750**
		BCR	**2.50**	

Thus, among the value added products of sugarcane, sugar juice was found most profitable, followed by jaggery and sugar with BCRs of 2.5, 1.22 and 1.13.

Policy Implications

1) The increase in cost of cultivation of sugarcane was mainly owing to the increase in labour wages, which in turn, shortage of labour during peak operations time. This forces the replacement of manual labour with mechanical labour.
2) Sugar juice production was most profitable among the value added products of Sugarcane. But its technical feasibility of keeping quality and financial feasibility of

taking up on large scale is needed further in-depth study

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Indian Journal of Sugarcane Technology 2011 26(1) : 55-59

Information and Communication Technologies tools for effective management of data in sugar mill zone

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ABSTRACT

Sugar Industry is a major agro-based industries in India making our country the second largest sugar producer in the world. Today Industry is facing challenges like fluctuation sugar production and law sugar recovery in comparison to other sugar manufacturing countries and can be addressed by an effective management of sugar industry entire business cycle. Paper demonstrate the opportunities from Information and Communication Technologies (ICT) for effective management of data in sugar mill zones. Further, ICT tools already developed for sugar industries has been escribed. An effective implementation of ICT tools and techniques like Artificial Intelligence, GIS applicatons, MIS applications, Multimedia, Internet technologies, etc will aid in entire business cycle of sugar industry for more profit.

Key words: Expert System, Decision-support system, ERP, MIS, Sugar Industry.

Sugar industry, one of the major agro-based industries in India, has been instrumental in resource mobilization, employment generation, income generation and creating social infrastructure in rural areas. Indeed, sugar industry has facilitated and accelerated pace of rural industrialization. More than 4.50 crore farmers are engaged in sugarcane cultivation and about 5 lakh rural people have got direct employment in the industry. Sugar cultivation is done on around 4 million hectares of land in India and its production has fluctuated between 230-300 million tones in past several years. The Rs.250 billion sugar industry has about 500 sugar mills in India with an average installed capacity of 18 million tones. India is the largest consumer of sugar and second largest producer in the world.

The main concern of sugar industry in India is fluctuations in sugarcane production due to inadequate irrigation facilities, lower sugarcane yield, and frequent droughts in tropical and sub-tropical areas where sugarcane is grown on a large scale. In addition, sugarcane yield has been lower (59 tons per hectare). Sugar recoveryis also lower in comparison with other sugar manufacturing countries. This leads to escalation of production costs and weakness competitive edge of the industry. Most of sugar mills in India are having daily sugarcane crushing capacity of 1250 tonnes. These mills cannot have economies of scale so they have to incur high production costs. There is need to lower the production cost, and increase sugar recovery by an effective management of sugar industry entire business cycle.

Opportunities from Information & Communication Technologies (ICT)

During last decade, progress in Information and Communication Technology (ICT) has affected all spheres of our life. ICT is assuming ever increasing importance in agricultural development of the country. Like-wise ICT has major role to play in sugar industry. There is no doubt about potential of ICT, as it has a variety of tools / technologies available for sugar industry. Here we discuss some of the opportunities from ICT for an effective management of sugar industry.

Database and data warehouse technologies are used to store and retrieve large amount of data (both text and image) efficiently at affordable cost [Chaudhuri *et al.* (2001) and Humpshires (1999)]. Temporal / historical data on crop production, protection and utilization statistics, meteorological facts and pest / disease survey data and other useful data may be managed using these repositories for further analysis and decision support. Data Mining and OLAP techniques make it possible to extract new finding and meaningful patterns from large historical database [Ganti *et al.* (1999) and Humpshires (1999)]. Based on these analytical techniques useful advices can be developed for farmers.

An Expert System is an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution. Expert in crop production and protection are the modern extension tools for decision support at farmer level. It can suggest suitable variety, method of field preparation and sowing, irrigation, fertilizer application, etc. Disorder diagnosis and treatment are one of oldest application of expert system.

A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. Major application of GIS in agriculture includes land use analysis, thematic mapping, demographic analysis, socio-economic studies and environment management.

Modeling and simulation technology can be used to model an ideal crop situation and predict its growth through extrapolation and other techniques by considering a specific crop environment. Crop Simulation Models can be developed for environmental characterization, optimizing crop management, pest / disease management, impact study of climate change, yield forecasting, effective crop scheduling, *etc.*

Multimedia means many media – text, video, narrated sound, music, graphics, animations, special effects, etc. which are controlled, coordinated and integrated by a computer. Multimedia is simply multiple forms of media integrated together. Multimedia based Instructional Tools, Encyclopedia, Tutorials, Videos, etc not only give enhancement over text only messages but also improves understanding and retention of information.

MIS applications can improve the efficiency and effectiveness of decision-making process. It helps in monitoring, evaluation, and coordination of activities in entire business process. MIS systems may be applied in various functional disciplines of management like finance, personnel, estate, *etc.*

Internet technology has revolutionized the world of information communication [Agarwal (1999)]. With this the information dissemination to farming community can be made instantaneously in parallel. Further this technology provides a powerful collaboration mechanism for knowledge sharing using WWW, email, Chatting, News Group, *etc.*

ICT tools developed at the institute and by external agencies

ERP solution for Sugar Industries

Enterprise Resource Planning (ERP) is such ICT based solutions that cater all the information need of an organisation and provide automation of activities at full length. ERP solutions contributes to greater production by providing efficient coverage to the entire information processing cycle from sugarcane acquisition planning, through cane receipt and grower payment processing as well as to the peripheral accounting and administrative processes. Solutions are normally provided by way of software agents / modules to cater major process of sugar mills. Following are the major software agents available in most of the ERP solutions:

Administration and Control Agents

The major features covered by this agent are information about growers, contractors, purchase centre, growing regions, etc.

Cane Planning Agents

The scope of this agent starts from capturing detailed survey information to serve as the basis for cane procurement planning. In the crushing season, system uses this data to schedule the issuance of daily permits/indents to growers thereby guaranteeing regular and regulated supply, and optimising plant utilization and yield. It provides

- Complete sugar cane field structure
- Individual grower survey information on crop variety and acreage level
- Computerized printing of Grower's Passbooks with survey information
- Planning reports covering all aspects of data ranging from Zone to individual Grower level

Cane Procurement Agents

The Cane Procurement agent aims at making available the required materials of the right quality, in the right quantity, at the right time and at the right price for the smooth functioning of the organization.

Cane Yard Management Agents

Fully automated cane yard process with bar code facility to ensure the complete traceability, continuity, consistency and accuracy in the system. This not only provides reliability and security to the management but also increases the credibility of the mill for growers.

Cane Accounting Agents

The process of Cane Accounting covers secure Cane Procurement Receipt processing, payment and bank scroll processing and bank batch tagging for bank reconciliation as well as many procedures for special and adjusted payments against loans.

General Ledger Agents

This agent streamlines the financial systems and operations of the mill. Using this module the company can generate its Balance Sheet, General Ledger, Trial Balance, Profit & Loss Statement and Daybooks, as well as many other management information and transactional reports.

Inventory Agents

The Inventory Module covers all stock related functions of the organization. The Inventory Module handles issues, dispatches, receipts and quality control. The stock of each item is maintained and various MIS reports are provided for tracking stock movement.

Sales and Marketing Agents

Sales is a key function for any organization. The Sales and Marketing Agent in this system handles all the sales activities in the organization.

Payroll Agents

Employees are the most important assets of an organization. The Payroll Module facilitates all Payroll related activities. A detailed employee database is maintained along with details of salary, attendance and leave record of each employee.

Major ERP solutions offered and implemented by Sugar Mills in India are:

1. NexGen Sugar ERP
2. Sugar Mill Cane Management ERP
3. Sugar Mill Automation Management System
4. ERP for Sugar Industries
5. Sugar Mill ERP
6. Sathguru@Sugar
7. K2
8. Sugar Udyog Cane Management System

Farmer's Field Information System

Sugarcane production is a complex process involving many operations, *viz.* land preparation, variety selection, seed cutting and treatment, planting, irrigation, nutrient application, inter-cultural operations, crop protection measures, harvesting, etc. All these operations are to be executed at different crop stages for high cane yield and sugar recovery. To achieve the objective of high cane yield and sugar recovery, efficient scheduling of all operations at various stages of sugarcane cultivation is a must.

There should be a system for an efficient scheduling of farm operations depending on agro climatic conditions, input resources used, stress conditions, planting and harvesting time, level of mechanization, labour, cost, *etc.* at farmers' field level. For efficient scheduling of farm operations, the availability of historical data on farm operations/inputs used is a must. In this connection, institute has taken an initiative to adopt Information and Communication Technology (ICT) based database management techniques in sugarcane field management. To attain this objective a software prototype "Farmer's Field Information System" has been developed at the institute.

The software uses five categories of data, *viz.,* farmer information, farmer's field, history of field crops, operation performed in crop undertaken and input used during various farm operation schedules. Database of the software stores these information in various tables and incorporates relationship among them using Entity-Relationship modeling technique. Software provides a number of data management modules to add and update data with user friendly interfaces. Further, to view information about sugarcane farmers, history of field crops, crop operations schedule and input used at various levels, software generate reports in various tabular formats. Viewing of data may be achieved using search engine based approach, which facilitate the user to search on a variety of parameters stored in the database viz. Farmer Name, State/District/Village, Field Area, Crop Undertaken, Variety, Date of Planting, Operations Performed, Duration of Operation, Input Used, Date of Harvesting, Input Rate, Production, Productivity, *etc.*

The software requires wider availability to ensure its accessibility to users; hence, web-oriented approach has been used in application design, which works in Client-Server architecture. In web-oriented nature of application, data and programme modules resides on central web and database server and gives accessibility to user with web browser on Internet communication channel. It also provides user-friendly graphical user interface and online remote accessibility to its user. Software is under verification stage of various modules developed and further need addition of scheduling modules. In times to come, implementation of this ICT based data management technique in sugarcane farm/ crop scheduling will lead to increasing trend in sugarcane yield and sugar recovery, thus win-win situation for both farmers and mill owners.

Sugarcane Field Management System

Information management in traditional research system has been seen as specific to individual research project. Integration of data related to research projects and result thereof are not available in this system. Further, analysis of data of domain specific experiments in the historical and spatial aspects are not possible in traditional system. Institute has taken an initiative to manage the data generated in sugarcane field of the institute with the development of software "Sugarcane Field Management System", with the objective of an effective management of data generated in sugarcane field experiments conducted at the institute farm. It is a web-based application with following features:

1. Integrated results of experiments conducted within and across domain is a major problem in research planning. Data integration of experimental results along historical perspective, research domain and experimental fields is most important feature of the software in this perspective. Integrated reporting of field operations and input schedule performed on experimental fields of various projects is also possible with this software to aid in decision support for resource use planning.
2. Software endow with powerful reporting mechanism on experimental results and input resources used in field experiments. A tabular report presents existing data of database while analytical reports give a logical understanding of data using various summarization functions and statistical tools. Software also renders reports on institute projects, field experiments, farm operations & input schedule, farm inventory, *etc.*
3. It supports scheduling of project activities in general and field operation & input in particular. Reports generated thereof assist research worker in scheduling of field operations and further in analysis of data of field operations and input schedule.
4. Software modules of Sugarcane Field Management System are based on generic models to reclaim in other crops. Thus software may be reused for experimental field management of other crops as well, by changing the basic data on institute, project profile, user profile, field experiments and crop under consideration in the database. Data may be added and updated using a range of software modules available in the system.
5. Software supports three types of users', *viz.,* Administrator, Project Leader and General User. Project Leader has all rights to record, update and search experimental record of their project. General User may only see data for which rights are provided to them. Administrator has full rights to all data and modules in the system.
6. Web-oriented architecture of the software offer online accessibility of the same through internet / intranet with data and application module residing on central server.

To cater the above features, software uses information in six categories viz., Project Details, User Profile, Experimental Details, Field Operations, Farm Inventory and Experimental Results. On software front, it consists of eight modules namely Project Details, Experiments, Field Operations, Farm Record, Results, General Reports, Analytical Reports, and User Profiles.

Data Warehouse on Sugarcane Production System

Data Warehouse work has been undertaken to have a better insight into the dynamics of sugarcane production and sugar industry using historical data generated on sugarcane production, sugar industry, agro-met data generated by government department and agencies. Dimension Modeling technique has been applied in data warehouse development, in which two types of entities are used viz. Fact and Dimension. We have taken two dimensions into consideration, *viz.,* Place and Time. Place dimension corresponds to the administrative hierarchy of a state. Time dimension consist of temporal intervals such as day, week, month and year. Facts are the metrics associated with and reported for dimensions, *e.g.,* Sugarcane Area, Production, Productivity, *etc.,* are facts recorded for Place and Time dimension.

A data mining software tool has been developed to explore and analyze the data stored in the data warehouse of sugarcane production. It has three components, *viz.,* user Interface, Search Engine and Data Warehouse. Web-oriented nature of the tool provides a web-browser-based user interface to search the data from data warehouse.

Data warehouse techniques best support management of vast amount of agricultural data for analytical exploration

[Hasan (2008)]. It provides flexible, efficient and reliable data storage and retrieval techniques for ad hoc and in depth analysis of vast amount of data. A comprehensive information system on sugarcane production will provide systematic and periodic information to the planners, decision-makers, developmental agencies and growers.

Decision Support Tools in Sugarcane Cultivation

Sugarcane production process involves many sub-processes, *viz.,* variety selection, planting, irrigation, fertilization, crop protection, harvesting, *etc* and requires decision support at various stages. Considering the complexity of the problems, we have planned to develop such decision support tools for various sub-processes [Hasan (2010)]. Crop protection requires to have good knowledge of various crop disorder (at various stages) along with their symptoms to identify the disorder occurs, which in turn causes low production or yield. Area of domain thus undertaken at the beginning is sugarcane crop disorder diagnosis and treatment.

Development of knowledge base is the first and most important aspect of developing knowledge based systems and goes through knowledge acquisition, knowledge representation and knowledge verification. Categories of knowledge obtained are important insect / pest and diseases of sugarcane, textual & visual symptoms of diagnosis and other details such as biology, economic importance, control measures, etc. In our approach of knowledge representation we have used two type of entities 'Data Table' and 'Rule Table'. Data Tables are repository of domain ontology acquired during knowledge acquisition. Rule entities contain relationship between two entities in the form of various combination of identification keys defined in those entities along with some other measurable attribute.

Further, two categories of software module has been identified while developing decision support tools, *viz.* Knowledge Updation modules and Decision Support modules. Knowledge updation deals with the loading of knowledge in the knowledge base and updation of the same, while Decision Support modules are end user software to get decision support from the system. Knowledge Updation modules has been developed using computer scripting languages *viz.,* Active Server Pages (ASP) and Hyper Text Markup Language (HTML), while MS-Access support the repository of knowledge in the form of knowledgebase. Since domain experts for knowledge updation may have different physical locations, web-oriented nature of knowledge updation will enable updation of knowledge online using internet services. Decision Support Tools for disorder diagnosis will aid in diagnosis of disorder in a very effective manner by providing appropriate diagnosis of disorder found in sugarcane crop.

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Hints for the preparation and submission of manuscripts

General

All correspondences should be addressed to the Secretary, Association of Sugarcane Technologists of India, Indian Institute of Sugarcane Research, Lucknow – 226 002, India. The contribution must contain the original research work related to sugar crops in the form of full length articles or short communications. Book reviews are also published. The papers submitted for publication in *Indian Journal of Sugarcane Technology* should not have been submitted elsewhere for publication or already published. The senior author or at least one of the authors should be a member of the Association.

Manuscript and its Arrangement

Two copies (along with manuscript of floppy/CD composed in MS Word) of the manuscript complete in all respects should be submitted. The paper may be submitted by e-mail (rajesh_iisr.hotmail.com) alongwith hard copy. These should be typed on bond paper (A4 size) in double space throughout with wide margins on the left and at least 2 cm on the remaining sides.

The contents of the papers should be arranged as – Title, Authors, Addressed, Abstract, Key Words, Introduction, Materials and Methods, Results and Discussion (combined), Acknowledgements and References. A short title may also be provided.

All quantitative data should be in metric units. The following abbreviation should be used. Yr, wk, h, min, sec, rh, g, kg, g/ml, g/l, temp., kg/ha, a.i., w:1 (v/v) 1:2 (w/w), N,P, K, mm, cm, nm, μm, rpm, DNA, RNA, Fig. (Figs for plural), CV (CVS, for plural), % etc.

Tables, figures or illustrations must have a self-contained legend.

Title

This should be self-explanatory, specific and relevant to the contents.

Abstract

This should not exceed 150 words and indicate main findings of the paper.

Text

The text should be organized under primary and secondary headings. Where methods are well known, reference of such should be cited by author and date. Results and discussion should be combined to avoid repetition.

References

At the end of the paper, all references cited in the text should be arranged in alphabetical order and set out as follows:

Patel, J.R., Mali, H.N. and Salunhe, C.D. 1986. Weed management in pre-seasonal sugarcane. *Indian J. Weed Sci.* **18**: 238-244.

Jackson, M.L. 1969. *Soil Chemical Analysis.* Prentice Hall, New Delhi, pp. 498.

Yadav, D.V. and Yaduvanshi, NP.S. 1993. Management of soils and nutrients. *In Sugarcane Research and Development in Sub-tropical* India, Eds. G.B. Singh and O.K. Sinha, pp 113-142. IISR Science Club, Indian Institute of Sugarcane Research, Lucknow-226 002, India.

Dhar, N.R. and Mukerjee, S.K. 1936. Alkali soils and their reclamation by molasses and press mud. Proc. 5th Ann. Conv. Sugar Technol. Assoc., India, pp. 12-25.

Tables

Each table should be self-explanatory and typed on a separate page. The data should be statistically analysed.

Figures and Photographs

Figures and photographs should be submitted in duplicate. Drawing should be made in the black ink on good quality tracing paper or drawing sheets. Photographs should be on high quality glazed paper, along with typed explanation. On the back of photographs, write names of authors, figure number, etc. Colour photographs are also accepted for publication subject to printing charges borne by the authors/institution.

Short Communication

Follow the guidelines as above. Abstract is not needed. Also, introduction, materials and methods and results and discussion, the sub-headings be avoided. At the end, the communication should be concluded.

Note

The current issue of the Journal may be consulted for style of presentation and other minute details. Abbreviation of periodical titles (to be given under references) should follow those given in *A World list of Scientific Periodicals,* Butterworths, London.

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STATEMENTS ABOUT OWNERSHIP AND OTHER PARTICULARS ABOUT INDIAN JOURNAL OF SUGARCANE TECHNOLOGY

1.	Place of Publication	—	Lucknow
2.	Periodicity of Publication	—	Half Yearly
3.	Printer's Name and Nationality	—	C.M. Bajaj Indian Army Printing Press 33 Nehru Road, Sadar Cannt Lucknow - 226 002
4.	Publisher's Name, Nationality and Address	—	Dr. Rajesh Kumar Indian Hony. Secretary Association of Sugarcane Technologists of India Indian Institute of Sugarcane Research, Lucknow-226 002, India
5.	Chief Editor's name Nationality and Address	—	Dr. A.K. Shrivastava Indian Indian Institute of Sugarcane Research, Lucknow-226 002, India
6.	Name and Address of individuals who own the newspapers and partners of share-holders holding more than one per cent of the total capital	—	The Association of Sugarcane Technologists of India

I, Rajesh Kumar, hereby declare that the particulars given above are true to the best of my knowledge and belief.

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