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CONTENTS

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Export competitiveness of sugarcane jaggery in Karnataka – a comparative analysis

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ABSTRACT

Karnataka is one of the major sugarcane growing states, with an area of 3.06 lakh hectares and production of 262.40 lakh tonnes. More than 50% of the sugarcane produced is processed into sugar. In recent years, the sugar industry is facing problems of high stocks and financial crunch. The jaggery industry is also expanding in the sugarcane growing areas both for export and domestic markets. Hence, the study was undertaken in Mandya and Bagalkot districts of Karnataka to assess the export competitiveness of jaggery. The data were collected from 30 jaggery producers each from Mandya and Mahalingapur market hinterlands which represent highest jaggery producing districts in the state. The Nominal Protection Coefficient (NPC) was found to be less than unity (0.57), which implies that jaggery is a good exportable product; hence there is competitive advantage for export of jaggery from India. Similarly Domestic resource cost (DRC) was found to be less than unity. All these ratios indicated comparative advantage in production and export of jaggery. Therefore, its export should be encouraged to earn foreign exchange.

Keywords: Export, Jaggery, NCP and DCR

Sugarcane is grown extensively in India. The crop occupies over 50.55 lakh hectares in the country with a production of 3481.87 lakh tonnes, of which 66% is concentrated in the northern states. Sugarcane in India is processed in to sugar, jaggery and *khandsari*. The methods of manufacturing this value added consumable products are different. The National Commission on Agriculture (1976) estimated that per capita consumption of sweeteners would increase to about 40 kg/ head/annum by 2020 AD from 25 kg/head/annum when the country's population would go to 1360 millions.

The acceptable taste and nutritive value of jaggery have attracted man since ancient times. Jaggery is also called 'Non Centrifugal Sugar' or Artisan Sugar. It forms an important item of Indian diet as a sweetening agent. White sugar contains mainly sucrose (99.70%), where as jaggery has less sucrose (51.00%) but it contains protein (0.25%), glucose (21.20%) and minerals (3.40%) in addition to traces of fats (0.02 to 0.03%), calcium (0.39%), vitamin A, vitamin B, phosphate (0.025%) and provides 383 Kcal/100g jaggery.

Export potential

Per capita consumption of sucrose in India is much lower (15 kg), compared to that in developed countries (50 kg). Major share (above 75%) of sucrose consumption in rich countries has been through manufactured foods. But, excessive sucrose consumption leads to a variety of problems such as dental caries and coronary thrombosis. To over-come these problems many of these countries are seriously looking for alternative sweeteners from sugarcane crop. India has one of such eco-friendly sweeteners jaggery which contributes more than 70% to the production of the world. It is being exported to many countries like, Bangladesh, Great Britain, Canada, Chili, Egypt, Fizi, Iran, Iraq, Kuwait, Malaysia, Nepal and USA.

Karnataka is one of the leading producers of jaggery apart from sugar. Large numbers of jaggery production units are operating in the states which have a great employment potential. In India, only Uttar Pradesh and Maharashtra produce export quality jaggery because they have specialized centers for jaggery production. This information will have an impact on farmers' income and industry performance in the state. Hence, the study was undertaken to assess the export competitiveness of jaggery from Karnataka.

MATERIALS AND METHODS

In order to study the export competitiveness, the primary data were collected from the sample farmers in the markets hinterlands of Mandya taluka of Mandya District and Mahalingapur market of Mudhol taluka of Bagalkot District. At the same time, the secondary data were collected from APMC Mandya and APMC Mahalingapur and also from District Statistics Office (DSO), Mandya and Bagalkot.

Multistage random sampling procedure was followed. In the first stage, Mandya district in the South Karnataka and Bagalkot district in the North Karnataka were selected because of more number of jaggery units located on one hand and higher

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sugarcane acreage in these districts on the other.

The data for the study were collected through personal interview method for the year 2008-09. The primary data were collected from the sample farmers who are cultivating sugarcane and having their own jaggery processing units. Thirty sample farmers were selected randomly from each selected talukas, with a total of 60 sample farmers.

Nominal Protection Coefficient (NPC) is a straight forward measure of competitiveness. It is calculated as a ratio between the domestic price to the international price of a comparable grade of commodity, adjusted for all the transfer costs such as freight, insurance, handling costs, margins, losses, etc under exportable hypothesis. A decision criterion is, if NPC is less than one, then the commodity is competitive that is worth exporting. If NPC is greater than one, the commodity is not competitive that is not worth exporting.

Similarly, the Domestic Resource Cost (DRC) was worked out, which is defined as the value of domestic resources, it takes to save or earn a unit of foreign exchange through the production or export of the commodity. The Domestic Resource Cost ratio is usually presented in the form

$$DRC_i = \frac{\sum_{j=k+1}^{n} a_{ij} P_j^D}{P_i^B - \sum_{j=1}^{k} a_{ij} P_j^B}$$

Where,

a_{ij} = quantity of the j-th traded (if j£k) or non-traded (if j>k) input (j = 1, 2, ..., n) used to produce one unit of output i

P^D_j = social price of non-traded input j

P^B_i = border price of output i

P^B_j = border price of traded input j.

Non traded inputs are those factors which are not traded internationally. To estimate the DRC of jaggery, shadow price of jaggery was taken as a proxy for social cost. Shadow prices of input are the products of the marginal product of input and the domestic price of the output. Thus,

Shadow price = MPj * P^D

The data to calculate the DRC of jaggery was obtained from the primary source through pre-tested interview schedule.

Decision rule is, when the estimated value of

DRC < 1, the input is used efficiently and it is export competitive;

DRC > 1, the input is used inefficiently and is not export competitive.

DRC indicates whether it is profitable to produce and export the commodity.

RESULTS AND DISCUSSION

Export competitiveness of jaggery

In the context of World Trade Organization (WTO) regime, the theory of comparative advantage in its simplest state reveals that a particular nation can enhance the resource use efficiency and thereby by producing and exporting commodities in which it is relatively efficient and importing commodities in which it is relatively not so efficient. Keeping this in mind, especially in a free trade environment, it is advantageous for any country to focus on those commodities that have greater comparative advantage than others, so as to maximize its export revenue. The nominal protection coefficient (NPC) explains the comparative advantage envisaged by commodities in the context of free trade regime. In this context, the competitiveness of Indian jaggery export was examined using NPC. The data on nominal protection coefficients of jaggery presented in Table 1 indicate that the NPC was found to be less than unity (0.57), which implies that jaggery is a good exportable product.

The observation revealed that the domestic prices received by the farmers were lower than the international prices, suggesting that the domestic producers were disprotected or rather taxed compared to a situation prevailing under free trade condition. It also revealed that jaggery export had a high degree of comparative advantage in the world market, but for the trade barriers de-linking the domestic and world market. Thus, India has a great advantage to expand the production of jaggery and to export the surplus to earn valuable foreign exchange.

The results revealed that India in general and Karnataka in particular, have competitive advantages for jaggery export to USA.

Domestic Resource Cost (DRC) of jaggery

It can be observed (Table 2) that the human labour accounts for Rs. 1335.98 which is a non tradable input followed by all other inputs like sugarcane, sodium hydrosulphate, lime super phosphate, fuel, diesel, super phosphate, sodium bicarbonate etc., which are all considered as a tradable inputs. The ratio of the proportion of the non traded inputs to the value added by the proportion of traded inputs in the production of jaggery worked out to be -0.24 which means that Indian jaggery is

Table 1 Nominal Protection Coefficient (NPC) for export of jaggery to United States of America

Particulars	Place	Unit	Value
Wholesale price of jaggery	Mandya	Rs/q	1075
Plus transport cost to	Chennai	Rs/q	37.5
Plus marketing margin (5%)		Rs/q	53.75
Plus Port clearing & handling charges		Rs/q	135
Equal FOB Price(1+2+3+4)	Chennai	Rs/q	1301.25
Plus Freight charge		Rs/q	212.62
Plus insurance at 2% of price		Rs/q	21.5
Equals landed cost (5+6+7)	US	Rs/ q	1535.37
Exchange rate		1$=Rs	48.00
CIF price (row 8 / row 9)		US $/q	31.99
Reference price	US	US $/q	55.73
NPC of jaggery (row 10/row 11)			0.57

Table 2 Domestic resource cost (DRC) of jaggery

Particulars	Value (in Rs.)
Marginal value of non traded inputs	
Human labour (Man days)	1335.98
Total non tradable inputs (A)	1335.98
Marginal value of tradable inputs	
Sugarcane (tonnes)	7395.42
Sodium hydrosulphate	134.43
Lime super phosphate	23.4
Sodium bicarbonate	64.30
Super phosphate	84.53
Bindi extract	16.63
Sunflower oil	22.60
Soda powder	13.11
Fuel	172.15
Diesel	179.82
Polythene bags	27
Total tradable inputs (B)	8133.39
International reference price ($/tonne) (C)	55.73
Exchange rate (1 $ = Rs) (D)	48.00
Domestic resource cost ratio {A/ {(C*D)-B}}	-0.24

having high export competitiveness for export. The DRC ratio worked out to be less than one (-0.24), indicating high export competitiveness of jaggery. NPC proved that Indian jaggery export is competitive and the lower than unity, DRC of jaggery also indicates high export competitiveness because of cost effectiveness in production.

From the present study, it can be concluded that NPC and DRC which are less than unity imply that the jaggery export from India is having good export competitiveness. Therefore, it should be encouraged.

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Rind hardness: An efficient parameter to estimate fibre content in sugarcane

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ABSTRACT

A field experiment was conducted to estimate the rind hardness (RHD) in sugarcane using potable maize penetrometer and hence its correlation with fibre% (FIB) in advanced sugarcane genotypes during autumn 2010 and spring 2011 at University Seed Farm, Ladhowal, Punjab Agricultural University, Ludhiana. Seventeen sugarcane genotypes comprising elite advance selections/released varieties from different research centres of the North Western zone and three commercial varieties (checks) of Punjab, were used as research material. The grouping trend of genotypes for RHD and FIB remained similar in both the seasons, though the autumn planted genotypes exhibited higher values than their counterparts planted in spring season. The correlation coefficients inferred significantly high positive relationship between rind hardness and fibre content in both autumn (r=0.675) and spring (r=0.610) seasons. These result strongly indicated that rind hardness could be considered as an efficient parameter for otherwise laborious fibre estimation in sugarcane. This observation could also be highly useful to index fibre content in large base population through rind hardness.

Keywords: Correlation coefficients, Crop season, Fibre%, Rind hardness, Penetrometer, Sugarcane

Sugarcane fibre, the water-insoluble component required for structural support of cane plant, also determines the crop quality because of its inverse relationship with juice extraction and milling efficiency. The fibre content is gaining importance nowadays since many sugar factories rely on the fibre (bagasse) as fuel for co-generation. Bagasse forms the raw material for power generation in many sugar industries. As sugar price is fluctuating from year to year, co-generation has become one of the important sources of generating additional revenue to the industry. This calls for evolving value added varieties with higher fibre content even compromising with little reduction in sugar recovery. The sugar factories with co-generation facility demand for high fibre (up to 16%) varieties as it helps in increasing the baggase availability. The overall income generated by this would be extremely advantageous to the millers as well as to the farmers in terms of higher yield level (Natarajan 2000). Though obtaining fibre estimates is laborious, yet it is necessary for cultivar and parents selection decisions. In the sugarcane improvement programme, selection for fibre content is postponed to later generations when the population becomes manageable due to non availability of reliable non-destructive canes. Moreover, in base populations the numbers of millable canes are generally less per genotype, hence cannot be spared for fibre estimation.

To circumvent this problem, a simple device called rind hardness tester can be used for indirect estimation of fibre content in larger samples in a shorter period (Babu *et al.* 2009). It measures the force required by the tester to pierce the rind of a cane. Earlier many workers have attempted to assess the rind hardness using different penetrometers for the initial selection of sugarcane genotypes (Davidson 1969 and Skinner 1974).If the rind hardness is positively associated with the fibre content in sugarcane genotypes, then the genotypes possessing other desirable features with appreciable level of fibre content suitable for co-generation purpose can also be evolved. Apart from this, rind hardness is also associated with other desirable varietal features like resistance to internode borers and non-lodging cane characteristics for easy mechanical harvesting (Babu *et al.* 2009). Using tester a large number of samples can be tested for rind hardness in a day and thus it can be used in the initial base populations.

Many methods of measuring rind hardness have been used in sugarcane. In this context, the portable maize (*Zea mays* L.) rind penetrometer offers an opportunity for this purpose. Kang *et al.* (1990) suggested that the maize rind penetrometer would be a useful device for differentiating rind hardness in sugarcane. In view of this, the present investigation was conducted to (i) estimate the fibre percent and rind hardness in the advanced sugarcane genotypes and hence, to work out the correlation between these two traits, and (ii) find out the effect of crop season on fibre content and rind hardness across the genotypes.

MATERIALS AND METHODS

A field experiment was conducted at University Seed Farm, Ladhowal, Punjab Agricultural University, Ludhiana. Seventeen sugarcane genotypes *viz.,* 'Co 0238', 'Co 05009', 'Co 05011', 'CoH 05262', 'CoH 05265', 'CoH 05266', 'CoH 05269', 'CoLk 05201', 'Co Pant 05222', 'Co Pant 05224', 'CoPb 05211', 'CoPb 06219', 'CoPb 07213', 'CoPb 08214',

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'CoPk 05191', 'CoPk 05192' and 'UP 05233' comprising elite advance selections/released varieties from different research centers of the North Western zone and three commercial varieties 'CoH 119', 'CoJ 64' and 'CoJ 88' as checks were planted in randomized block design with three replications in two seasons *viz.*, autumn 2010 and spring 2011 at seed rate of 12 buds per meter row length with row to row spacing of 0.90m for autumn and 0.75m for spring planted crops. The recommended package of practices was followed to raise the crop in each season.

Rind Hardness (RHD)

Portable maize (*Zea mays* L.) rind penetrometer (Fig 1) was used to measure the rind hardness (RHD). At maturity, the single stalk per clump was pierced at the middle and the data were recorded from five randomly taken canes of each genotype from each of three replications. The force required to pierce the mature canes was recorded. Data were pooled for each replicate and analyzed.

Fig 1 Rind hardness tester (maize portable penetrometer)

Fibre% (FIB)

For fibre% estimation, five canes were randomly taken from each genotype in each replication. These canes were subjected to electric operated high efficiency cane shredder. The resultant product after thorough mixing was sub-sampled and 100 g was taken in cloth bags for the estimation of fibre%. The samples were washed repeatedly in fresh water to remove the juice present in the fibre and dried to remove the moisture content and to attain a constant weight. Fibre% was calculated as per the formula given by Thangavelu and Rao (1982)

$$\text{Fibre\%} = \{(A - B) \times 100\} / C$$

Where,

A = Dry weight of bag + bagasse (g)

B = Dry weight of bag alone (g)

C = Fresh weight of cane (g)

RESULTS AND DISCUSSION

The rind hardness (RHD) was recorded in mature canes in autumn and spring planted crops. The data on mean performance of twenty genotypes for RHD are presented in Table 1. The genotypes having RHD more than 14.0, were categorized as hard canes whereas the genotypes with RHD less than 9.0 were considered as soft canes. In autumn planted canes, 'Co 0238', 'CoH 119', 'CoH 05262','CoH 05265', 'CoJ 88', 'CoLk 05201', 'CoPant 05224','CoPk 05191' and 'UP 05233' were reckoned as hard canes and 'CoPb 06219' as soft cane genotype. In spring season too, the performance of genotypes for RHD remained the same. 'CoJ 88', a commercial sugarcane variety of Punjab, recorded the highest value of RHD both in autumn (16.98) and spring (15.99) seasons. In general, the RHD values of autumn planted crop were higher than those of spring planted one.

Table 1 Mean performance of sugarcane genotypes for rind hardness (RHD)

Genotype	Rind hardness (RHD)	
	Autumn planted	Spring planted
'Co 0238'	14.10	13.48
'Co 05009'	11.16	10.53
'Co 05011'	12.77	12.76
'CoH 119'	14.63	15.49
'CoH 05262'	14.2	13.00
'CoH 05265'	14.83	14.07
'CoH 05266'	13.79	14.19
'CoH 05269'	11.28	11.38
'CoJ 64'7	11.24	9.93
'CoJ 88'	16.98	15.99
'CoLk 05201'	14.27	13.51
'CoPant 05222'	13.76	13.31
'CoPant 05224'	14.62	14.21
'CoPb 05211'	13.18	11.94
'CoPb 06219'	8.78	8.27
'CoPb 07213'	11.01	10.77
'CoPb 08214'	11.02	10.49
'CoPk 05191'	14.64	15.36
'CoPk 05192'	9.64	11.09
'UP 05233'	15.65	14.23

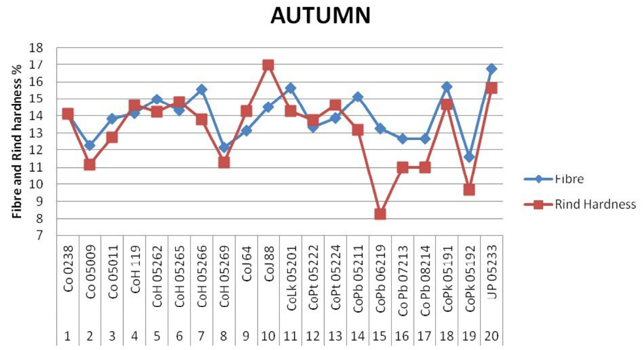
At harvest, the genotypes were sampled for fibre estimation and data are presented in Table 2 for autumn and spring planted crops. In autumn season 'Co 0238', 'CoH 119', 'CoH 05262', 'CoH 05265', 'CoH 05266', 'CoJ 88', 'CoLk 05201', 'CoPb 05211', 'CoPk 05191' and 'UP 05233' were found as high fibre genotypes with fibre content >14% whereas 'CoPk 05192' as low fibre type with FIB <12%. In spring season, 'CoH 05266', 'CoPk 05191' and 'UP 05233' were having >14% fibre and 'Co 05009', 'CoH 05269', 'CoPk 05192' recorded with <12% fibre. The genotypes with high fibre% exhibited high potential for co-generation and can fetch extra revenue for ailing sugar industry.

The genotypes, in general, having high RHD recorded high fibre%. The genotype 'UP 05233', which recorded the highest rind hardness (15.65) also registered the highest mean value for fibre content i.e. 16.77 in autumn and 15.22 in spring planted crop. The test genotype 'CoPk 05192' recorded the lowest fibre value of 11.62 in autumn and 11.02 in spring planted crop. This in turns also registered low rind hardness. The grouping trend of genotypes for RHD and FIB were similar in both seasons, though the autumn planted genotypes

Table 2 Mean performance of sugarcane genotypes for fibre% (FIB)

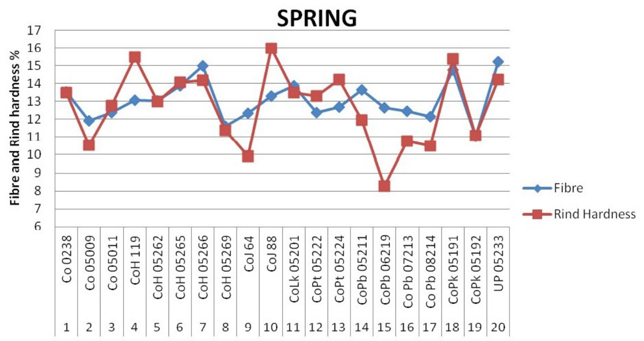
Genotype	Fibre % (FIB)	
	Autumn	Spring
'Co 0238'	14.1	13.55
'Co 05009'	12.29	11.92
'Co 05011'	13.82	12.38
'CoH 119'	14.12	13.08
'CoH 05262'	14.99	13.03
'CoH 05265'	14.28	13.87
'CoH 05266'	15.56	14.98
'CoH 05269'	12.16	11.61
'CoJ 64'	13.14	12.35
'CoJ 88'	14.48	13.32
'CoLk 05201'	15.65	13.88
'CoPant 05222'	13.34	12.39
'CoPant 05224'	13.87	12.67
'CoPb 05211'	15.13	13.66
'CoPb 06219'	13.26	12.66
'CoPb 07213'	12.69	12.45
'CoPb 08214'	12.69	12.15
'CoPk 05191'	15.73	14.78
'CoPk 05192'	11.62	11.02
'UP 05233'	16.77	15.22

exhibited higher values than their counterparts planted in spring season, owing to probably more crop duration (Fig 2 and 3). The correlation coefficients worked out inferred significantly high positive relationship (at 1 % level of significance) between rind hardness and fibre content in both autumn (r = 0.675) and spring (r = 0.610) seasons. These results strongly indicated that rind hardness could be considered as an efficient parameter to estimate fibre content in sugarcane and this observation could be highly useful to index fibre content in large base population. Kang *et al*. (1990) also documented the direct relationship of fibre estimation with rind hardness. They, therefore, suggested that the only character for which large unmanageable numbers of genotypes could be screened at the earliest is the rind hardness, which gives an index of fibre content in sugarcane. Bhat *et al*. (1985) observed highly significant correlations and repeatability association between rind hardness and fibre content in sugarcane genotypes in plant and ratoon crops. They concluded that unlike fibre estimation, rind hardness measurement is a simple, quick and non-destructive field technique aimed at increasing breeders' efficiency. Kang *et al*. (1989) reported that the direct effect of fibre content to sugar cane productivity per hectare is low (0.024) and negligible as compared to other characteristics such as single stalk weight (0.478) and the millable cane number (0.841). Sugarcane fibre contents are the minor components of sugar yield. These findings suggest that it would be possible to choose high fibre content variety accompanied by high yield and high sugar content characteristics.



Correlation coefficient (Autumn) = 0.675**

Fig 2 Relationship of fibre per cent with rind hardness in sugarcane genotypes during autumn season



Correlation coefficient (Spring) = 0.610**

Fig 3 Relationship of fibre per cent with rind hardness in sugarcane genotypes during spring season

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Economics and yield potential of single bud planted autumn and spring sugarcane (*Saccharum spp.* hybrid) intercropped with pulses

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ABSTRACT

Sugarcane cultivation necessitates the generation of an innovative technique that aims at reducing seed rate, enhancing plant population and maximizing land use efficiencies. It was in this context that present investigation was, undertaken during 2009-10 to assess the potential of single-bud planted autumn (Variety 'CoJ 64') and spring sugarcane (Var. 'CoH 119') intercropped with pulses (gram/ lentil/ summer green gram/ summer mash) at farmers' field in sub-tropics of Roopnagar (Punjab). The results revealed 94-97% bud germination in single-bud planted cane as opposed to 76-84% in three-bud sett planted one. The yield of autumn sugarcane was increased by 3.97 and 2.48%, respectively with intercropping of gram and lentil over sole cane. The highest cane yield (125.6 t/ha) was obtained when sugarcane was intercropped with gram followed by intercropping with lentil (123.8 t/ha) and sole cane (120.8 t/ha). The economic analysis demarcates autumn sugarcane + gram as the most profitable intercropping system that gave the highest net returns (Rs. 178042.50/ha) and B:C ratio (1.84) as compared to autumn sugarcane + lentil and sole cane. Maximum values of production efficiency (356.9 kg/ha/day) and economic efficiency (Rs. 462.4/ha/day) in sugarcane + gram intercropping system also reflected the similar trend. The highest cane yield (121.6 t/ha) was obtained with intercropping of sugarcane with summer green gram followed by intercropping with summer mash (120.4 t/ha) with an edge over of 3.2 and 2.2 over sole sugarcane (117.8 t/ha). In turn, sugarcane + summer green gram intercropping system gave highest net returns (Rs. 177607.9/ha), production efficiency (404.2 kg/ha/day) and economic efficiency (Rs. 530.2/ha/day) than sugarcane + summer mash and sole sugarcane. Thus, it can be concluded that single bud planting technique in both spring and autumn sugarcane intercropped with pulses, has immense scope in subtropical areas of India.

Keywords: Single bud planting, Pulse crops, Production efficiency, Economic efficiency, Intercropping

Sugarcane is an important and assured crop in tropical and subtropical India. Sugarcane production in India during the last decade has been reported to fluctuate between 233 and 355 Mt, in contrast to its productivity at the farm level which is as low as 40 t/ha (Gujja *et al*. 2009). However, the low plant population owing to the low germination rate (35-40%) albeit of high seed rate (6.0 t/ha) in sugarcane (*Saccharum spp*. hybrid) has been recognized as major culprit for lower cane production. Owing to the high seed rate of sugarcane, the profit margins of farmers are dwindling since the planting material costs 22-25% of the total production cost. Heavy tiller mortality in sugarcane (Kapur *et al*. 2011) causing reduction in crop yield also cannot be neglected. In order to increase sugarcane and sugar productivity, the only alternative is to increase the sugarcane productivity per unit area. Suryavanshi *et al*. (2010) observed that ploy bag settlings, two eye bud and single eye bud planting were economical for sugarcane (Var. 'Co 94012') cultivation. The single bud planting might be a convincing option for reducing seed rate. Sugarcane being long duration and widely spaced crop, offers considerable scope for intercropping for maximization of land-use. Under Sustainable Sugarcane Initiative (SSI), the farmers have been able to reduce its cost of cultivation by about 21% and increase yield by 24% to 30% apart from extra income from inter crops (NRMC 2011). Intercropping has been reported to be the most efficient and profitable production system especially for small farmers with limited land and inputs resources (Nazir *et al.* 1988). Earlier research on economics, production and feasibility of intercropping in sugarcane focused primarily on planting of multi-bud setts (Khakwani *et al.* 2001; Shafi Nazir *et al*. 2002; Gana and Busari 2003; Saini *et al*. 2003; Bhullar *et al.* 2006). Moreover, India is still not self reliant in pulses therefore the un-planted space between two sugarcane rows can be exploited for pulse production. Studies carried for assessing the scope of pulse intercropping in sugarcane are confined only in traditionally (multi-bud setts) planted sugarcane. The studies on single bud planted sugarcane intercropped with pulse crops are still lacking. Therefore, the present study was under taken to assess the feasibility and profitability of intercropping pulse crops in single bud planted sugarcane.

MATERIALS AND METHODS

The study area is located in village-Paprali, Block-Morinda, Ropar (Roopnagar), Punjab. The climate of the experimental site is sub-tropical characterized by hot summer with mean maximum temperature of 42 ± 5^{0}C during June and cool winter with mean minimum temperature of 4 ± 2^{0}C during December. The average annual rainfall in the study area varies from 650-1300 mm of which ~75-80% is received during rainy season extending from July to September and rest during the winter season. The relative humidity in the district varies from 36.3-93.7% demarcating a peak during July-August, the days when *monsoon* in the area is on full swing. The surface with a sandy loam in texture (0-15 cm) soil of pH 7.83, electrical conductivity 0.256 dS/m, soil organic carbon 4.35 g/kg, Available P 17.3 kg/ha and Available K 166.5 kg/ha. Soil pH and EC were determined using 1:2 soil: water suspension (Jackson 1967). Soil organic carbon content was determined by Walkley and Black's (1934) rapid titration method. The Available P content in the soil sample was determined as described by Olsen *et al.* (1954). Available K was determined using 1N, CH_3COONH_4 (pH=7.0) followed by flame photometric estimation.

The field study was conducted during 2009-11 at farmer's field to assess the potential of single-bud planted autumn sugarcane (Var. 'CoJ 64') intercropped with gram and lentil and spring sugarcane (Var. 'CoH 119') intercropped with Summer Green gram and Summer Mash as practised in sub-tropics of Punjab (District Roopnagar). In autumn, sugarcane variety 'CoJ 64' was planted in third week of September and in spring 'CoH 119' was planted in second week of March 2010, during both the years. Single buds of sugarcane were planted on southern side of 80 cm wide raised beds made in east-west direction with 40 cm wide furrows for irrigation keeping bud direction towards outer-side. Buds were planted keeping bud to bud distance of 60 cm and row-to-row distance of 120 cm. In autumn cane two rows of gram (Var. 'PBG 5') and lentil (Var. 'LL 931') were planted on bed top having 30 cm row to row spacing in the first fortnight of October. The bed top was intercropped with two rows of summer green gram (Var. 'SML-668') and summer mash (Var. 'Mash-1008') in case of spring sugarcane. For planting one hectare, 13,500 buds (10-11.25 q) were used. At the time of planting 37.5 kg K_2O and 115 kg P_2O_5 /ha were applied before making beds. Nitrogen @ 172.5 kg/ha was applied through urea in six splits. No separate fertilizers were applied for intercrops. Plant protection measures were followed as and when required. Weed control was done manually. Irrigation was applied as and when required depending upon soil type and rainfall. More frequent irrigations were applied in hot summer months. On the other hand, three bud sugarcane was planted using a seed rate of 87.5 q/ha at row spacing of 75 cm in spring (third week of March) and at 90 cm in autumn (first week of October) planted sugarcane. The fertilizer dose was same for three bud sett planted cane as described for single-bud planted sugarcane. To evaluate the profitability of intercropping system, the economics was worked out from the gross returns calculated by taking normal market prices of the produce and total expenditure incurred. The cane equivalent yield was calculated based on the average selling price of the crops used in the study. The economic efficiency (EE) was calculated from the average net-returns on unit area basis and average crop duration. The production efficiency (PE) was worked out by dividing crop yield on unit area basis by average crop duration as described by (Tomar and Tiwari 1990).

RESULTS AND DISCUSSION

Per cent bud germination

The per cent bud germination of autumn and spring planted sugarcane was observed for both single-bud and three bud planted crop (Fig 1). The results revealed that bud germination of single-bud planted autumn sugarcane was 94 and 96 per cent, respectively during 2009 and 2010. However, the bud germination of three-bud setts planted autumn sugarcane was 83 and 76%, respectively during 2009 and 2010. The average of two years thus showed 19.5% higher bud germination in single-bud planted than three-bud sett planted autumn sugarcane. Likewise, the bud germination of single-bud planted spring sugarcane was 95 and 97% during 2010 and 2011, respectively in contrast to 79 and 84%, the bud germination of three-bud setts planted spring sugarcane. Thus, it could be inferred that single-bud sugarcane planting results in achieving 18-20% higher bud germination, owing to the selection of healthy bud for planting.

Yield and economics of three-bud and single-bud planted autumn sugarcane intercropped with pulses

The autumn planted single-bud sugarcane (Var. 'CoJ 64') intercropped with gram (*Cicer arietinum* L. Var. 'PBG 5') and lentil (*Lens culinaris* Var. 'LL 931') was compared for yield and economics with sole single-bud planted sugarcane for two consecutive years. The results revealed ~28.2% higher cane yield in single-bud planted plots over three-bud planted plots, owing to better germination (Table 1). The average sugarcane yield of single bud planted crop was 120.8 t/ha, which increased to 125.6 t/ha (4.0%) with gram intercropping. However, there was no significant ($p=0.05$) yield difference between single-bud planted sugarcane plots intercropped with either gram or lentil during both the years (Table 1). The average yield of intercropped gram and lentil was 0.9 t/ha and 0.4 t/ha. The intercropping thus resulted in single-bud planted sugarcane equivalent yield of 137.1 and 130.0 t/ha, respectively from plots intercropped with gram and lentil, which exhibited an increase in sugarcane yield by 13.5 and 7.6%. The average cost of cultivation for sole autumn planted single-bud sugarcane crop was Rs. 88292.50/ha against Rs. 96667.50 and Rs. 93458.20/ha, respectively for sugarcane intercropped with gram and lentil, respectively (Table 1). The variation in average gross returns *viz.* Rs. 241600, Rs. 274710 and Rs. 260000/ha, respectively for single-bud planted sugarcane or its inter cropping gram and lentil was observed due to the variation in minimum support price for different crops. Likewise, the average net-returns were highest (Rs. 178042.50/ha) from plots

Table 1 Yield and economics of different sugarcane based intercropping systems (pooled over two years)

Intercropping system	Yield (t/ha)	Equivalent cane yield (t/ha)	Average cost of cultivation (Rs/ha)	Average gross returns (Rs/ha)*	Average net returns (Rs/ha)	B:C Ratio
Autumn Sugarcane (Var. 'CoJ 64')						
Three-bud sett planted sole sugarcane	94.2	--	90386.00	188400.00	98014.00	1.08
Single- bud planted sugarcane	120.8	--	88292.50	241600.00	153307.50	1.73
Single-bud planted sugarcane + Gram	125.6+0.9	137.1	96667.50	274710.00	178042.50	1.84
Single-bud planted sugarcane + Lentil	123.8+0.4	130.0	93458.20	260000.00	166541.80	1.78
Spring Sugarcane (Var. 'CoH 119')						
Three-bud sett planted sole sugarcane	91.4	--	88654.50	182800.00	94145.50	1.06
Single-bud planted sole sugarcane	117.8	--	85458.50	235600.00	150141.50	1.76
Single-bud planted sugarcane + Summer Green gram	121.6+0.8	135.4	93192.50	270800.40	177607.90	1.91
Single-bud planted sugarcane + Summer Mash	120.4+0.7	131.1	93667.50	262200.50	168533.00	1.80

*Average gross returns were worked out by considering minimum support price (MSP) for different crops during two study years. (MSP of Sugarcane Rs. 200/q, Gram Rs. 2550, Lentil Rs. 3100, Moong Rs. 3450, Mash Rs. 3050/q)

where single-bud planted sugarcane was intercropped with gram, followed by intercropped with lentil (Rs. 166541.80/ha). The results also revealed that, although pulse intercropping in single-bud planted sugarcane has increased the cost of cultivation, but the practice proved economical since the benefit: cost (B:C) ratio was higher for plots having single-bud planted sugarcane intercropped with pulses than single-bud planted sugarcane sale. However, the monetary returns B:C ratios were higher from autumn single-bud planted sugarcane intercropped with gram as compared to single-bud sugarcane intercropped with lentil. Saini *et al*. (2003) while evaluating relative profitability of intercropping vegetable crops in autumn planted three-bud sett planted sugarcane reported 5.1-11.5% decline in cane yield in plots intercropped with radish, turnip and spinach in contrast to plots intercropped with peas- a leguminous crop where there was no difference in cane yield from intercropped and non-intercropped plots. At Faisalabad (Pakistan), Shafi Nazir *et al*. (2002) reported higher gross returns (Rs. 150125/ha) and net (Rs. 96207/ha returns) from autumn sugarcane intercropped with gram as compared to sole sugarcane crop, with Rs. 131197.50/ha and Rs. 81048/ha, as gross and net returns, respectively.

Yield and economics of three-bud sett and single-bud planted spring sugarcane intercropped with pulses

The data on yield and economics of spring single-bud planted sugarcane (Var. 'CoH 119') intercropped with summer green gram (*Phaseolus aureus* L. Var. 'SML-668') and summer mashes (*Vigna mungo* Var. 'Mash 1008') are presented in Table 1. Three bud sett planted sugarcane yielded ~29.0% lower cane than single-bud planted one. The average yield of spring single-bud planted sugarcane was 117.8 t/ha, which increased to 120.4 t/ha (2.2%) with intercropping of summer mash and to 121.6 t/ha (3.2%) with intercropping of summer green gram. However, there was statistically no difference between sugarcane yields from plot intercropped with summer green gram and mash during both the years (Table 1). The average yield of summer green gram and mash was 0.8 t/ha and 0.7 t/ha, planted as intercropped crops between single-bud planted sugarcane rows. The intercropping thus resulted in single-bud planted sugarcane equivalent yield of 135.4 and 131.1 t/ha, respectively from plots intercropped with summer green gram and summer mash. The average cost of cultivation for sole spring single-bud planted sugarcane was Rs. 85458.50/ha against Rs. 93192.50 and Rs. 93667.50/ha, respectively for plots having single-bud planted sugarcane intercropped with summer green gram and summer mash, respectively (Table 1). The variation in average gross returns *viz.* Rs. 235600, 270800.40 and 262200.50/ha, respectively for single-bud planted sugarcane sole or its intercropping with summer green gram or mash was due to the variation in minimum support price of these component crops. Likewise, the average net-returns were highest (Rs 177607.90/ha) from plots where single-bud planted sugarcane was intercropped with summer green gram, followed by summer mash (Rs. 168533/ha). The lowest (Rs. 150141.50/ha) net returns occurred from single-bud planted sole sugarcane planted plots. The monetary returns and B:C ratios were higher from single-bud planted sugarcane intercropped with summer green gram than with summer mash. The lowest B-C ratio using three-bud setts was due to increased cost of cultivation and reduced cane yield.

Efficiency of three-bud sett and single-bud planted sugarcane intercropped with pulses

The production efficiency of autumn single-bud planted sole sugarcane was 313.8 kg/day/ha which increased to 356.9 kg/day/ha and 337.8 kg/day/ha, respectively with gram and lentil intercropping. On the other hand, the production efficiency of spring single-bud planted sugarcane was 351.6 kg/day/ha which increased to 404.2 kg/day/ha when intercropped with summer green gram and to 391.3 kg/day/ha when intercropped with summer mash (Table 2). The economic efficiency of single-bud planted autumn sole sugarcane was Rs. 398.20/day/ha which increased by Rs. 64.20/day/ha (16.1%) and Rs. 34.40/day/ha (8.6%) when intercropped with gram and lentil. For spring crops, the highest economic efficiency of Rs. 530/day/ha was observed in single-bud planted sugarcane intercropped with summer green gram followed by Rs. 503.10/day/ha in summer mash. The lowest economic efficiency of Rs. 448.20/day/ha was attained with single bud planted sole sugarcane (Table 2). The comparison demarcates lower production and economic efficiency of sugarcane planted by using three-bud setts as compared to single-bud planted sugarcane during both autumn and spring seasons.

Table 2 Production and economic efficiency of different sugarcane based intercropping systems (pooled over two years)

Intercropping system	Production efficiency (kg /day ha^{1})	Economic efficiency (Rs /day /ha)
	Autumn Sugarcane (Var. 'CoJ 64')	
Three-bud sett planted sole sugarcane	251.2	259.3
Single- bud planted sugarcane	313.8	398.2
Single-bud planted sugarcane + Gram	356.9	462.4
Single-bud planted sugarcane + Lentil	337.7	432.6
	Spring Sugarcane (Var. 'CoH 119')	
Three-bud sett planted sole sugarcane	240.5	336.2
Single-bud planted sole sugarcane	351.6	448.2
Single-bud planted sugarcane + Summer Green gram	404.2	530.2
Single-bud planted sugarcane + Summer Mash	391.3	503.1

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Performance of animal operated sugarcane crushers

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ABSTRACT

The performance of animal operated KVIC and ATDA sugarcane crushers was evaluated and compared with traditional sugarcane crushers. The results revealed that the average juice extraction was 6.0-7.1% higher as compared to traditional Kirloskar's Kumar crusher. Juice extraction varied with the cane varieties and was higher for the varieties having lower fibre content. The increase in juice extraction was not significant with recycling of crushed cane as compared to without recycling in KVIC crusher. In ATDA design crusher, the juice extraction increased significantly with 4th roller in comparison to without 4th roller. There was non-significant difference in the juice extraction by the KVIC crusher with recycling and ATDA crusher with 4th roller. However, there was significant increase in juice extraction in ATDA crusher with 4th roller as compared to KVIC crusher without recycling of crushed cane.

Key words: Sugarcane, Crusher, Performance, Juice extraction, Crushing capacity

Sugarcane occupies a prominent place as a cash crop in India. It is cultivated in an area of about 4.83 million hectares, with an annual production of about 355 million tonnes (Anon. 2008). Over 45 million farmers constituting about 7% of the rural population and a large force of agricultural labourers are engaged in sugarcane cultivation in the country (Jain 1999). Out of the total sugarcane production, 27.7% is used by unorganized or semi-organized sector for production of *jaggery* and *khandsari* by cottage based industry which provides employment to over 25 lakh people in rural areas (Alam 2000).

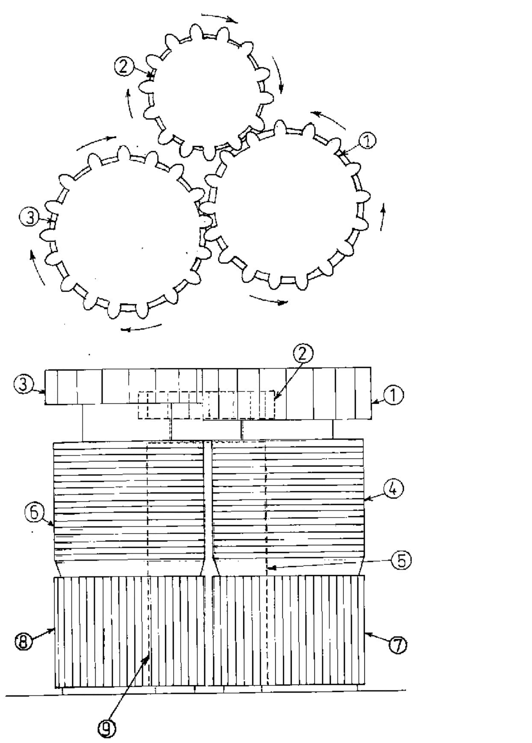
Sugarcane crushers are used for juice extraction by farmers and *jaggery* and *khandsari* industry. However, most of the traditional sugarcane crushers used by the farmers have less juice extraction capacity. Two improved designs of animal operated sugarcane crushers (*Khadi* and Village Industries Commission of India (KVIC) and Appropriate Technology Development Association (ATDA) were procured at Indian Institute of Sugarcane Research (IISR), Lucknow (Singh 1992; Singh 1998). The present study was undertaken to evaluate the performance of these crushers and compare their performance with traditional Kirloskar's Kumar crusher.

MATERIALS AND METHODS

Design details of crushers tested

Two improved sugarcane crushers as given below were procured for evaluation of their performance. Their design details are as follows:

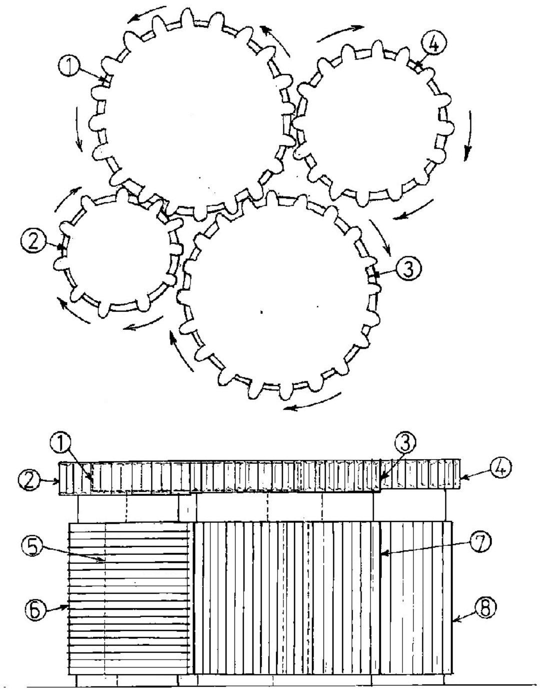
Animal operated KVIC design crusher: It is a three roller vertical crusher provided with a chute for recycling of crushed cane. The engineering drawing (Plan and Elevation) of the crusher is presented in Fig 1.



1. King roller's gear (17 teeth) 2. Crushing roller's gear (14 teeth) 3. Extraction roller's gear (17 teeth) 4. King roller, dia- 225 mm, 19 circumferential V-grooves in upper 200 mm length 5. Crushing roller, dia- 175 mm, 19 circumferential V-grooves in upper 200 mm length 6. Extraction roller, dia- 225 mm, 19 circumferential V-grooves in upper 200 mm length 7. King roller, dia- 225 mm, 43 longitudinal grooves in lower 160 mm length 8. Crushing roller, dia- 175 mm, 43 longitudinal grooves in lower 160 mm length 9. Extraction roller, dia- 225 mm, 43 longitudinal grooves in lower 160 mm length

Figure 1 Engineering drawing (Plan and Elevation) of KVIC Crusher

Animal operated ATDA design crusher: It is a four roller vertical crusher of which the engineering drawing (Plan and Elevation) is presented in Fig. 2.



1. King roller's gear (20 teeth) 2. Crushing roller's gear (11 teeth) 3. 1st Extraction roller's gear (20 teeth) 4. 2nd Extraction roller's gear (16 teeth) 5. King roller, dia- 225 mm, length- 180 mm, 66 longitudinal grooves 6. Crushing roller, dia- 125 mm, length- 180 mm, 23 circumferential V-grooves 7. 1st Extraction roller, dia- 225 mm, length- 180 mm, 66 longitudinal grooves 8. 2nd Extraction roller, dia- 175 mm, length- 180 mm, 66 longitudinal grooves

Figure 2 Engineering drawing (Plan and Elevation) of ATDA Crusher

Methodology

KVIC design crusher was provided with recycling chute. This crusher was tested under both the conditions i.e. with recycling chute (for recycling of crushed cane through the extraction roller) and without recycling chute. The effect of fourth roller in juice extraction by ATDA crusher was tested by increasing the gap between fourth roller (second extraction roller) and king roller. A constant gap of 0.7 mm was maintained between king roller and extraction roller in both the crushers.

Four extensively used *jaggery* making varieties of sugarcane namely 'CoLk 8001', 'CoS 767', 'CoJ 64' and 'Co 1148' were used for evaluating the performance of the crushers. The proximate composition of all the varieties were recorded and presented in Table 1. The fibre content of above varieties was 14.18, 13.28, 12.65 and 12.63%, respectively. Typical composition of total soluble solids (TSS) of cane juice is given in Table 2 (Madan *et al.* 1998). 25 kg of sugarcane was fed manually through the crusher for extraction of juice and the extracted juice was collected in a container. The number of replications was 5 for each treatment of crushing. Methodology used for testing of crushers was as prescribed by Bureau of Indian Standards (IS: 6997-1973). Weight of juice and time taken for crushing was recorded. Juice extraction (percentage of juice extracted on cane weight basis) and cane crushing capacity of crushers were calculated by using following mathematical relationships;

Juice extraction % = W_2*100/W_1

Cane crushing capacity of crusher kg/h = W_1*60/t

Where,

W_1 = Weight of cane crushed (kg); W_2 = Weight of juice extracted (kg); t = Time taken in crushing of cane (min)

Table 1 Proximate composition of sugarcane varieties tested

Sugarcane variety	Fibre content %	Juice content (%)		
		Total soluble solids (TSS)	Water	Total
'CoLk 8001'	14.18	20.10	65.72	85.82
'CoS 767'	13.28	20.13	66.59	86.72
'CoJ 64'	12.65	20.28	67.07	87.35
'Co 1148'	12.63	20.08	67.29	87.37

Table 2 Typical composition of total soluble solids (TSS) of cane juice

Sugar	
Sucrose, %	70-88
Glucose, %	2-4
Fructose, %	2-4%
Salts	
Inorganic, %	3.0-4.5
Organic, %	1.5-4.5
Organic acid	
Carboxylic acids, %	1.1-3.0
Amino acids, %	0.5-2.5
Other organic non-sugars	
Protein, %	0.5-0.6
Starch, %	0.001-0.050
Gums, %	0.3-0.6
Waxes, fats, phosphotides, %	0.05-0.15
Others	3-5

RESULTS AND DISCUSSION

Performance of crushers

The average juice extraction of KVIC (with recycling) and ATDA (with 4th roller) crushers was 64.2 and 65.3%, respectively (Table 3). The average juice extraction cane was 58.2% in traditional Kirloskar's Kumar crusher. The increase in juice extraction was 6.0 and 7.1%, respectively in KVIC and ATDA crusher as compared to traditional crushers.

Table 3 Test results of KVIC and ATDA crushers

Variety	Juice extraction, %				Cane crushing capacity, kg/h			
	KVIC crusher		ATDA crusher		KVIC crusher		ATDA crusher	
	With recycling	Without recycling	With 4th roller	Without 4th roller	With recycling	Without recycling	With 4th roller	Without 4th roller
'CoLk 8001'	63.6	63.2	63.2	60.4	86.7	107.1	107.1	121.0
'CoS 767'	62.0	60.0	64.0	61.6	73.5	126.1	111.9	116.3
'CoJ 64'	64.0	63.2	64.8	63.6	101.1	111.1	98.0	111.9
'Co 1148'	67. 2	66.4	69.2	68.4	80.6	88.2	78.1	86.7
Mean	64.2	63.2	65.3	63.5	85.5	108.1	98.8	109.0
C.V. %	0.72	1.01	1.30	1.22	4.75	6.55	4.19	5.71
S.E.	0.206	0.286	0.381	0.347	1.814	3.166	1.851	2.782
C.D. (P=0.05)	0.634	0.881	1.175	1.069	5.590	9.755	5.703	8.572

Table 4 Effect of recycling of crushed cane in KVIC and 4th roller in ATDA crusher (Variety: 'CoJ 64')

Particular	Juice extraction, %						
	R1	R2	R3	R4	R5	Mean	Difference
KVIC crusher with recycling of crushed cane	64.1	64.1	62.6	63.8	65.4	64.0	-
KVIC crusher without recycling of crushed cane	63.2	63.5	62.1	62.8	64.4	63.2	0.8
ATDA crusher with 4th roller	64.7	64.4	64.5	65.0	65.4	64.8	1.6*
ATDA crusher without 4th roller	63.6	64.0	63.3	63.4	63.7	63.6	1.2*
C.D. (P=0.05)						0.83	

Effect of variety

The maximum juice extraction of 67.2% was observed in case of variety 'Co 1148' followed by 'CoJ 64' (64.0%), 'CoLk 8001' (63.6%) and 'CoS 767' (62.0%) by KVIC crusher with recycling of crushed cane (Table 3). In case of ATDA crusher with 4th roller, the maximum juice extraction occurred for variety 'Co 1148' (69.2%) followed by 'CoJ 64' (64.8%), 'CoS 767' (64.0%) and 'CoLk 8001' (63.2%). The fibre content (Table 1) of 'Co 1148' was minimum (12.63%) followed by 'CoJ 64' (12.65%), 'CoS 767' (13.28%) and 'CoLk 8001' (14.18%) indicating that the juice extraction was the highest for the variety having lowest fibre content. It may be due to availability of more juice on cane weight basis and increased extraction of juice, at applied compressive pressure by the rollers.

Effect of recycling in KVIC and 4th roller in ATDA crusher

In order to study the effect of recycling of crushed cane in KVIC and 4th roller in ATDA crusher, the performance data of KVIC crusher (with recycling and without recycling) and ATDA crusher (with 4th and without 4th roller) were statistically analyzed for the variety 'CoJ 64' and presented in Table 4. The average juice extraction was 64.0% with recycling of crushed cane as against 63.2% without recycling. However, the increase in juice recovery was not significant due to recycling. Non-significant increase in the juice extraction with recycling of crushed cane may be due to re-absorption of extracted juice (of the first cycle crushed cane) by the recycled bagasse. It is also evident from the data in Table 4 that the average juice extraction of 64.8% with the fourth roller was significant than that without the fourth roller (63.6%), which may be due to two stage extraction consecutively without giving much time for re-absorption of extracted juice (of the first stage crushing) by the bagasse. On comparing the KVIC crusher with recycling and ATDA crusher with 4th roller, it was found that there was non-significant difference in the juice extraction. However, there was significant increase in juice extraction (1.6%) in ATDA crusher with 4th roller as compared to KVIC crusher without recycling of crushed cane (Table 4).

The average cane crushing capacity was 88.0 and 108.1 kg/h with recycling and without recycling, respectively in KVIC crusher (Table 3). Hence, the cane crushing capacity decreased by 18.6% with recycling of crushed cane in KVIC crusher. In case of ATDA crusher, the crushing capacity was 98.8 and 109.0 kg/h with 4th and without 4th roller, respectively. Thus, there was a reduction of 9.4% in the cane crushing capacity in case of 4th roller. Reduction in the cane crushing capacity with recycling in KVIC crusher and with 4th roller in ATDA crusher was due to increased power requirement for cane crushing thereby reducing the speed of animals for operating the crushers.

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Ring-pit planting method modulates assimilatory traits with increased yield of sugarcane

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ABSTRACT

Stagnating sugar production is a great concern to farmers, mill owners and planners in India. Various methods have been tried to overcome this bottleneck, but none had served the purpose. Here a comparison of conventional planting (CP) with an upcoming ring pit planting (RPP) method based on assimilatory traits has been made. Fraction of stalk in dry biomass was 0.86 when green aerial biomass was 4.3 kg/m^2 at 360 days of planting (DAP) in CP whereas in RPP only at 240 DAP it was 0.87 with aerial biomass of 3.89 kg/m^2. Trash fractions were more with aerial biomass (0.01-0.33) in CP than in RPP (0.01-0.20). This caused yield decline of dry stalk in CP (3.8 kg/m^2) compared with RPP (4.6 kg/m$^{2)}$ at 360 DAP. Different assimilatory traits like LAI, SLW (g/m^2), BD (gday*10^4), LAR (m^2/kg), and RGR (kg/ha/d) were 5.18, 110, 126.6, 2.08 and 136.07 in CP compared with RPP where it was 7.12, 140, 164.97, 2.51 and 222.48. The ranking of these parameters was made along with a regression equation for dry matter calculation in different growth stages indicated decreased Mallows' C_p ratio in RPP led to increased dry matter in RPP (55136 kg/ha) than CP (44155 kg/ha). Efforts had been made to establish their correlation and contributions in dry matter production. RPP method showed a promise to improve the sugarcane yield.

Keywords: Dry matter partitioning, Conventional planting, Ring-pit planting, Assimilatory parameters, Sucrose

Several attempts to improve the dry matter production and its partitioning towards stalk have been reported. Sugarcane has relatively high radiation use efficiency (varied from 1.63 to 2.09 g/MJ) which plays significant role in dry matter production and appears to be consistent across the cultivars and climatic zones in different countries (Sinclair and Muchow 1999). The average stalk cane yield in India has stagnated at 71 t/ha far below a record annual yield of 255 t/ha. The alternative left is thus to increase DM production through maneuvering RUE or related assimilatory attributes through non-monetary inputs.

Therefore, if population of mother shoot is increased and that of tillers decreased, considerable improvement in DM production and stalk yield can be achieved. Ring-pit planting (RPP), an up coming technique in sugarcane, is one of planting methods where number of mother shoots are increased while the tillers are suppressed as compared to the conventional planting (CP) method (by making ridges and furrows at 75 cm spacing and placing three budded setts in furrows from end to end along with fertilizers and insecticides. The maximum cane yield obtained in CP method is 70 t/ha against 184 t/ha in RPP (Yadav 1991). The major reasons responsible for enhancement of yield in RPP are sufficient utilization of light and air as well as nutrients due to localized placement of manures. The sufficient light and air improves plant structure which reduces disease incidence and insect infestation. Sufficient space between pits helps in operations like spraying, dusting and propping. Besides this, the root zone is deeper thus remained always moist. Lodging too is checked which adds to the enhancement in the yield as compared to CP.

The reports on understanding the physiological reasons responsible for yield differences in two planting methods are however is meager. It is thus reasonable to expect that yield of sugarcane depends on various expressions of radiation, temperature and plant water status in addition to the stalk biomass (Robertson *et al.* 1996). Therefore, investigation was undertaken to evaluate the assimilatory traits governing the increase in DM production and consequently the stalk yields. The work might help in a better understanding of the factors influencing DM partitioning in CP and RPP as a basis for improving the functional responses in sugarcane grown under different planting conditions. Later, it might help in assessing the capability of DM partitioning in sugarcane grown under two planting methods. Further, assessing the extent of DM partitioning into sucrose is possible in the two different planting methods which provide a basis for determining the sugarcane yields. The objectives of the study were: 1. DM partitioning pattern in sugarcane grown by conventional and ring pit plating

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methods. 2. Efficiency of RPP planting in comparison to CP for enhancing the DM through stalk mass, leaf number per stalk, leaf area index (LAI) and specific leaf weight (SLW) and leaf area ratio (LAR). 3. Correlation amongst growth parameters and DM production.

MATERIALS AND METHODS

Experimental site

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 Semiarid Eco-region with Alluvial-derived soils) (Sehgal 1990). Two experiments were conducted during 2004-2005 and 2005-2006 at the farm of the Institute. Data on weather parameters like mean temperature, relative humidity, rainfall and sun shine hours are presented in Table 1. The climate of the place is characterized by three distinct seasons, a very hot summer from April to June with maximum temperature up to 42°C, rainy season from July to September and cool winter from October to March with minimum temperature as low as 7°C. The organic carbon (OC) content of the soil was 0.78% with total nitrogen of 0.069%. The available N, P, K were 183.7, 18.7, 192 kg/ha, respectively in 2004-05 and corresponding the values in 2005-06 were 0.76% (OC), 0.067% (total nitrogen) and 185.6, 18.2, 190 kg/ha available N, P, K, respectively. Sugarcane variety 'CoSe 92423' was planted in spring season of 2004-05 and 2005-06 under conventional and ring pit planting methods keeping 60,000 / ha three budded sets constant in randomized block design with three replications.

Conventional planting (CP)

Furrows were opened with tractor drawn furrow opener at 75 cm spacing alternated by ridges and treated with chlorpyriphos 20% EC to control termites. N, P and K were applied @ of 150:80:80 kg/ha in the furrows, as urea, di-ammonium phosphate and muriate of potash, respectively. The three budded setts were placed in the furrows in such a way that their ends were overlapping to each other accommodating five setts per meter. The crop irrigated with five times up to June and two irrigations after September till harvest of crop in March. From July to September monsoon rains were sufficient to meet the water requirement of crop.

Ring pit planting (RPP)

Instead of laying ridges and furrows as per existing CP method, 45 cm deep pits of 90 cm (diameter) were dug with help of tractor mounted pit digger. Equal squares of 1.20 x 1.20 m size were marked on properly leveled field. The pit is dug in the centre of this square with the help of pit digger. The total number of pits was 6900/ha. These pits are then filled with a mixture of 5 kg farm yard manure, 45 gm DAP, 50 gm K and 45 gm urea and mixed with soil before sett placement. Planting of 3 budded 10 setts per pit was done horizontally in cyclic manner after treating cane seed with Bavastin 10 gm (a.i.)/l. To control the termites, 5.0 l chlorpyriphos 20% EC/ ha was applied at time of planting. A light irrigation in pits was given followed by hand hoeing at field moisture to break crust for further germination. Each pit was filled by transferring back half excavated soil lying at the edge of pits with 25 g urea in the month of March/April when plants attain a height of about 22-25 cm. Similarly, the remaining part of soil was put back in pits with 25 g urea and 4.5 g Carbofuran 3G per pit by the end of June. Weeds were controlled as recommended practice for CP. Propping was done 2-3 times. Care was taken to remove the tillers emerged in August, September and October. The field was irrigated 5-6 times before rainy season and 3 times thereafter. Earthing-up was done after 150 days of planting to avoid stagnation of water in pits during rainy season.

Table 1 Weather data of mean temperature, total rainfall, relative humidity and sun shine in the period from February 2004 to February, 2006.

	Month												
	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan 05	Feb
2004													
T Max ^{0}C	25.1	33.0	37.8	39.3	35	33.7	33	33.1	30.6	27.7	22.8	21.9	24.9
T Min ^{0}C	9.7	16.1	21.5	25.7	25.9	25.3	26.1	24.6	18.4	11.3	8.7	8.7	12.2
Rain fall (mm)	0	0	9.1	31.8	250.7	147.3	105.2	166.2	21.3	1.8	0	18	17.8
R.H. (%) (14.00 hrs)	40	27	23	30	57	73	74	63	48	41	54	47	44
Sun Shine (hr/d)	7.8	8.2	5.8	5.5	4.5	2.8	4.7	5.9	6.4	5	2.8	4	6.3
2005													
	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan 06	Feb
T Max ^{0}C	24.9	31.9	37.6	38.9	40.7	32.4	33.4	32.6	31.6	28.8	23.8	24	29.7
T Min ^{0}C	12.2	17.4	19.7	23.5	27.7	25.6	26.4	25.2	19.8	10.5	6.3	6.8	13.1
Rain fall (mm)	17.8	8.2	0	41	159.4	256.5	147.5	164.7	0	0	2.2	0	0
R.H. (%) (14.00 hrs)	44	33	16	25	34	75	67	68	53	31	38	35	34
Sun Shine (hr/d)	6.3	7.1	6.8	7.5	5.5	3.1	4	5.4	6.1	5.6	3	4.5	5

Sampling of dry matter

At one month interval, the plants from an area of 5m x 4.5m were dug out from both the planting methods as monolith of soil up to 72 cm depth and floated on water gently to remove extraneous soil. The plant parts were separated as leaf lamina, leaf sheath, dry trash, stalk and root. On each sampling date three samples were taken from pit as well conventional planted plots. The area of leaf laminae was recorded with the help of leaf area meter (CI-202 leaf area meter, CID Inc, USA). After recording the fresh weight of all morphological plant parts, the samples were dried in hot air oven first at 102 ˚C, then at 80 ˚C till constant weight were obtained.

The total leaf area of the individual stalk was obtained by adding the area of all leaves of each stalk. Results were expressed in m^2/ha. Leaf area index (LAI) was calculated by dividing the total leaf area with ground area covered by the plants. The growth parameters were individually computed using the formulae of Kvet *et al.* (1971). Net assimilation rate (NAR) = (W_2-W_1) ln L_2-L_1/ $[(t_2-t_1)\ (L_2-L_1)]$, dry matter produced per leaf area and time unit (g cm^2d^{-1}).

a. Leaf area ratio (LAR) =L/w, relates leaf area with total stalk dry matter (m^2/kg)

b. Leaf area duration (LAD) = $L_2+L_1\ (t_2-t_1)/2$ (cm^2d)

c. Biomass duration (Z) = $W_2+W_1\ (t_2-t_1)/2$ (g d) where W and L are the mean values of dry weight and leaf area at an specific time W_1 and W_2 represent initial and final mean value of dry weight of stalk and L_1 and L_2 are the initial and final mean value of leaf area corresponding to period t_2 and t_1.

Statistical design and data analysis

The experimental layout was a randomized complete block design with three replications. Mean values with standard error (S.E.) and least significant difference (LSD) are reported. Mallows' C_p (1973) criteria, error sum of square and R^2 (Adjusted), with the help of computer package Minitab release 6.1, were used to identify the important factors in dry matter production at different stages of crop growth. Regression analysis was done to assess the combined effect of these factors on dry matter production.

RESULTS AND DISCUSSION

Dry matter partitioning

Dry matter partitioning up to 90 days after planting (DAP) was 39.63, 28.4, 21.14 and 10.81% in leaf laminae, leaf sheath, stalk and root portion of sugarcane in CP whereas in RPP it was 35.62, 31.36, 25.4 and 7.85% (Table 2). It indicated that

Table 2 Dry matter production of sugarcane in different plant parts (kg/ha) monthly intervals starting from 90 days in ring-pit and conventional planting methods

Plant part/DAP	90	120	150	180	210	240	270	300	330	360	LSD (p=0.05)
CP											
Leaf lamina	568	1124	3139	5158	5814	5243	3295	3191	4292	3258	54.6
	(39.63)	(38.97)	(34.62)	(26.53)	(22.73)	(15.88)	(9.79)	(8.37)	(10.64)	(7.37)	
Leaf sheath	407	833	2363	3373	4002	3005	1811	2179	2223	2400	46.4
	(28.4)	(28.88)	(26.06)	(17.39)	(15.64)	(9.10)	(5.38)	(5.72)	(5.52)	(5.43)	
Stalk	303	672	3000	10469	15069	24178	28065	32147	33149	37978	23.8
	(21.14)	(23.30)	(33.08)	(53.85)	(58.92)	(74.56)	(83.45)	(84.40)	(82.36)	(86.01)	
Tops	1278	2629	8502	19000	24886	32426	33171	37517	39665	43636	121.4
	(89.18)	(91.15)	(93.76)	(97.73)	(97.31)	(73.24)	(98.64)	(98.50)	(98.55)	(98.82)	
Roots	155	255	565	441	686	585	456	571	582	519	12.7
	(10.81)	(8.84)	(6.23)	(2.26)	(2.68)	(1.77)	(1.35)	(1.50)	(1.45)	(1.17)	
Whole plant	1433	2884	9067	19441	25572	33011	33627	38088	40246	44155	134.6
tops/root	8	10	15	43	36	55	73	66	68	84	0.78
RPP											
Leaf lamina	254	554	3729	5124	6507	2549	3173	5059	5386	5119	55.2
	(35.62)	(44.64)	(35.48)	(25.20)	(18.40)	(6.45)	(7.88)	(10.24)	(9.82)	(10.00)	
Leaf sheath	222	400	2793	3817	4545	1857	2405	2854	3385	3211	42.7
	(31.36)	(32.23)	(26.57)	(18.77)	(12.85)	(4.69)	(5.97)	(5.77)	(6.17)	(5.82)	
Stalk	180	208	3518	11060	23523	34506	34106	40781	45388	46145	24.3
	(25.24)	(16.76)	(33.47)	(54.39)	(66.51)	(87.24)	(84.77)	(82.58)	(82.75)	(83.69)	
Tops	656	1162	10040	20001	34575	38911	39684	48693	54158	54475	141.5
	(92)	(93.63)	(95.54)	(98.36)	(97.76)	(98.38)	(98.64)	(98.60)	(98.74)	(98.80)	
Roots	56	79	468	333	789	639	546	690	687	661	14.6
	(7.85)	(6.36)	(4.45)	(1.63)	(2.23)	(1.61)	(1.36)	(1.40)	(1.25)	(1.19)	
Whole plant	713	1241	10508	20334	35364	39550	40230	49383	54845	55136	45.9
tops/root	12	15	21	60	44	61	73	71	79	82	1.25

Figures in parenthesis are % partitioning of dry matter

Table 3 Growth parameters in conventional and ring-pit methods of planting

Growth parameters/DAP	90	120	150	180	210	240	270	300	330	360	LSD (p=0.05)
CP											
Total No. of shoots (,000/ha)	300	220	150	180	160	190	250	160	180	240	4.5
Total dry matter (kg/ha)	1433	2884	9067	19442	25572	34234	38088	40246	43563	44155	86.4
Leaf area (m^2/ha)	5021	11744	25012	45006	51869	43349	34182	29705	29273	26074	123.6
Leaf sheath moisture %	74.8	83.4	76.3	76.6	73.7	73	72.3	70.6	69.8	69	0.04
LAI	0.50	1.17	2.50	4.50	5.18	4.33	3.41	2.96	2.92	2.61	0.05
LAR (m^2/kg)	3.93	4.47	2.94	2.37	2.08	1.34	0.69	0.86	0.88	0.68	0.04
SLW(g/m^2)	110	90	130	110	110	120	120	130	110	100	NS
Biomass duration g day X 10^4	-	6.48	17.93	42.67	67.52	87.87	99.96	107.57	117.50	126.60	3.4
RPP											
Total No. of shoots (,000/ha)	310	260	200	180	210	180	250	180	220	240	6.7
Total dry matter (kg/ha)	713	1241	10508	20334	35364	39550	40230	49383	54845	55136	45.9
Leaf area (m^2/ha)	2023	5488	26020	50228	60929	71287	43204	45716	26833	21998	145.6
Leaf sheath moisture %	79.7	83.7	85.5	75.4	73.2	72.9	71.4	70.9	70.2	70.1	0.05
LAI	0.20	0.55	2.60	5.02	6.09	7.12	4.13	4.56	2.68	2.19	0.02
LAR (m^2/kg)	3.08	4.72	2.59	2.51	1.76	1.30	0.88	0.84	0.67	0.56	0.04
SLW(g/m^2)	120	100	140	100	100	120	120	120	120	130	NS
Biomass duration g day x 10^4	-	2.93	17.62	46.26	83.55	112.37	119.67	134.42	156.34	164.97	4.3

more dry matter diversion in to stalk and less in root portion of sugarcane in RPP at this stage (Table 2). The rate of dry matter accumulation (Table 3) remained low in stalk portion (0.93 kg/ha/d) in RPP up to 120 DAP compared to CP (12.3 kg/ha/d). Up to 150 DAP rate of dry matter accumulation towards stalk increased to 110.33 kg/ha/d in RPP as compared with CP (77.6 kg/ha/d). Dry matter partitioning up to 180 DAP in leaf laminae, leaf sheath and stalk was higher in CP as compared to RPP. At this stage dry matter accumulation into the stalk was practically same. From 210 DAP, the dry matter partitioning increased into the stalk which was 415 kg/ha/d in RPP compared with 153.34 kg/ha/d in CP. After 330 DAP, the dry matter partitioning was >83% in the stalk of RPP whereas it was only 76% in CP (Table 2). This increase in dry matter was supported by an increase in DM in leaf laminae (9.3%) in RPP after 300 DAP as compared to 7.3% in CP. The total dry matter production up to 330 DAP was 99.4% in RPP whereas in CP it was 91%. The peak dry matter accumulation was after 330 DAP in RPP whereas it was after 360 DAP in CP. Since the dry matter partitioning was more in the stalk in RPP, the ability of crop canopy to export net photosynthates to stalk was higher in RPP than the CP. The stalk fraction of green biomass reached a maximum of 0.85 after 240 DAP in RPP where as it was achieved after 270 DAP in CP.

Up to 90 and 120 DAP dry matter production in different plant parts was lesser in RPP than CP. It may be because of more mother shoots and enhanced leaf area in RPP. After 120 DAP, due to establishment of mother shoots along with higher leaf area in RPP, the dry matter production increased. Due to the death of tillers, dry matter could not accumulate with the same pace in CP. The accumulations of dry matter in RPP start increasing from 150 DAP, onwards probably due to more number of mother shoots and increased leaf area for photosynthesis. Thus, sink strength and sink activity both are higher in RPP than CP. The enhanced sink activity was because of increased leaf area. The daily partitioning of assimilate in aerial part linearly increased in RPP as compared with CP. The higher rate of dry matter partitioning to the stalk in RPP, showed a better source strength. Partitioning of stalk dry matter was regulated by sink capacity and source to sink ratio. It follows that sink capacity was dictated by growing conditions which were better in ring-pit method.

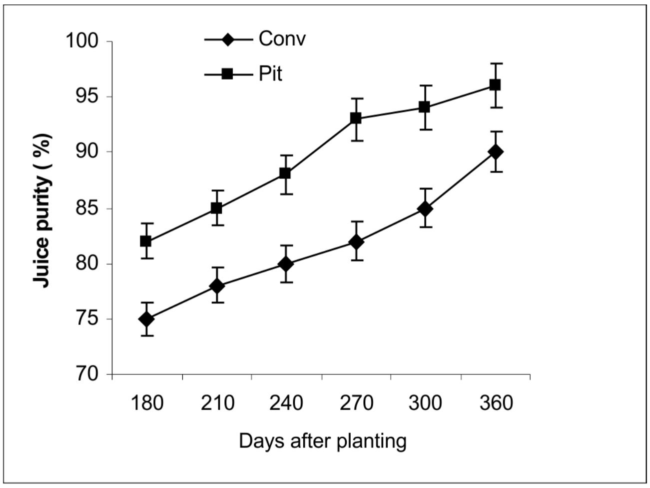
In CP, the maximum dry matter accumulation in leaf laminae was after 180 DAP but in RPP this was achieved earlier i.e. 180 DAP indicating faster development of source strength in RPP. Further, the rate of dry matter (kg/ha/d) accumulation in leaf laminae of RPP (105.8) than CP (67.2) after150 DAP. Partitioning of dry matter in leaf sheath was found to be maximum at 150 DAP in both the methods but accumulation of dry matter was higher in RPP (79.8 kg/ha/d) than CP (51.0 kg/ha/d). This showed higher sink activity in RPP than CP. Singels and Bezuidenhout (2003) observed higher sink strength with increased sink activity. The observation in this experiment had also shown enhanced sink strength in RPP due to enhanced dry matter accumulation into stalk at 210 DAP. In CP maximum dry matter partitioning per day was occurred at 180 DAP but its magnitude was less than the RPP. In this way the development of sink strength was higher in RPP as compared with CP due to enhanced photosynthetic area at 120 DAP. The partitioning of dry matter increased in leaf sheath and stalk in RPP but not achieved in CP. The trend of total dry matter accumulation (kg/ha/d) showed a decrease later on at 120 DAP in RPP.

Fraction of Leaf Lamina, Leaf Sheath and Stalk in aerial dry biomass

Fraction of stalk in dry biomass was 0.86 when green aerial biomass was 4.3 kg/m^2 after 360 days of growth in CP (R^2=0.97) but it was 0.87 with aerial biomass of 3.89 kg/m^2 achieved after 240 days of growth in RPP (R^2=0.92). This is an indicative of plant robustness in RPP over CP. Maximum fraction of leaf sheath and leaf lamina was 0.29 and 0.40 and R^2 (0.61 and 0.95), achieved after 120 days and 90 days of growth in CP when aerial green biomass were 0.26 and 0.12 kg/m^2, respectively. In RPP these were achieved at 120 DAP when the fractions of leaf sheath and leaf lamina were 0.32 and 0.45 at 0.11 kg/m^2 of green aerial biomass (R^2=0.41 and 0.85) . It indicated quicker dry matter partitioning towards stalk in RPP. At low bio-mass, allocation of fraction of dry matter was more in leaf sheath and leaf lamina in RPP as compared with CP. RPP produced 5.44 kg/m^2 at harvesting time against 4.36 kg/m^2 in CP. Trash fraction varied slightly with aerial biomass (0.01-0.33; R^2= 0.79) in CP and was lesser for RPP (0.01-0.20; R^2= 0.70). This resulted in decline of dry stalk in CP (3.8 kg/m^2) compared with RPP (4.6 kg/m^2) at 360 DAP. It indicated that about 10 to 20% of dry mass accumulated by sugarcane in RPP where as this value was 10 to 33% in CP. Differences in trash fraction between two methods also indicated the suitability of RPP because it adjusts leaf area for longer duration. Juice purity % and sucrose (g/g DM) was low in CP than RPP (Fig 1) starting from 180 to 360 days after planting. Higher accumulation of sucrose in to the stalk indicated more diversion of photosynthates to sugar yield.

Leaf area duration (LAD)

Leaf area duration in RPP was less up to 150 DAP but later on it increased in comparison to CP. The increased LAD was recorded up to 330 DAP in RPP. After 150 DAP, maximum photosynthates were diverted for building of parenchyma cells of stalk for accumulation of sugar. Stalk development as well as sucrose synthesis remain at high peak due to availability of leaf area for photosynthesis longer duration for in RPP than CP. Consequential the dry matter accumulation and shoot population were more in RPP than CP. Thus the variation in DM in both methods of planting was mainly a reflection of leaf area duration (LAD). Drastic increase in biomass duration was noted during sugarcane ripening phase in two methods. However accumulation occurred during growth period in RPP.



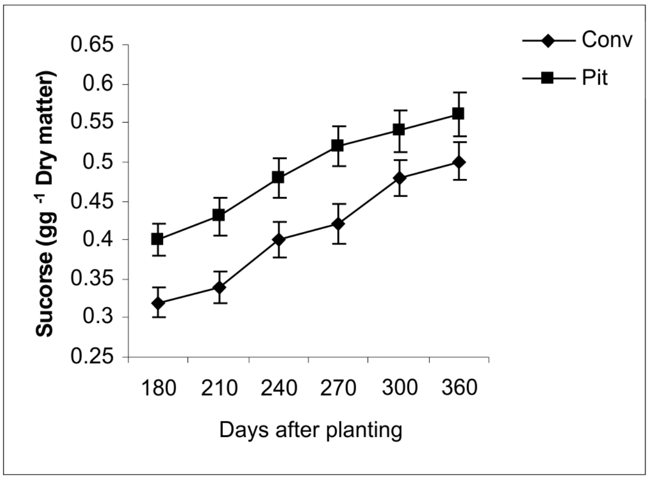


Fig 1 Sucrose and juice purity from the stalk portion sampled at different days of planting. The stalks were segmented from base upward. Bars show mean ± one standard error.

Leaf area index (LAI) and leaf area expansion

LAI increased from 150 to 330 DAP in RPP than the CP and decreased at 240 DAP in RPP indicating that plant apical growth ceased and accumulation of sugar started into stalk. But LAI in general was higher in RPP than in CP. The higher LAI increased canopy photosynthesis through enhanced interception of quantum of radiation, so in RPP this was increased to 7 compared with 4 in CP indicating higher interception of radiation resulting in more dry matter production. Waldron *et al.* (1967) noted that when leaf area index reaches 4-5, more than 80% of the incident photosynthetically active radiation will be intercepted by the canopy. The rate of canopy closure and early development of LAI is much faster in RPP; hence solar radiation absorption. The increased photosynthesis was achieved by enhancing LAI. LAI was positively associated with tonnage of cane. A significant positive relationship between LAI at early stages and yield contributed to better crop establishment. The relationship of biomass accumulation and LAI for an autumn-planted sugarcane crop was positive. The increase in LAI had increased crop yield also (Silva *et al.* 1998).

The leaf expansion rate (m^2/d) remain low in CP compared with RPP up to 240 DAP indicating increase in photosynthetic area in RPP. Since leaf area index is closely related to planting density and crop age, the leaf expansion rate is a reflection of short term crop growth rate (CGR). The CGR is usually linearly related to the amount of photosynthetically active radiation intercepted by canopy, which in turn is primarily a function of the LAI. When the LAI is below 3, there is an approximate linear gain in CGR with increasing LAI. As the LAI increases up to about 6, the CGR reaches a maximum, apparently a saturated rate. The increase in LAI up to >7 in RPP indicated the robustness of plants in this method over CP (Table 2). The leaf width, SLW and leaf porosity were significantly correlated with total dry matter production but not with yield. However, yield was associated with canopy characteristics of LAI and leaf arrangement. The differences in dry matter production in two methods may be due to changes in canopy structure. The increase in yield in RPP might due to alteration in canopy characteristics relating to light interception rather than alteration associated with net photosynthetic rate which is a measure of photosynthetic capacity. The net photosynthetic rate was positively associated with SLW. In thicker leaves there was a higher concentration of protein-N, P and K on unit area basis which seemed to account for the higher net photosynthetic rate measured.

The partitioning of dry matter into leaf area is an important component of growth. Accordingly, an expression was developed to measure leaf area partitioning. Compared with leaf area at 90 DAP an increase at 120 DAP was 133.9% in CP but it was 117.3% in RPP. At 150 DAP increase was 112.9% in CP and 374% in RPP. Later on it declined in both the plantings but again it increased to 93% and 80% in RPP and CP at 180 DAP over 150 DAP. After 180 DAP, per cent increase was 21.3 and 15.3 in RPP and CP, respectively. At 180 DAP; increase in leaf area was 17% in RPP and 16.43% in CP indicating early setting of dry leaf (trash) formation in CP compared with RPP. After 250 DAP leaf area decreased in both the plantings. The expansion rate per day of leaf area was 4.46, 3.77, 2.66, 0.51 (m^2/d) in CP at 120, 250, 180, 210, DAP whereas in RPP the rate was 5.71, 12.47, 3.10, 0.71, but partitioning of weight gain in leaf dry weight per day, at same DAP, was 33, 60, 21, 4 (g/d) in CP against 39, 191, 46, 9 g/d in RPP. These differences caused a large difference in relative growth rate of different growth parameters of two planting methods (Fig 2). Relative growth rates were poorly correlated with net assimilation rates in two methods of planting. The product of net assimilation rate and leaf area was found to be equal to the relative leaf area expansion rate. These results indicate that growth responses due to planting methods were more sensitive to changes in leaf area partitioning or relative

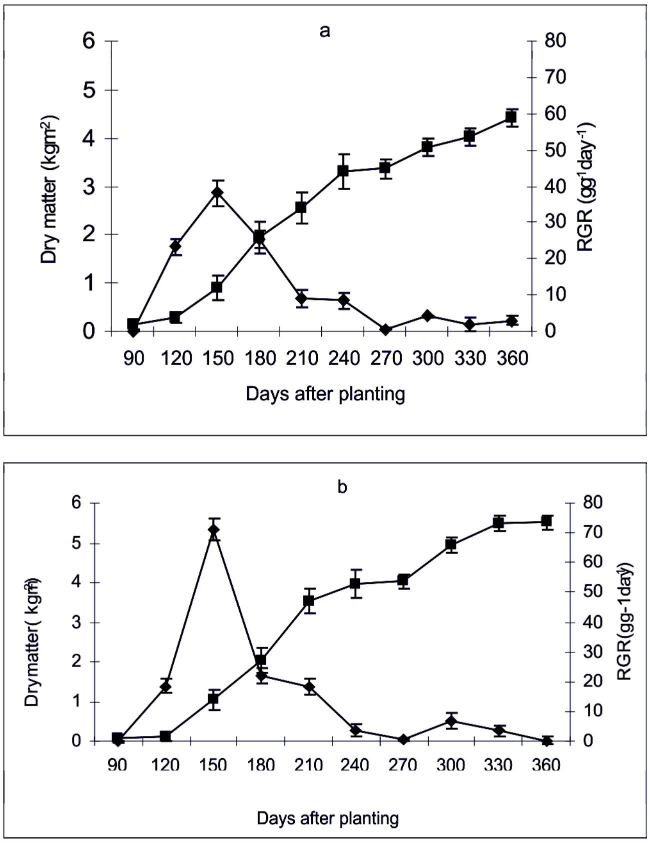


Fig 2 Dry matter production (■) and relative growth rate (◆) at different days after planting in a (conventional), b (Ring-Pit) method of sugarcane planting. Values are means of three replicates. Vertical bars represent ± standard error of the mean.

leaf area expansion rates than to net assimilation rates. Because the changes in leaf area partitioning or relative leaf area expansion rates can have an effect on relative growth rates that overshadow changes in net assimilation rates. Moreover net assimilation rates are largely a function of unit area rates of DM production, it's the correlation should include consideration of leaf area partitioning or relative leaf area expansion rates. The process of leaf appearance, expansion and eventual senescence (trash formation) are closely related to each other in sugarcane (Inman-Bamber 2004) and dynamics of this relationship is affected by both environmental and metabolic factors. The drying of leaves in sugarcane is related to stalk sucrose content, rather than merely a consequence of leaf shading or other physiological stresses which may accumulate as the plant reaches to maturity. Further, it may be at least partly due to a perturbation of source-sink signaling resulting from an increase in sucrose accumulation in the stalk (McCormick *et al.* 2008). The growth parameters such as net assimilation rate, relative growth rate, leaf area index and leaf area duration under different planting methods, during the formative phase determine total dry matter at harvest. Leaf area ratio was not found to correlate with total dry matter at harvest in either planting methods.

Leaf sheath moisture

Leaf sheath moisture was 79.7% at 90 DAP which increased to 85.5% at 150 DAP in RPP but in CP it was 74.8 at 90 DAP and 76.3% at 150 DAP. For optimal growth of sugarcane, the leaf sheath moisture should be maintained 85% or more (Clements 1980). This indicated that the magnitude of decrease in leaf sheath moisture was of higher order in CP than RPP. The moisture% decreased to 73% at 210 DAP in RPP at 240 DAP in CP. This may be due to better root development and utilization of available water in RPP than CP. Further, due to closed canopy the loss of moisture was less in RPP.

Top : root ratio

The top: root ratio is morphological trait commonly used for water balance perspective. A low top: root ratio in CP up to 240 days of growth means that roots are abundant in comparison to the foliage, and that plants have high water stress avoidance potential. This characteristic was not present in RPP where water stress avoidance potential was low due to higher top: root ratio. A high ratio after 300 days of growth in CP means that the roots are not abundant, and the plants are more likely to suffer water stress compared with RPP, particularly in drought with high evaporative demand. This characteristic help in early maturity of the cane in CP with low yield compared with RPP.

Specific Leaf Area (SLA)

The growth characteristics was faster up to 120 DAP in conventional planting because LAI was 1.17 compared to ring-pit method where LAI was 0.55 at 150 DAP the LAI values were practically same. Thereafter, LAI increased much faster in ring-pit method to 7.12 at 240 DAP against 4.33 in conventional planting. It showed a higher dry matter production at the early stage of growth. However, the relative growth rate (RGR) of stalk was higher (110.3 kg/ha/d) up to

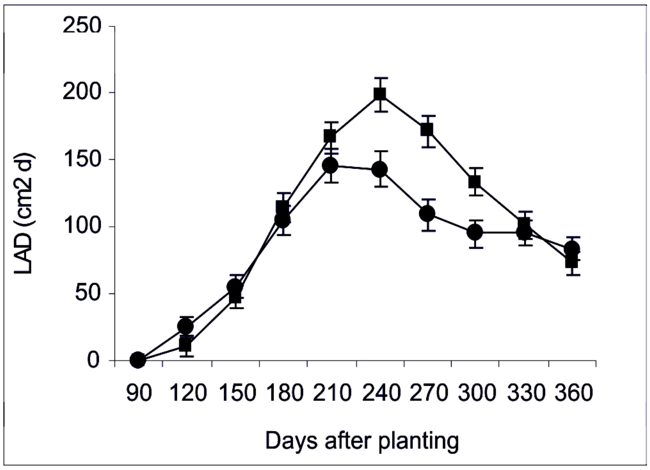


Fig 3 Net assimilation rate and leaf area duration in Conventional (●) and Ring-Pit (■). Vertical bars show mean ± SE.

150 DAP in ring-pit method compared with conventional planting (77.6 kg/ha/d). The low accumulation of DM in conventional method was presumably due to the very low leaf area ratio associated with the very low specific leaf area (Table 3), in spite of the higher net assimilation rate (Fig 3). Moreover, a high leaf laminae growth rate (Table 3) at early stage in RPP might have enhanced dry matter production within the short period. A slow growth during the early stage in sugarcane yields low in spite of its long crop duration, though the photosynthetic ability is high. A small specific leaf area (SLA) is the main reason; it takes longer for the canopy structure to complete in CP (Table 3). Enhancement of the early growth in RPP was due to the leaf characteristics. SLA negatively correlates with leaf thickness and leaf length per width ratio (leaf index). It is appropriate to have leaf blades short, wide, and thin to get high SLA. Dry matter per stalk was obviously higher (Table 2) because the number of tillers did not affect the total dry

Table 4 Rate of dry matter accumulation (kg/ha/d) in different plant parts at different DAP as influenced by methods of planting.

DAP	CP			RPP		
	Leaf Lamina	Leaf Sheath	Stalk	Leaf Lamina	Leaf Sheath	Stalk
120	18.51	14.22	12.3	9.98	5.94	0.93
150	67.19	50.98	77.58	105.83	79.78	110.33
180	67.28	33.65	248.98	46.52	34.12	251.4
210	21.88	21.00	153.34	46.09	24.27	415.43
240	19.04	33.24	303.63	131.92	89.61	366.08
270	64.92	39.81	129.55	20.77	18.29	133.12
300	3.48	12.28	136.07	62.87	14.95	222.48
330	36.71	1.47	33.41	10.9	17.7	153.57
360	34.48	5.9	160.95	124.43	60.86	174.76

Table 5 Important factors responsible for dry matter production in different stages of growth in sugarcane

CP

Crop stage (DAP)	Factors in order of importance					R^2 (Adj.)	Mallows' C_p ratio	Error sum of square
	I	II	III	IV	V			
1-180	LA	LAI	RGR	SLW	LAR	98.0	3.9	1.301
181-270	SLW	LA	LAI	LAR	RGR	90.1	4.9	12.157
271-360	RGR	LAR	SLW	LAI	LA	98.3	2.5	20.935
Over three stages	LA	LAI	LAR	SLW	RGR	93.3	2.6	34.689

RPP

Crop stage (DAP)	Factors in order of importance					R^2 (Adj.)	Mallows' C_p ratio	Error sum of square
	I	II	III	IV	V			
1-180	LA	LAI	RGR	LAR	SLW	94.0	2.9	1.012
181-270	SLW	RGR	LAR	LAI	LA	98.2	3.8	10.345
271-360	SLW	RGR	LA	LAR	LAI	90.2	2.1	19.456
Over three stages	LA	LAI	SLW	RGR	LAR	92.4	1.8	31.234

Table 6 Regression equations for predicting DM in different stages of growth in sugarcane

CP

Crop stages (DAP)	Regression equation	R^2 (Adj.)
1-180	DM=65.1+0.235 LA+0.125 LAI+4.07 RGR+2.78 SLW-10.9 LAR	98.3
181-270	DM=89.2 SLW+0.0658 LA+0.488 LAI -6.73 LAR- 38.07 RGR	90.1
271-360	DM=153+0.43 RGR-0.94 LAR-0.80 SLW)- 0.94 LAI-0.96 LA	98.0
Over three stages	DM=57.7-71.2 LA+0.201 LAI + 0.425 LAR + 23.2 SLW- 0.432 RGR	93.3

RPP

Crop stages (DAP)	Regression equation	R^2 (Adj.)
1-180	DM=75.1+0.435 LA+0.725 LAI+2.07RGR+2.38 LAR-18.9 SLW	98.2
181-270	DM=92.2 +2.45SLW+6.0623RGR+0.344 LA -7.53 LAR- 28.04LAI	94.0
271-360	DM=173+0.83 SLW-0.85 RGR-0.76LA- 0.74 LAR-0.06 LAI	90.2
Over three stages	DM=87.7-42.2 LA+0.712 LAI + 0.825 SLW +13.4 RGR- 0.535 LA R	92.4

matter production in early growth. The rapid stalk growth with less-tillering enables quicker growth in the early stage. The effective canopy structure for solar radiation is a key morphological characteristic for rapid growth in the early stage (Takayoshi and Makoto 2000).

Factors responsible by dry matter production

On ranking the different parameters in early growth stages (1-180 DAP) in decreasing order of importance were leaf area (LA), LAI, RGR, SLW and LAR in CP whereas in RPP these ranking were LA, LAI, RGR, LAR and SLW. In middle stage (181-270 DAP), these factors for CP were SLW, LA, LAI, LAR and RGR in whereas in RPP these were SLW, RGR LAR, LAI and LA. In late stage (271-360 DAP), these in decreasing order were RGR, LAR, SLW, LAI and LA in CP and SLW, RGR, LA, LAR and LAI in RPP. For the crop as a whole, the major factors in decreasing order were LA, LAI, LAR, SLW and RGR in CP; LA, LAI, SLW, RGR and LAR in RPP. In early stage (1-180 DAP), the best combination of these factors explained 98.3 % variation in dry matter production with lowest Mallows' C_p ratio (3.9) in CP and 98.2% variation in RPP at lowest Mallows' C_p ratio (2.9). This ratio showed variation in different growth stages (Table 4). Based on the above observations regression equations for three stages of growth and for the crop as a whole depict the responsible factors for dry matter production have been presented in Table 5.

The dry matter partitioning was >83% in the stalk of the plants in RPP whereas it was only 76% in CP at 330 DAP. This increase in dry matter was supported by increase in DM in leaf laminae (9.3 %) in ring-pit method against 7.3% in

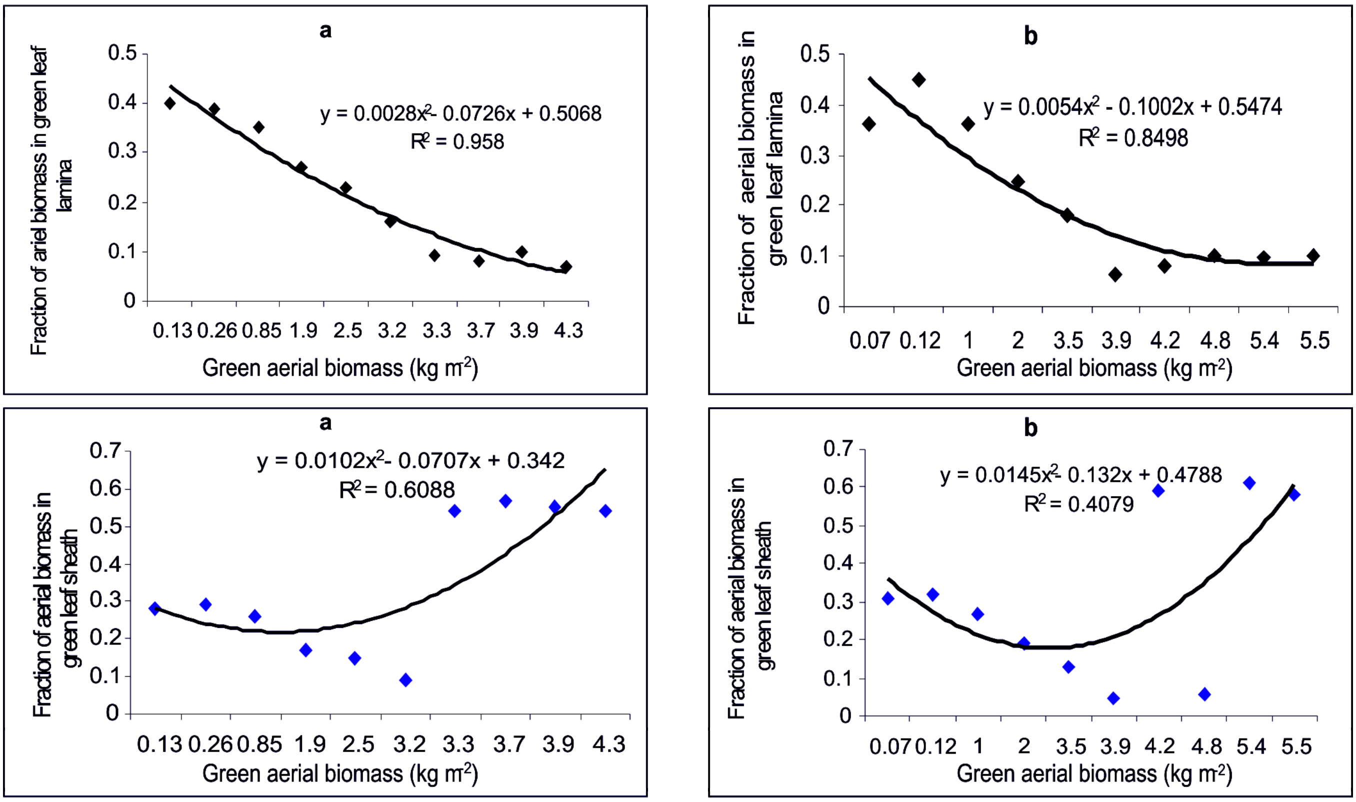


Fig 2 Fraction of aerial biomass in green leaf lamina and leaf sheath of aerial biomass in relation to days after planting in a (conventional) and b (Ring-Pit). Values are means of three replicates.

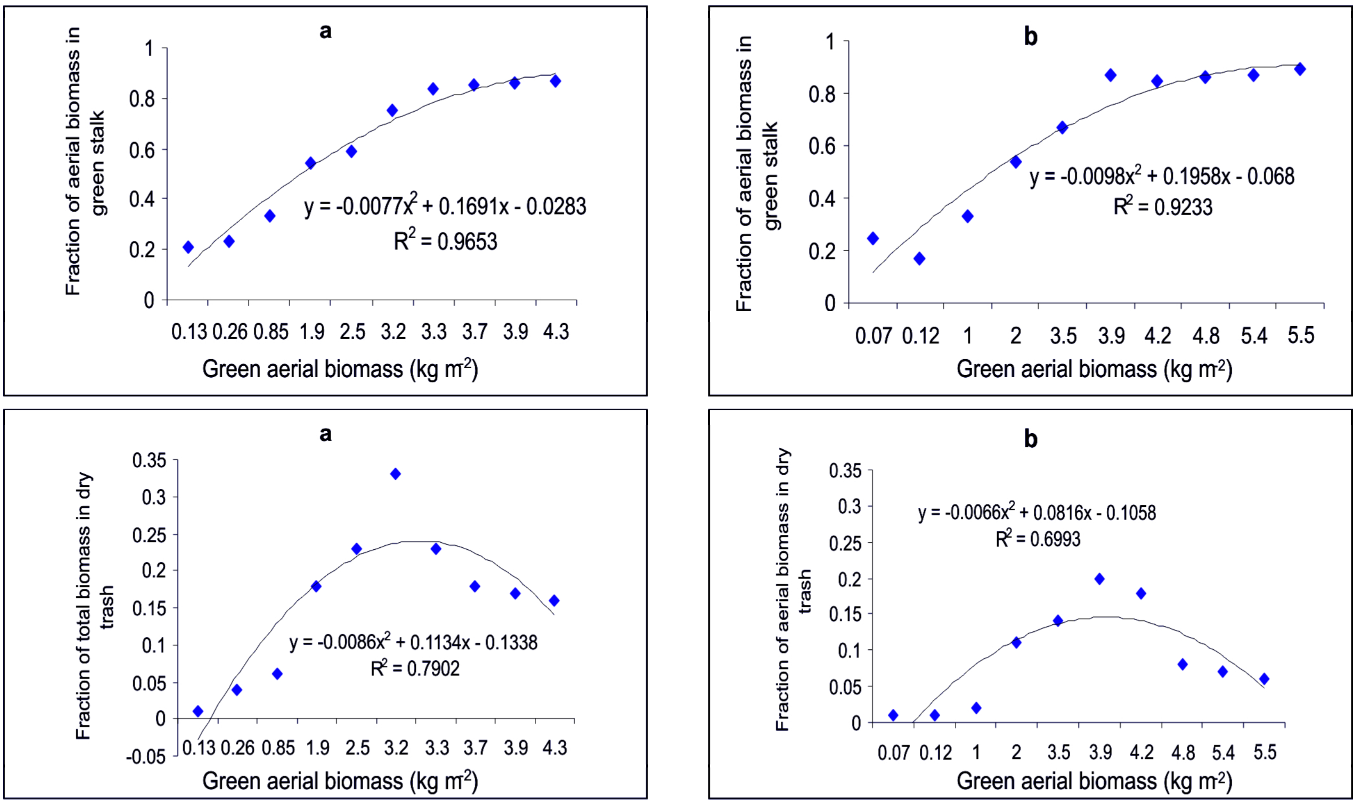


Fig 5 Fraction of aerial biomass in green stalk and trash in relation to days after planting in a (conventional) and b (Ring-Pit). Values are means of three replicates.

conventional method. The sink strength and sink activity were higher in RPP than CP. The rate of dry matter (kg/ha/d) accumulation was much higher in leaf lamina of RPP (105.8) at150 DAP than CP (67.2). Increased LAD indicated that the process of photosynthesis was more in RPP because of functional leaf area available for longer duration. That was the reason why shoot population as well as dry matter accumulation was more in RPP than in CP. High net assimilation rate, biomass duration, optimum leaf area index, high relative growth rate and an early partitioning of dry matter into the stalk were found to be more in RPP than CP which are desirable for higher biomass production. Fraction of stalk in dry biomass was 0.86 when green aerial biomass was 4.3 kg/ m^2 at 360 days of growth in CP (R^2=0.97) but it was attained at 240 days of growth in RPP (R^2=0.92) with almost similar fraction of dry biomass (0.87) with aerial biomass of 3.89 kg/ m^2. This is an indicative of early robustness of plants of RPP over CP. Differences in trash fraction between two methods indicated the suitability of RPP because it maintain leaf area for longer duration. Juice purity % and sucrose (g/g DM) were low in CP than RPP starting from 180 to 360 days after planting.

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Evaluation of primary and secondary infestation in sugarcane caused by *Chilo tumidicostalis* Hampsom

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ABSTRACT

Per cent infestation, intensity and infestation index in primary infestation were gradually increased reaching a peak in the month of August and proved was highly significant than that of other months. While in case of secondary infestation, these parameters showed a steady increase reaching a peak in the month of October with slight decline in preceding and succeeding months. The data clearly indicate that per cent infestation, intensity, and infestation index were of higher magnitude in primary infestation than secondary infestation in the crop. The primary infestation occurred just after internode formation in the plant, while severe secondary infestation was noticed in later stage of plant.

Key words: Infestation, Infestation index, *Chilo tumidicostalis*, Sugarcane

Sugarcane (*Saccharum* spp. hybrids) is an important agro-industrial commercial crop which plays vital role in national economy by contributing 0.67% to GD. However sugarcane crop is attacked by a number of insect pests, Plassey borer, *Chilo tumidicostalis* Lampson is one such major pest that causes an economic loss to the crop from planting to harvesting. According to Bhuyan (1999) the insect causes primary damage resulting in drying up of crown leaves and top few internodes, while secondary damage is caused by migratory larvae feeding to tunneling of internodes without drying up of crown leaves. He further reported that the insect enters through the top of spindle in primary infested canes, while it bores little above spindle in secondary infestation. The proportion of damaged length was significantly more in primary infested canes than in secondary infested ones.

The pest is responsible for yield losses due to primary and secondary infestation and causes damage to an extent of 60-70% of sugarcane every year throughout the cropping period in the state of Assam (Anonymous 1993), In view of great economic importance of sugarcane in agro-ecosystem of Bihar and the extent of damage caused by *C. tumidicostalis*, the experiment was conducted in order evaluate primary and secondary infestation caused by *C. tumidicostalis*, intensity and infestation index of target pest during in sugarcane.

MATERIALS AND METHODS

The experiment was conducted at Sugarcane Research Farm, SRI, Rajendra Agricultural University, Pusa (Bihar) during crop season of 2011-12 with sugarcane variety 'CoP 9702'. The planting was done during 2nd week of February, 2011 with recommended agronomical practices for sugarcane cultivation in Bihar.

The observations were recorded at fortnightly interval starting from May 2011 onwards harvest of the crop till in February, 2012. For this 20 plants randomly selected from 5 places were examined at each occasion to record the primary and secondary damaged canes based on the presence of borer holes, frass and dry crown along with the total number of canes. Both the types were recorded by tagging the damaged canes based on damaged symptoms in sugarcane field. The per cent damage, per cent intensity and per cent infestation index due to primary and secondary infestation were calculated using the following formulae.

$$\% \text{ Infestation} = \frac{\text{No. of canes infested}}{\text{Total no. of canes examined}} \times 100$$

$$\% \text{ Intensity} = \frac{\text{No. of bored internodes in infested canes}}{\text{Total no. of internodes in infested canes}} \times 100$$

$$\% \text{ Infestation index} = \frac{\% \text{ Infestation} \times \% \text{ Intensity}}{100} \text{ x}$$

RESULTS AND DICUSSION

The per cent infestation was 7.47 in the month of June 2011 and gradually increased, reaching a peak (12.47%) in the month of August 2011. Its intensity and infestation index percentage was 19.66 and 2.44, respectively in August (Table 1). The per cent infestation was 2.47 in the month of January, 2012 and it gradually increased, reaching a peak (12.47%) in the month of August, 2011 with intensity and infestation index

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Table 1 Percent infestation, intensity and infestation index caused by plassey borer in primary infestation

Observation month	Fortnight	No. of infested plants (on 20 plants basis)		% infestation		Total no. of internodes in infested canes		No. of bored internodes in infested canes		% intensity		% infestation index	
May 2011	I	1.00	(1.16)	5.00	(5.82)	11.00	(11.16)	1.00	(1.16)	9.09	(10.41)	0.45	(0.61)
	II	1.33		6.65		11.33		1.33		11.73		0.78	
June 2011	I	1.66	(1.49)	8.30	(7.47)	3.33	(2.33)	0.33	(0.33)	9.90	(17.37)	0.82	(1.23)
	II	1.33		6.65		1.33		0.33		24.81		1.64	
July 2011	I	1.66	(1.83)	8.30	(9.15)	12.00	(11.33)	2.00	(2.16)	16.66	(19.25)	1.38	(1.78)
	II	2.00		10.00		10.66		2.33		21.85		2.18	
August 2011	I	2.66	(2.49)	13.30	(12.47)	10.33	(8.49)	2.00	(1.66)	19.36	(19.66)	2.57	(2.44)
	II	2.33		11.65		6.66		1.33		19.96		2.32	
September 2011	I	1.66	(1.49)	8.30	(7.47)	9.66	(9.49)	1.33	(1.33)	13.76	(14.00)	1.14	(1.04)
	II	1.33		6.65		9.33		1.33		14.25		0.94	
October 2011	I	1.00	(1.65)	5.00	(5.82)	14.66	(14.83)	1.66	(1.83)	11.32	(12.32)	0.56	(0.72)
	II	1.33		6.65		15.00		2.00		13.33		0.88	
November 2011	I	1.00	(0.83)	5.00	(4.15)	10.33	(8.49)	1.33	(1.16)	12.87	(12.20)	0.64	(0.57)
	II	0.66		3.30		8.66		1.00		15.54		0.51	
December 2011	I	0.66	(0.66)	3.30	(3.30)	8.33	(8.49)	0.66	(0.66)	7.92	(7.77)	0.26	(0.255)
	II	0.66		3.30		8.66		0.66		7.62		0.25	
January 2012	I	0.33	(0.49)	1.65	(2.47)	10.66	(10.83)	1.66	(1.66)	15.57	(1.33)	0.25	(0.37)
	II	0.66		3.30		11.00		1.66		15.09		0.49	
February 2012	I	1.00	(1.65)	5.00	(5.82)	13.66	(13.49)	1.66	(1.33)	12.15	(9.82)	0.60	(0.54)
	II	1.33		6.65		13.33		1.00		7.50		0.49	
SEm (±)		0.007				0.588		0.077					
CD (P = 0.05)		0.215*				1.631*		0.215*					
CV (%)		10.475				10.213		10.024					

*Significant at 0.05 probability level; Tabulated data indicate mean of three replications; Parenthesis values are averages of 1st and 2nd fortnightTable 2 Percent infestation, intensity and infestation index caused by plassey borer in secondary infestation

percentage of 19.66 and 2.44, respectively, which was highly significant (P=0.01) than other months. In the subsequent months from September 2011 to January 2012, there was slight decline in the percentage of these infestation indices. Further, was the same (5.82%) as that in the month of May, 2011. However, the percentages of infestation in the primary infestation caused showed highly significant difference (P = 0.05).

The infestation, intensity and infestation index percentages were 7.47, 15.24 and 1.16, respectively, which showed a steady increase reaching to a peak in the month of October, 2011 in secondary infestation of the canes Table 2. A slight declined trend was observed during the preceding and succeeding months except in the month of February, 2012. The lowest infestation, (2.47%), intensity (3.74%) and infestation index (0.095%) occurred in the month of January, 2012. The data also indicated that infestation, intensity and infestation index percentage in secondary infestation were less than that of the primary ones. However, significant differences among the treatments observed. The slight decrease in infestation, intensity and infestation index percentage in both primary and secondary infestations of the canes from November, 2011 to January, 2012 was due to the fact that larvae during winter months undergone hibernation and did not feed on the canes. More over some of the canes damaged earlier might have perished. Similar observations were recorded by Rajmedhi *et al*. (1998) they observed that the average loss in cane yield and sugar recovery varied from 1.24 to 7.85% and 0.06 to 0.73% due to primary infestation, while the corresponding values were 0.23 to 2.82% and 0.004 to 0.15%, respectively due to secondary infestation. In their study the internode damage varied from 30.80 to 46.10% in different varieties with the maximum (46.10%) recorded in variety 'Co 8112' and the minimum (30.80%) in 'Co 740'.

Thus, it may be inferred that per cent infestation, intensity and infestation index were more in primary infestation than in secondary infestation. The primary infestation gradually increased reaching to a peak in the month of August and showed a slight declining trend from September to January. While in case of secondary infestation, the peak occurred in the month of October with slight decline during preceding and succeeding months of the study.

Table 2 Percent infestation, intensity and infestation index caused by plassey borer in secondary infestation

Observation month	Fort-night	No. of infested plants (on 20 plants basis)		% infestation		Total no. of internodes in infested canes		No. of bored internodes in infested canes		% intensity		% infestation index	
May 2011	I	0.66	(0.49)	3.30	(2.47)	13.66	(13.16)	0.33	(0.49)	2.41	(3.81)	0.079	(0.082)
	II	0.33		1.65		12.66		0.66		5.21		0.085	
June 2011	I	0.33	(0.49)	1.65	(2.47)	10.66	(10.16)	0.33	(0.49)	3.09	(4.96)	0.050	(0.13)
	II	0.66		3.30		9.66		0.66		6.83		0.22	
July 2011	I	0.66	(0.66)	3.30	(3.30)	9.66	(9.16)	1.00	(1.00)	10.35	(10.94)	0.34	(0.36)
	II	0.66		3.30		8.66		1.00		11.54		0.38	
August 2011	I	0.66	(1.49)	3.30	(4.15)	2.66	(2.83)	0.33	(0.33)	12.40	(11.70)	0.40	(0.47)
	II	1.00		5.00		3.00		0.33		11.00		0.55	
September 2011	I	1.33	(1.33)	6.65	(6.65)	11.33	(10.99)	1.33	(1.49)	11.73	(13.65)	0.78	(0.90)
	II	1.33		6.65		10.66		1.66		15.57		1.03	
October 2011	I	1.66	(1.49)	8.30	(7.47)	10.66	(10.99)	2.00	(1.66)	18.76	(15.24)	1.55	(1.16)
	II	1.33		6.65		11.33		1.33		11.73		0.78	
November 2011	I	1.33	(1.33)	6.65	(6.65)	9.00	(8.83)	0.66	(1.49)	7.33	(9.43)	0.48	(0.62)
	II	1.33		6.65		8.66		1.00		11.54		0.76	
December 2011	I	1.00	(1.49)	5.00	(4.15)	8.33	(7.99)	0.66	(0.66)	7.92	(8.26)	0.39	(0.33)
	II	0.66		3.30		7.66		0.66		8.61		0.28	
January 2012	I	0.33	(0.49)	1.65	(2.47)	10.33	(8.99)	0.33	(0.33)	3.19	(3.74)	0.05	(0.095)
	II	0.66		3.30		7.66		0.33		4.30		0.14	
February 2012	I	1.00	(1.49)	5.00	(4.15)	12.66	(12.83)	1.00	(1.49)	7.89	(10.34)	0.39	(0.40)
	II	0.66		3.00		13.00		1.66		12.76		0.42	
SEm (±)		0.080				0.784		0.052					
CD (P = 0.05)		0.221*				2.174*		0.143*					
CV (%)		16.00				14.712		10.336					

*Significant at 0.05 probability level; Tabulated data indicated mean of three replications; Parentheses values are averages of 1st and 2nd fortnight

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Lignocellulosic biomass: a potential bio-ethanol feedstock

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ABSTRACT

Bioenergy is now fairly recognized as not only a necessity, but an inevitable path to secure the planet future energy need. There is, however, a global consensus that the overall feasibility of bioenergy will require an integrated approach based on diversified feedstocks and conversion processes.The major bioethanol feedstock are sugarcane (*Saccharum sp.* hybrids) and maize (*Zea mays*) and both are highly efficient in converting solar energy into chemical energy. Bio-ethanol from lignocellulosic biomass is one of the important alternatives being considered due to the easy adaptability of this fuel to existing engines and because this is a cleaner fuel with higher octane rating than gasoline. Lignocellulosic biomass is considered as the only foreseeable feasible and sustainable resource for renewable fuel; but the lignocellulosic ethanol commercialization is largely limited due to the lack of cost effective processing technologies and cost of enzymes. The potential of the country's lignocellulosic based bioenergy is equivalent to 200 million tonnes of coal, the utilization of which would reduce the consumption of fossil energy by 10%. As the systems for lignocellulosic bioethanol production are becoming more efficient and cost effective, plant biomass from any source may be used as a feedstock for bioethanol production. However, the bioethanol industry will need a continuous and reliable supply of biomass that can be produced at a low cost, with minimal use of water and fertilizer from less arable land. The productivity and resource use of some important candidate plant species are considered and the biomass 'quality', that is, the composition of the plant cell wall has been discussed.

Key words: Lignocellulosic biomass, Bio-ethanol, Sugarcane

Recent phenomenon of climatic change poses serious threat to crop productivity which in turn has led to decline in yield of some crops and does not augur well for food security, exports, growth and poverty alleviation. With a population of around 1.22 billion to feed, India is also the world's second most populous country and ranks fifth in energy consumption, accounting for about 3.5% of the world's commercial energy demand. India is world's eleventh largest energy producer, with a share of 2.4% of global energy production and the world's sixth-largest consumer, with 3.5% of global energy consumption. India still needs about 160000 MW of power generation and demand for energy is expected to double by 2025, wherein, with present projections, 90% of India's petroleum will be imported (Lesourne *et al*. 2009).

Domestic coal reserves account for 70% of India's energy need. The remaining 30% of energy need is met by oil, of which more than 65% is imported. With 7% of the world's coal, India has the fourth largest coal reserves. The Carbon Sequestration Leadership Forum (CSLF) estimates that at the current level of consumption and production, India's coal reserves will last for just 200 years. Unfortunately, in addition to limited reserves and environmental concerns (coal being one of the dirtiest hydrocarbon fuels), coal cannot meet all of India's energy needs. Various estimates indicate that India would need to increase its primary energy supply by at least 3 to 4 times and its electricity generation capacity by 5 to 6 times of the 2003-04 levels, by the year 2031 (Batra *et al*. 2011).

Indian bioethanol requirement and status

Ethanol as a bio-fuel has gained worldwide acceptance as an eco-friendly substitute for oil in the transportation sector. Government of India has mandated 5% ethanol blending in petrol from October 2006 with a planning to blend up to 25% ethanol in near future. India also aims to achieve Energy Independence by 2030 and therefore biofuels are going to play an extremely important role in meeting India's energy needs. At present only cane molasses is used for the production of ethanol, which is just sufficient to meet the demand of our chemical and potable industries. In order to sustain the biofuel program, it is imperative to explore the alternate substrates for ethanol production as being used in Brazil and USA. Now it is well established that the ligno-cellulosic plant fibre is one of the most recognized potential source of the mixed sugars for fermentation to fuel ethanol owing to its large-scale availability, low cost and environmentally benign production.

Ethanol production in India is absolutely sugarcane molasses based. The total quantity of molasses currently produced in India is about 8.4 million tonnes per year, sufficient to produce 1.85 million kl of ethanol. With a figure of around 21.6 million tonnes of petrol to be consumed annually by 2017 and a 20% blending target, India would require 5.76 million kl of bioethanol per year. For the sake of analysis, with the present crop productivity figures, we assume that half of this i.e., 2.88 million kl will be produced from molasses. So molasses would be insufficient to meet the full blending needs at the 20% level. The other feedstocks, we can look for, are sugarcane, sweet sorghum and sugar beet. However, it needs to be kept in mind that regardless of oil prices, these crops compete with food crops for land and other resources. Sugarcane juice cannot be depended on as it competes with sugar production. On the other hand, if sweet sorghum or sugar beet passes economic and financial tests, they still conflict with the government policy of not compromising food security in order to promote energy crops. Molasses based bio-ethanol would not permit a 20% blending, but lower levels (up to 5%) might be accomplished without affecting food security and at current level of sugarcane productivity, 20% blending with bio-ethanol may be achieved without affecting the food sector. Today, about 144 million tonnes of sugar is produced each year in as many as 127 countries around the world (Table 1). But, this raw material base for ethanol and diesel production is not sufficient to meet and sustain the future energy requirements. Consequently, future large scale production of ethanol will certainly have to be based on biomass/ lignocellulosic materials.

interception is largely defined on a land area basis by the architecture of the canopy and the planting density. Plants with C_4 pathway utilize a photosynthetic mechanism whereby CO_2 is pumped into specialized cells surrounding the vascular bundles, where Rubisco is exclusively localized, and CO_2 can accumulate to levels in excess of ten fold atmospheric concentrations in these cells (Furbank 1998). This biochemical pump requires both biochemical specialisation through cell specific gene regulation, and morphological specialisation in the form of “Kranz” anatomy. Atmospheric CO_2 from the intercellular spaces of mesophyll cells is fixed by PEP carboxylase into C4 acids which move to the bundle sheath cells to be decarboxylated and release CO_2.

Lignocellulose is the term used to describe the three-dimensional polymeric composites formed by plants as structural material. It consists of variable amounts of cellulose, hemicellulose, and lignin (Bayer *et al.* 1998). Cellulose (30–50% of total feedstock dry matter) is a glucose polymer linked by ß–1,4 glycosidic bonds. The basic building block of this linear polymer is cellubiose, a glucose-glucose dimer. Hemicellulose (20-40% of total biomass) is a short, highly branched polymer of five-carbon (C_5) and six-carbon (C_6) sugars. Specifically, hemicellulose contains xylose and arabinose (C_5 sugars) and galactose, glucose, and mannose (C_6 sugars). Hemicellulose is more readily hydrolyzed compared to cellulose because of its branched, amorphous nature. A major product of hemicellulose hydrolysis is the C_5 sugar xylose. Lignin (15–25% of total biomass), a polyphenolic structural constituent of plants, is the largest non-carbohydrate fraction of lignocellulose. Unlike cellulose and hemicellulose, lignin cannot be utilized in fermentation processes. Ash (3-10% of total feedstock dry matter) is the residue remaining after ignition (dry oxidation at 575 ± 25°C) of herbaceous biomass. It is composed of minerals such as silicon, aluminum, calcium, magnesium, potassium, and sodium. Other compounds present in lignocellulosic feedstocks are known as extractives. These include resins, fats and fatty acids, phenolics, phytosterols, salts, minerals, and other compounds.

Table 1 Sugar and ethanol yields from sugar crops

Crop	Growth period (months)	Water requirement (m^3/ha)	Brix (%)	Sugar yield t/ha	Calculated ethanol yield (L/ha)	Reference
Sugarbeet	5-11	18000	15-18	6.2-12	4 000-7 000	FAO (2006)
Sugarcane	12	3600	13-14.7	10.4-17.4	3 000-7000	Lingle *et al.*
Sweet sorghum	4-6	12000	11-23	5.4-1.3	2 129-8000	2009

Characteristics of Lignocellulosic biomass

Lignocellulosic materials (biomass) are the most abundantly produced organic biopolymers on earth. Lignocellulosic feedstocks are composed primarily of carbohydrate (cellulose and hemi-cellulose) and phenolic polymers (lignin). Lower concentrations of various other compounds, such as proteins, acids, salts, and minerals, are also present. Cellulose and hemicellulose, which typically make up two-thirds of cell wall dry matter, are polysaccharides that can be hydrolyzed to sugars and then fermented to ethanol. Process performance, in this case ethanol yield from biomass, is directly related to cellulose, hemi-cellulose, and individual sugar concentration in the feedstock. Lignin cannot be used in fermentation processes; however, it may be useful for other purposes.

Each year photosynthetic fixation of CO_2 yields more than hundred billions tonnes of dry plant biomass worldwide and almost half of this material consists of cellulose (Peters 2006). The biomass production in plants is a function of radiation use efficiency multiplied by light intercepted. Light

Optimizing Biomass Production for sustainable India's Energy Needs

The main feedstocks for bio-ethanol are sugarcane (*Saccharum spp. hybrids*) and maize (*Zea mays*), highly efficient in converting solar energy into chemical energy. Sugarcane produces about 60 million tonnes of bagasse and co-products, which could theoretically, be used to produce 18 million kl of cellulosic ethanol. If even 30% of this can be made available, the ethanol production would be 5.4 million kl, close to the 20% blending requirement for 2017. It has been estimated that, of the total crop residue of 415.4 million tonnes, about one fourth could be available for bioethanol inputs. This surplus could produce more than 20 million kl of cellulosic ethanol. As the systems for lignocellulosic bioethanol production become more efficient and cost effective, plant biomass from any source may be used as a feedstock for bioethanol production. Thus, a move away from using food plants to make fuel is possible, and sources of biomass such as wood from forestry and plant waste from cropping may be used and that shall pave way for preventing the "*food vs fuel*" conflict and also utilizing wasteland and saline soils. However, the bio-ethanol industry will need a continuous and reliable supply of biomass that can be produced at a low cost and with minimal use of water, fertilizer and arable land. As we have large areas of waste and saline lands, options for growing many plants having high radiations, water and nitrogen use efficiency might prove to be ideal lignocellulosic feedstock crops.

The main limitation is land area and matching agronomic practices that can be made available for energy crops, without compromising with food production. Thus priority would be to maximize the energy output from such crops per unit area and minimize the cost input (Hammerslag *et al*. 2006).

Biomass feedstocks plants

There are a number of plant species that generate high yield of biomass with minimal inputs eg. Aleman grass (*Echinochloa polystachya*), Elephant grass (*Pennisetum purpureum*), fox tail millet (*Setaria italica*), miscanthus (*Miscanthus giganteus*), sweet sorghum (*Sorghum bicolor*), sugarcane and switchgrass (*Panicum virgatum*). These are ideal energy crops because they possess high conversion efficiency of light into biomass energy, high water use efficiency and high leaf level nitrogen use efficiency (Taylor *et al*. 2010), capacity to grow in marginal land areas and a relatively high tolerance to soil constraints such as salinity and water-logging. Poplar (*Populus*) and willow (*Salix*) also generate high yield of biomass, but take longer to grow and have higher contents of lignin, making the polysaccharides less accessible, thus the biomass quality is lower. Miscanthus (Heaton *et al*. 2004; Dohleman and Long 2009), variants of sugarcane (Nair *et al*. 1999), sweet sorghum (Propheter *et al*. 2010) and switchgrass (Schmer *et al.* 2008) have been the focus for considerable research and development activities in India, Europe and the USA for biomass yield (Table 3). The chemical energy contained within biomass may be harvested by conversion to bioethanol or by conversion to alternate fuels, by direct combustion or by pyrolysis. In the context of bioethanol production, high quality biomass refers to a composition that can be easily and cheaply converted to liquid transport fuels. That is, the maximum accessible yield of firstly, monosaccharides and disaccharides, and secondly, easily extracted polysaccharides. Large quantities of polysaccharides, such as cellulose, contribute to biomass 'quantity' but biomass 'quality' is also important. Cellulose may be bound within lignin, and thus, inaccessible to processing. Lignin content, composition, and also the type of bonds among lignin, hemicellulose and cellulose are factors that influence biomass quality.

Ethanol yields

Biomass production (tonnes/ha/yr) may be the single greatest factor limiting global lignocellulosic ethanol yields. Corn stover, miscanthus, switchgrass and willow are currently being used as biomass feedstocks in trial on lignocellulosic bioethanol studies (Li *et al.* 2010; Van Hulle *et al*. 2010). However, many promising plants with greater biomass production, such as *Echinochloa polystachya* (Table 2) are yet to be tested as lignocellulosic feedstock crops. *Echinochloa polystachya* may produce ten times the quantity of biomass per year as willow (Table 2 &3). Biomass recalcitrance, the natural resistance of plant cell walls to microbial and enzymatic deconstruction, increases the cost of conversion of cellulose to glucose. Lignin significantly contributes to biomass recalcitrance. Not surprisingly, tree species such as poplar and willow have higher lignin contents than grasses (Table 3). Greater energy (temperature and pressure) and or quantity of enzymes (cellulases) are needed to hydrolyse cellulose that is embedded within lignin. In addition to blocking the liberation of sugars from cellulose and adhering to hydrolytic enzymes, lignin may also release aromatic compounds that inhibit fermentation. Modifying lignin content, composition, hydrophobicity and cross-linking can improve the enzymatic hydrolysis of cell walls. Lignin content and composition may vary due to natural mutation in the genes involved in the lignin biosynthesis pathway, such as observed for brown-midrib (bmr) mutant plants. Bmr mutants produce a lignin which differs to the lignin of normal plants, this results in a red-brown

Table 2 Lignocellulosic composition of plants

Crop	Cellulose %	Hemicellulose %	Lignin%	Reference
Corn stover	35%	28%	10.4%	Karp and Shield (2008)
Miscanthus	57.6%	15.9%	10.5%	
Poplar	40%	14%	20%	
Sugarcane	24%	8%	7%	
Switch grass	31.6%	36%	6.1%	
Willow	55.9%	14%	19%	
Sweet sorghum	26.3%	20%	7.1%	Rooney *et al.* (2007)

Table 3 Biomass yields of plantations projected for grown under saline soils

Crop	Fresh weight t/ha	Dry weight t/ha	Ethanol yield from biomass (L/ha)	Reference
Aleman grass (*Echinochloa polystachya*)	150 - 200	99-100	7600	Somerville *et al*. 2010
Cassava (*Manihot esculenta*)	20- 24	6.1- 21	4500	Lee and Bressan 2006
Corn (*Zea mays* spp.)	10.6- 23.5	7.5-16	1500–2518	Somerville *et al*. 2010
Elephant grass (*Pennisetum purpureum*)	50-88	24-26	1200-2280	
Miscanthus (*Miscanthus x giganteus*)	27- 44	3.3-12.8	4600-12400	
Sweet sorghum	17.5- 31.6	14- 25	13032	Propheter *et al*. 2010
Switchgrass (*Panicum virgatum*)	23-24	10.3 -13.6	555 - 3871	
Willow (*Salix viminalis*)	7- 21	5 - 18	750-1890	Cannell *et al*. 1988

colour which is seen in the mid vein of the leaves, mutant plants have significantly less lignin than normal plants (Oliver *et al*. 2005). This has been one of the criteria for assigning quality in fodder sorghum. Lignin may also be altered by selective plant breeding and transgenic approaches. Approaches to reducing lignin have targeted each of the steps in phenyl propanoid metabolism (Vanhholme *et al*. 2012 a). As biofuels are likely to play a great role in meeting our energy requirements, biomass will undoubtedly form part of a solution to meeting our energy needs. C_4 plants are among the most efficient convertors of sunlight into biomass on the planet and thus present great opportunities for exploitation of genetic diversity in growth and nutrient use efficiency both within species and between species.

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Evaluation of sugarcane *jaggery* shelf life under modified environments: Influence on physico-chemical and microbial properties

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ABSTRACT

Sugarcane *jaggery* undergoes fast deterioration under ambient conditions. The present study was undertaken with an objective of enhancing *jaggery* shelf life at room temperatures by packaging under modified environments. *Jaggery* samples were prepared from sugarcane juice obtained from four varieties ('CoLk 8102', 'CoLk 9617', 'CoS 767' and 'CoSe 92423') in April 2004 and packed under nitrogen (N), vacuum (V), in polythene bags (PB) and airtight glass jars (ATGJ). The samples were analyzed after six months of storage for its physico-chemical, microbial properties and overall acceptability. The results revealed that there was a drastic increase in moisture (15-22%) of *jaggery* packed in polythene while no significant change occurred in moisture% of *jaggery* stored under nitrogen and vaccum environment when compare with fresh *jaggery*. The *jaggery* stored in bottles and in polythene bags got deteriorated after six months of storage. *Jaggery* packed under nitrogen environment sustained the sucrose, moisture, reducing sugars, titratable acidity, pore space, total microbial count levels as that of fresh *jaggery* at room temperature and remained distinctly superior in its overall acceptibilty. The physico-chemical properties and shelf life of *jaggery* under vacuum were at par with fresh *jaggery* samples but the major limitation turned out to be its hardness and consequent lesser acceptability.

Key words: *Jaggery*, Shelf life, Nitrogen Packaging, Vaccuum, Air tight glass jars

Jaggery (Gur) manufacture from sugarcane is an important cottage industry and plays an important role in the rural economy in India. The awareness that *jaggery* is not only a source of sugars but is also rich in vitamins and minerals, has increased its demand and utilization. This has attracted not only the *jaggery* manufactures but also added to its export potential. However, the problem in *jaggery* manufacture is loss of its colour and texture with storage time. The quality of *jaggery* gets deteriorated at the prevailing temperatures of storage in India (Baboo and Singh 1986; Agarwal *et al*. 1988; Baboo 1993). It has been reported that even under proper storage conditions at ambient temperatures, *jaggery* loses its colour, flavor and crystalline structure (Kapur and Kanwar 1983; Uppal and Sharma 1999a&b). The loss in original texture, colour and flavor are associated with the chemical and the microbial changes, which lead to deterioration of *jaggery* quality and a colossal loss to the industry. With an ever-increasing consumer trend all over the world for fresh and good quality food without addition of synthetic/ chemical preservative that has residual effect on human health, scientific packaging under nitrogen and vacuum of food material has emerged out as one of the most popular method for enhancing shelf life of processed food. Nitrogen and vacuum packaging have proved to be advantageous in extending the shelf lives, in prevention of microbiological spoilage and non-microbiological deterioration (Sharma *et al*. 2006). Though information on changes in *jaggery* quality with storage time is available, but information on influence of modified environment on physico- chemical and microbiological quality is lacking. Keeping these in view, the present work was undertaken to evaluate the shelf life of sugarcane *jaggery* under modified environment for its influence on physico-chemical and microbiological changes in *jaggery* and its overall acceptability after six months of storage.

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MATERIALS AND METHODS

Sugarcane varieties and juice extraction

Sugarcane varieties ('CoLk 8102', 'CoLk 9617', 'CoS 767' and 'CoSe 92423') were grown and harvested at the farm of Indian Institute of Sugarcane Research. Lucknow, India, located at 26° 56' N latitude, 80°52'E longitude and 111 m above mean sea level. Juice was extracted by a commercial vertical crusher (10 HP, 7 quintals capacity) installed in the *jaggery* unit of the Institute. The juice obtained was filtered using muslin cloth.

Preparation of jaggery

Fresh filtered cane juice (2L) extracted from al the genotypes were collected separately and taken in aluminium pan for heating immediately. First scum was removed just before boiling of juice. After removal of scum, aqueous extract of Deola (*Hibiscus ficulneus*, grown in farm) was added during boiling for clarifying the juice. Scum formed on the surface was again removed by stainless steel strainer leaving a clear juice. When all the scum formed was removed, the juice became transparent and yellowish brown in colour. This was concentrated till the striking temperature 116-118°C (Roy, 1951; Agarwal *et al*., 1988)) and transferred to mould for setting of *jaggery* cubes.

Storage under modified environments

Fresh *jaggery* prepared from the four genotypes was air dried at ambient temperature (Max. temp, 22.3 ^{0}C, Min temp, 19.3 ^{0}C), till it attained moisture of approximately 5%. The air-dried *jaggery* (250 g) was stored in airtight-capped bottles (500 ml capacity, Tarson), polythene bags (PB, 400 gauge), in cylinders attached with valves and gauges for filling nitrogen gas (95 %) and creating vacuum (21 inches Hg) at room temperature (25 ± 2^{0}C). *Jaggery* was packed under different environments, stored and evaluated for its quality, shelf life and overall acceptability. The fresh *jaggery* was analyzed for its physico-chemical and microbial parameters. Initial analysis of *jaggery* was carried out in April 2004 and later after six months of storage under varied environments.

Chemical analysis

The fresh and stored (after six months of storage) *jaggery* samples were analyzed for their physico-chemical properties viz. moisture%, sucrose%, purity, total sugars, reducing sugars, colour (% transmittance) and pore space by AOAC methods of 1980. The results are expressed on the dry weight basis (dwb) of *jaggery* samples. The pH of aqueous *jaggery* solution (0.5N) was measured with pH meter (Systronics, India).

Microbiological assay

The fresh and stored *jaggery* samples were assayed for their total bacterial count, total fungal count and total thermophillic count (ICMCF 1992).

The Sensory quality

The sensory qualities of fresh and stored *jaggery* samples were assessed on 100 point scale allotting 20 points each to appearance, colour, texture, flavour, taste and overall acceptability by method of Okolki *et al*. 1988.

Statistical Analysis

Data presented are mean of three replicates and critical differences (CD) at 5 % level of significance between the means of 3 replications were calculated for variables affecting the quality parameters like moisture, pH, colour, reducing sugars and total carbohydrates of the concentrates included the treatments with packaging environment and storage period. Differences in microbial counts and the sensory scores of samples were examined by analysis of variance (Snedecor and Cochran 1967).

RESULTS AND DISCUSSION

Physico-chemical properties of fresh jaggery

The physico-chemical properties of fresh *jaggery* samples are given in Table 1. Sucrose and purity% of *jaggery* were higher in *jaggery* from 'CoS 767' and 'CoLk 8102' than *jaggery* from 'CoLk 9617' and 'CoSe 92423' which were at par in terms of sucrose and purity% (Table 1). Reducing sugar% was found to be least in 'CoS 767' (7.3%) while it was higher in 'CoLk 8102', 'CoLk 9617' and 'CoSe 92423'. These variations might be attributed to the genotypic differences (Patil *et al*. 1994; Uppal and Sharma 1996). The transmittance% was highest in 'CoS 767' followed by 'CoLk 9617'. The minimum transmittance was found 'CoSe 92423' (70.2 %). All *jaggery* samples were attractive in colour and texture. The *jaggery* of 'CoS 767' and 'CoLk 8102' was of golden yellow colour with highly crystalline texture while *jaggery* from 'CoLk 9617' and 'CoSe 92423' was of brown colour with less crystalline texture (Table 2).

Physico- chemical properties of jaggery after six months storage

The physico-chemical properties of *jaggery* from different genotypes under different storage environments are presented in Table 2. The *jaggery* stored in glass jars turned blackish brown and got spoiled due to the fungal growth, hence the quality analysis evaluation could not be performed. The *jaggery* stored in polythene bags also turned dark brown in colour from the initial golden colour but remained free from the fungal growth. There was a drastic increase in moisture %

Table 1 Physico-chemical properties of fresh *jaggery*

Properties / Genotypes	'CoLk 8102'	'CoLk 9617'	'CoS 767'	'CoSe 92423'
Jaggery recovered (%)	10.56 ± 0.09	10.30 ± 0.07	10.81 ± 0.08	10.12 ± 0.03
Purity (%)	86 ± 0.12	85 ± 0.11	90 ± 0.16	85 ± 0.13
Sucrose (%)	90.5 ± 0.15	89 ± 0.13	92.3 ±0.19	85.3 ± 0.09
Reducing sugar (%)	7.3 ± 0.020	7.6 ± 0.02	5.3 ± 0.04	8.5 ± 0.07
Pore space %	11 ± 0.16	12 ± 0.19	14 ± 0.11	12 ± 0.09
pH	6.8 ± 0.01	6.54 ± 0.01	6.7 ± 0.12	6.8 ± 0.11
Transmittance (%)	73.8 ± 0.21	75.85 ± 0.53	80.2 ± 0.51	70.2 ± 0.23
Moisture (%)	5.5 ± 0.09	6.55 ± 0.08	6.3 ± 0.08	6.8 ± 0.08

The data presented are mean ± standard deviation of three replicates

Table 2 Physico-chemical profile of *jaggery* after six months of storage under varying packaging environment

Jaggery	Mode of packaging	Purity (%)	Sucrose (%)	Reducing sugar (%)	Pore space (%)	pH	Transmittance (%)	Moisture (%)
'CoLk 8102'	ATGJ	**	**	**	**	**	**	**
	PB	75 ±0.8	65±1.2	19±0.2	6.7±0.04	5.9±0.02	60.5±1.23	20±0.05
	N	85±0.02	89±0.9	16±0.1	11.4±0.06	6.9±0.03	70.8±0.93	5.6±0.06
	V	80±0.3	90±0.83	16.5±0.24	10.7±0.04	6.8±0.04	71±0.83	2±0.08
'CoLk 9617'	ATGJ	**	**	**	**	**	**	**
	PB	70±1.35	60±0.89	20±0.06	2.3±0.06	5.48±0.23	55.8±1.25	26±0.74
	N	84±1.25	85±0.92	5.2±0.04	12.5±0.45	6.6±0.34	73.2±1.08	6±0.08
	V	80±1.01	82±0.84	20±0.78	11.3±0.04	6.4±0.12	72±1.06	3±0.03
'CoS 767'	ATGJ	**	**	**	**	**	**	**
	PB	73±1.04	68±1.51	6.3±0.05	5.5±0.03	4.3±0.02	58.2±1.12	25±0.67
	N	89±1.13	90±1.78	7.2±0.06	11.9±0.04	6.8±0.03	78.2±1.04	5.5±0.06
	V	82±1.12	25±0.89	6.3±0.05	10.7±0.23	6.6±0.05	78±1.02	2.5±0.06
'CoSe 92423'	ATGJ	**	**	**	**	**	**	**
	PB	78±1.02	83±1.34	9.5±0.06	2.9±0.02	4.7±0.02	58±1.02	22±1.11
	N	81±1.03	80±0.97	9.3±0.05	10.7±0.04	6.4±0.04	66.6±1.11	5.3±0.96
	V	79±1.23	75±0.95	8.2±0.02	11.1±0.06	6.2±0.0	65±1.04	1.9±0.02

ATGJ=Air tight glass jars; PB=Polythene bags; N=Nitrogen; V=Vacuum; **=Spoiled *Jaggery*

The data presented are mean ± standard deviation of three replicates.

(15-22%) of *jaggery* from different genotypes and an increase of 22, 20, 16 and 15 % was recorded in 'CoSe 92423', 'CoLk 8102', 'CoLk 9617' and 'CoS 767' respectively. The colour and texture of *jaggery* stored under nitrogen and vacuum were identical to fresh *jaggery*. However, it was found that the *jaggery* stored under vacuum had turned very hard as compared to fresh *jaggery* as well as that stored under the nitrogen environment. There was no significant difference in the transmittance% of *jaggery* from all genotypes as compared to fresh *jaggery*. Mild change, however, occurred in *jaggery* of 'CoSe 92423' (7.8%) under nitrogen and 8.8% under vacuum.

The sucrose content declined drastically (20-28%) in all *jaggery* samples irrespective of genotypes. The maximum decline in sucrose content was in *jaggery* from 'CoLk 9617' followed by 'CoLk 8102' (25%) and 'CoS 767' (22%) with least decline in *jaggery* from 'CoSe 92423'. No significant change occurred in moisture% of *jaggery* stored under nitrogen environment. However, under vacuum there was significant decline in moisture%. It decreased by 5.5, 3.9, 3.8 and 3.5 % as compared to 7.3% in fresh *jaggery* in 'CoLk 8102', 'CoSe 92423', 'CoS 767' and 'CoLk 9617', respectively. Under vacuum condition as the air is removed, the moisture also gets removed (Sharma *et al.* 2006). This thus helped in maintaining the moisture content and also inhibited the hydrolysis of *jaggery*, enhancing its shelf life. The reduction in moisture content under vacuum appeared to be responsible for contributing hardness to *jaggery*.

p^H of *jaggery* ranged from 6.5 - 6.9 (Table 1). The p^H of *jaggery* stored in glass jars and polythene bags turned acidic, however no significant changes occurred in p^H of *jaggery* under nitrogen and vacuum environments (Table 2). The reducing sugar contents in the fresh *jaggery* samples were in range of 5.3 - 8.5%. The reducing sugars increased after six months of storage in glass jars and polythene bags, which in turn showed maximum increase (Table 2). The reducing sugars content increased significantly in ranging from 12 -20%, the increase being 12.5, 16.2, 19.0 and 20.0 % in 'CoSe 92423', 'CoLk 767', 'CoLk 8102' and 'CoLk 9617', respectively. The increase in reducing sugars is attributed to hydrolysis of sucrose that in turn gets triggered with increased moisture contents and p^H. The increase in p^H also leads to formation of several undesirable products (Uppal and Siddu 2002). Increased reducing sugars and undesirable by-products are responsible for the colour changes and significant reduction in transmittance% in stored *jaggery*. The transmittance % in *jaggery* declined by 18.0, 15.8, 15.0, and 13.3 % in 'CoLk 9617', 'CoSe 92423', 'CoS 767', and 'CoLk 8102' respectively.

Purity of fresh *jaggery* of 'CoLk 8102' was 86.03 %. It declined by 11% when stored in polythene bags for six months. However, purity% of *jaggery* under nitrogen packaging remained *at par* with the fresh *jaggery*. In *jaggery* prepared from 'CoLk 9617', the initial purity was 85% which underwent a significant decline by 15% in polythene bags while fresh *jaggery* from 'CoS 767' exhibited purity of 90% and declined by 17% in polythene bags. *Jaggery* from 'CoSe 92423' had 85% purity at the initial stage but declined by 7% plastic bags. Similar changes were observed in sucrose% but no significant changes occurred in sucrose contents of *jaggery* samples from all genotypes under nitrogen and vacuum environments. However, a drastic decline was marked in all *jaggery* samples stored in glass jars and polythene bags. The decline in sucrose contents ranged between 20 -28 %. The purity of *jaggery* stored under nitrogen and vacuum environment remained at par with purity% in fresh *jaggery* irrespective of the genotypes. Similarly, no significant changes occurred in sucrose%, reducing sugar % and p^H under nitrogen and vacuum environments (Table 1).

Microbial properties and sensory scores of jaggery after six months

The microbial profile of fresh *jaggery* samples have been compared with that of *jaggery* stored under different environments for a period of six months (Fig 1). The total

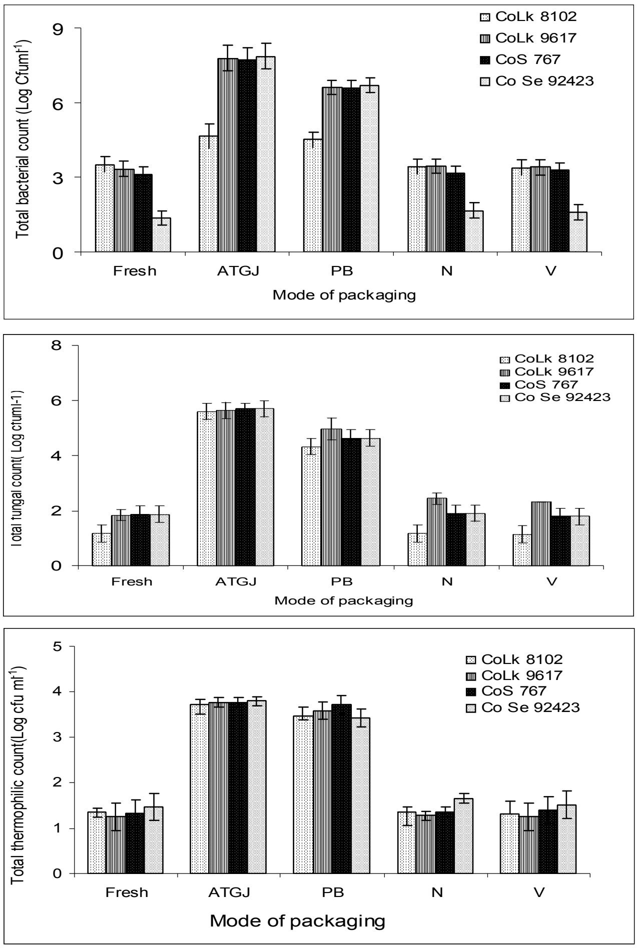

Fig 1 Microbial profile of jaggery a. total bacterial count b. total fungal count c. total thermophillic count after six months of storage under varying packaging environment. ATGJ=Air tight glass jars; PB=Polythene bags; N=Nitrogen; V=Vaccum.
Values are mean of three replicates; Vertical bars represent ± S.E

Table 3 Sensory attributes of jaggery stored for six months under varying environments at room temperature

Sensory attributes	Packed *Jaggery* (6 months)					CD (P<0.05)
	Fresh	ATGJ	PB	N	V	
Appearance	15	3.5	4	14.5	14.5	0.7
Clarity	16	3	4.6	18.5	16.5	1.3
Colour	15	5	6.5	15.0	15.0	1.9
Flavor	16	9	11.5	14	12	1.1
Taste	18	9	10	16	16	0.9
Texture	10	9	8	8	8	0.2

bacterial count increased significantly in *jaggery* from all the genotypes but was maximum in 'CoSe 92423' and 'CoLk 9617' (Fig 1a). The total fungal count and the total thermophillic count were also found to have increased significantly in the *jaggery* packed in glass jars and polythene bags (1b and 1c). No significant changes in total bacterial, fungal and thermophillic counts were found in *jaggery* from all the genotypes under nitrogen and vacuum environments (Fig 1a,b,c) as compared to that of fresh *jaggery*. The sensory quality of *jaggery* stored in different environments has been given in Table 3. The *jaggery* stored under nitrogen was superior in terms of appearance, clarity of colour and texture followed by vacuum. The overall acceptability of vacuum stored *jaggery* was at par for all the properties except texture as it had turned too hard. On basis of physico-chemical, microbial properties and sensory attributes, it was inferred that *jaggery* can be best stored under nitrogen packaging. The packaging under air tight glass jars and polythene resulted in deterioration of *jaggery* quality as compared with fresh *jaggery*. Though under both nitrogen and vacuum packaging, *jaggery* shelf life was maintained for six months but overall acceptability of the nitrogen packed *jaggery* was superior.

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Participatory demonstration for enhancing knowledge and adoption of water saving sugarcane production technologies: an action research

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ABSTRACT

Participatory demonstrations of water saving sugarcane production technologies were conducted on farmers' fields in reserved areas of Biswan (Sitapur), Rauzagaon and Haidergargh (Barabanki) sugar mills of Uttar Pradesh under Farmers' Participatory Action Research Programme (FPARP) funded by Ministry of Water Resources, Government of India during 2008-11. Four blocks (2 from each district) were selected following stratified random sampling technique. A total of 100 demonstrations each of one hectare were conducted in participatory mode on four proven technologies viz., Ring-pit method of planting, Trash mulching, Skip furrow method of irrigation and Irrigation at critical growth stages. The results revealed that farmers derived socio-psychological benefits in terms of enhanced knowledge and adoption. The considerable increase in knowledge level of farmers in cultivation practices as well as in water saving technologies for sugarcane was recorded. The adoption of recommended cultivation practices and water saving technologies for sugarcane by the farmers also increased. There was 21-45% saving in irrigation water by adopting water saving techniques in sugarcane in comparison with conventional method. The yield obtained by farmers in demonstrations varied between 80-125 t/ha against yield of 63.8 t/ha obtained in conventional method which in turn increased economic (B:C ratio) benefits to the farmers. Farmers are now telling fellow farmers of their villages and neighbouring villages to adopt these sugarcane production technologies to enhance their income and make their contribution in saving precious and dwindling water resources as well as to fetch more from less land and water.

Key words: Sugarcane, Water saving, Irrigation methods, Farmers' participatory

Sugarcane being high water requiring crop (1200 to 1500 mm in sub-tropical and 2000 to 2500 mm in tropical parts of the country), water has become the most scarce and expensive factor in its cultivation. It has therefore, become imperative to judiciously use the available water at appropriate time so that maximum sugarcane yield can be obtained.

It is generally accepted that adoption of scientific irrigation by farmers is far below expectations. The adoption rate depends on value of the crop and on type of irrigation system and that the farmers need more comprehensive technological support that is simpler to use, and can be integrated into farm management (Clyma 1996; Leib *et al.* 2002). Adoption of faulty irrigation techniques by the farmers lead to over irrigation, low water use efficiency and reduced profitably. A survey (Olivier and Singels 2004) concluded that the main reasons for non-adoption were the complexity of technology and the difficulty in applying it in the practice on the farm, and the perception that accurate scheduling provides little benefit. The challenge, therefore, is to provide practical and useful advice to farmers using state of the art technology and to convince them about benefits of irrigation water saving technologies by on-farm demonstration.

Many research findings in the past have reported that if the crop is irrigated scientifically, irrigation water use efficiency of sugarcane crop can be enhanced by 1.5 to 2.5 times. Considering the importance of conserving ever depleting and dwindling water resources, Ministry of Water Resources, Government of India has initiated Farmers Participatory Action Research Programme (FPARP) in 2008. Under FPARP participatory demonstrations on farmers' field were conducted with the aim to transfer water saving technologies to the farmers and suggest field refinement, if any, with the participation of the farmers. The programme intends to resolve the difficulties in adoption of the technologies with participation of both farmers and scientists. Indian Institute of Sugarcane Research, Lucknow has developed a number of applicable water saving sugarcane technologies for large scale adoption. In order to transfer and popularize these technologies participatory demonstrations on farmers' fields were conducted in Barabanki and Sitapur districts of Uttar Pradesh with the objectives of enhancing knowledge level of farmers in water saving sugarcane production technologies and to increase their adoption and work out the economic feasibility.

MATERIALS AND METHODS

Two districts viz. Barabanki and Sitapur were selected that are covered under the backward districts of the country as declared by the Planning Commission. From each selected district, two blocks thus, 4 blocks were selected following stratified random sampling technique. During the 2008-09 to 2010-11, 100 demonstrations in reserved areas of Biswan (Sitapur), Rauzagaon and Haidergargh (Barabanki) sugar mills were conducted (Table 1).

Table 1 Year-wise break up of demonstrations conducted

Water saving technology	**Number of Demonstrations Conducted**			Total
	2008-09	**2009-10**	**2010-11**	
Ring-pit method of planting	2	13	1	16
Skip-furrow method of Irrigation	14	10	8	32
Irrigation at critical crop growth stages	9	7	8	24
Trash mulching	10	10	8	28
Total	35	40	25	100

Criteria for farmers' selection

- The farmer should have at least one ha area under sugarcane cultivation.
- He must be growing sugarcane from last 4-5 years.
- He should be ready to spare his land for conducting demonstration as well as agree to actively participate in the programme.

Variables and their Measurement

To assess the impact of demonstrations, the economic and socio-psychological variables selected under the study and methods for their measurement are mentioned in table 2.

Table 2 Indicators and methods for measuring impact

Indicator	**Observation**	**Tools/methods**
Knowledge	Pre & Post score	Schedule
Adoption	Pre & Post score	Schedule
Yield	Demonstration & Check	Harvested cane yield
Water Saving	Demonstration & Check	Water meter
Benefit : Cost ratio	Demonstration & Check	Computation

Description of water use efficient sugarcane production technologies

Ring-pit planting technique: The field is marked at a regular distance of 105 cm, leaving 65cm space in the beginning, both length and width wise. Nearly 9000 pits per ha of 75 cm diameter and 30 cm depth are made by pit digger. The soil dug out from the pit is kept on the periphery of the ring-pit in 30 cm space left in between the two pits. In every pit, 3 kg farmyard manure or compost or press mud cake is mixed uniformly before placing the setts for planting. In addition, 8 g urea, 20 g DAP, 16 g MoP and 2 g zinc sulphate are also added in the pit to the soil. Twenty, two budded setts are placed in a circular manner in each pit. The chlorpyriphos solution is applied on the setts and 2-5 cm soil cover is made over the setts. One light irrigation is given just after planting and blind hoeing done at field moisture to enhance germination. Thirty days after germination, 16 g urea mixed with the moist soil is applied in the pit and half of the soil remaining at periphery is filled back in the pit. In the month of April-May, the remaining soil is filled back in the pit and 16 g urea is also applied. The filling of soil is completed when all the mother shoots have emerged. As the irrigation water is applied only in the pits, 25-30 per cent irrigation water is saved.

Skip-furrow method of irrigation: In this method, instead of irrigating all the furrows, irrigation is given in alternate rows. With this technique, limited water is used to irrigate larger area. In this method, sugarcane is planted in flat bed as usual and after germination, 45 cm wide and 15 cm deep furrows are made in alternate inter-row spaces. At the time of irrigation, the furrows thus made are irrigated. Irrigating sugarcane with this method results in 36.5 per cent water saving and 64 per cent increase in water use efficiency.

Irrigation at critical crop growth stages: Under limited water supply conditions, providing irrigation at most sensitive stage of the crop growth and deferring at somewhat at less sensitive stage, improves water use efficiency and cane yield. These critical stages for sugarcane are emergence, first order, second order and third order of tillering. Depending upon the availability of water, the crop is irrigated at one, two, three or all the four stages. If two irrigations are available, then the irrigations are provided at emergence and at third order of tillering. If three irrigations are available, then the irrigations are provided at emergence, first order and third order of tillering. If four irrigations are available, then of course the irrigations are provided at all the four critical stages.

Trash mulching: Trash is spread @ 8-10 t ha^{-1} in the inter-row spaces in ratoon crop at the time of its initiation. Because of trash mulching, effectiveness of irrigation water is increased as the evaporation loss of moisture from soil surface is reduced considerably. Sugarcane yield and water use efficiency increase by 26 and 40 per cent, respectively due to trash mulch which maintains the soil moisture at a higher level for a longer period as compared to uncovered soil surface. Increase in sugarcane yield due to trash mulch is also attributed to creation of favourable physical, chemical and microbial properties of soil in addition to water-soluble nutrients added from the trash. In the long run, soil organic carbon content is also improved.

Conventional method: Sugarcane was planted in flat bed and field was flooded each time to apply irrigation water (6 pre monsoon irrigations).

Sugarcane was planted as autumn cane in the month of February under each method (water saving technologies and conventional). Sugarcane variety used were Co 0238 and CoLk 94184 (both early). Other than water application method, agronomic practices applied were uniform in all plots (water saving technologies and conventional) as per recommendation for sub-tropical conditions.

RESULTS AND DISCUSSION

Effect of demonstrations on knowledge and adoption level of beneficiary farmers

The demonstrations conducted under FPARP on farmers' fields resulted into considerable increase in the knowledge level of farmers in sugarcane cultivation practices in general and in water saving technologies in particular (Table 3). The knowledge score in sugarcane cultivation before the start of FPARP was 49.56, which increased to 81.62 at the end of FPARP, recording 64.69% increase in knowledge level. The percentage increase in knowledge level of farmers in water saving technologies viz., ring-pit, skip furrows, critical crop growth stage irrigation and trash mulching was of the order of 95.58, 85.78, 82.80 and 62.13, respectively. The cognitive domains of farmers were triggered by regular visits of scientists, their interactions with them, on-farm discussion, distribution of literature etc.

The adoption level of farmers in sugarcane cultivation was 38.61 (Pre-FPARP), which increased to 55.36 (Post-FPARP) recording an increase of 43.38 percent. Likewise, the increase in adoption of water saving technologies viz., Ring pit, skip furrow method of irrigation, irrigation at critical crop growth stages and trash mulching increased to 81.18, 86.42, 84.81and 46.89%, respectively. The considerable increase in adoption of water saving technologies clearly indicates farmers' satisfaction with the performance of these technologies under their resource constraint conditions (Table 3).

Effect of demonstrated technologies on yield and irrigation water saving in sugarcane

The results of demonstrations (Tables 4) revealed that there was a significant increase in crop yield and irrigation water saving. The yield of sugarcane under demonstration plots ranged between 80-125 t/ha whereas, against only 63.8 t/ha in conventional method. The maximum increase in cane yield was recorded in ring-pit method of planting (96.4%) followed by skip furrow method of irrigation (38.8%), irrigation at critical crop growth stages (28.2%) and trash mulching (25.7%). The saving in irrigation water varied from 21.7 to 44.5%, the maximum being with irrigation at critical crop growth stages. Next in order were trash mulching (37.2%), ring-pit method of planting (23.5%) and skip furrow method of irrigation (21.7%).

Benefit: Cost Ratio (B:C Ratio)

Demonstrated water saving technologies resulted in enhanced benefits to the farmers and B:C ratio improved

Table 3 Effect of demonstrations on knowledge and adoption

Water saving sugarcane production technologies	Knowledge			Adoption		
	Pre-FPARP	Post-FPARP	% increase	Pre-FPARP	Post-FPARP	% increase
Sugarcane cultivation	49.56	81.62	64.69	38.61	55.36	43.38
Ring-pit method of planting	13.65	26.52	95.58	9.51	17.23	81.18
Skip-furrow method of irrigation	8.30	15.42	85.78	5.23	9.75	86.42
Irrigation at critical crop grwth stage	7.56	13.82	82.80	5.20	9.61	84.81
Trash mulcohing	13.23	21.45	62.13	11.75	17.26	46.89

Table 4 Effect of demonstrated technologies on sugarcane yield and saving in irrigation water

Technology	Average yield (t/ha)		Increase in cane yield (%)	Irrigation water applied (ha-cm)		Saving in irrigation water (%)
	Demonstration	Conventional		Demonstration	Conventional	
Skip-furrow method of irrigation	88.54	63.80	38.8	53.72	65.37	21.7
Ring-pit method of planting	125.28	63.80	96.4	52.92	65.37	23.5
ICGS	81.76	63.80	28.2	45.25	65.37	44.5
Trash mulching	80.18	63.80	25.7	47.66	65.37	37.2

ICGS- Irrigation at critical crop growth stages significantly. Highest increase in B:C ratio was observed in trash mulch technology and the lowest in ICGS. However, the increase in B:C ratio under ring-pit method of planting and skip-furrow irrigation was statistically at par but significantly higher than that of conventional method (Table 5).

Table 5 Year wise Benefit-Cost Ratio

Technology	2008-09	2009-10	2010-11	Average
Ring-pit method of planting	1.85	2.03	1.52	1.80
Skip-furrow method of irrigation	2.04	1.96	1.86	1.95
ICGS	1.91	1.45	1.30	1.55
Trash mulching	2.28	2.83	2.08	2.40
Farmers' practice	1.53	1.29	0.91	1.24
$SE_m\pm$		0.17		
CD (0.05)		0.53		

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Growth of spring sugarcane (*Saccharum spp* hybrid complex) as influenced by phosphorus and sulphur nutrition

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ABSTRACT

A field experiment was conducted during spring season of 2003-04 and 2004-05 on sandy loam soil at Sugarcane Research Institute, Pusa, Bihar to investigate the effects of four levels each of phosphorus (0, 17.5, 35.0 and 52.5 kg/ha) and sulphur (0, 40, 80 and 120 kg/ha) on growth of sugarcane (*Saccharum spp* hybrid complex) variety 'CoP 9301'. The result revealed that application of 52.5 kg P/ha recorded the highest number of tillers at 65 (113000 and 113600/ha) and 95 DAP (166400 and 167300/ha) during 2003-04 and 2004-05, respectively. Plant attained almost 50% of the height at 150 DAP (mid July), 74% at 180 DAP (mid August) and 90% of the height at 210 DAP (mid September) irrespective of the levels of nutrients. Phosphorus nutrition registered significant increase in plant height. The extent of increase in plant height under 52.5 kg P/ha over control treatment at 150, 180 and 210 DAP was 19.2, 12.9 and 16.6% during 2003-04 and 19.2, 12.2 and 15.2 % respectively during 2004-05. Leaf area index increased markedly with increased doses of phosphorus and attained its peak at 230 DAP under 52.5 kg P/ha (4.24 in 2003-04 and 4.25 in 2004-05), respectively. LAI increased at a rapid rate from 70-150 DAP. Thereafter, its increase was at decreasing rate up to 230 DAP. Sulphur fertilization recorded significant increase in number of tillers at 65 DAP though it did not exhibit significant effect at 95 DAP. S-nutrition brought significant influences on plant height at 210 DAP only but had no marked influences at 150 and 180 DAP during both the years. Application of S caused significant increase in LAI at all the stages of growth except at 230 DAP in 2003-04.

Key words: Growth, Phosphorus, Sulphur, Spring sugarcane

Sugarcane is one of the most important commercial crops of India is cultivated over an area of 4.9 million hectares and the production is estimated to be about 342.4 million tones (ISMA, 2012). However, the productivity of sugarcane is estimated to be low in Bihar (51.4 t/ha) as compared to national average (70.1 t/ha). The main reason for low productivity of sugarcane in the state is inadequate and imbalanced nutrient use. Among nutrients, phosphorus is essential for cell division as well as photosynthetic activities in turn for growth of the plant. Besides it regulates sugar synthesis and its storage in plants and P concentration in the development of fibrous roots for greater absorption of nutrients. It helps in juice formation and sugar crystallization in mills. Today sulphur is being recognized as the fourth major nutrient in order of importance after NPK. It plays a key role in the formation of chlorophyll. Hence, the present investigation was taken up to find out the effects of phosphorus and sulphur on periodical growth of sugarcane crop.

MATERIALS AND METHODS

Field experiment was conducted at Sugarcane Research Institute, Pusa during spring seasons of 2003-04 and 2004-05. The soil was sandy loam with pH 8.3, organic carbon 0.44%, free $CaCO_3$ 29.8%, EC 0.28 dS/m, available sulphur 10.9 ppm and 199, 19.8 and 100 kg/ha available N, P and K respectively. The treatments comprised four levels each of phosphorus (0, 17.5, 35.0 and 52.5 kg/ha) and sulphur (0, 40, 80 and 120 kg/ha). As such 16 treatment combinations were replicated thrice in randomized block design. The crop was uniformly fertilized with 150 kg N and 60 kg K_2O/ha. The total quantity of phosphorus and sulphur was applied based on treatments at planting along with half of nitrogen and full dose of potassium as basal dose. Remaining half of nitrogen was top dressed in two equal splits after the first irrigation and at the time of earthing up during both the years. Urea, diammonium phosphate, muriate of potash and phosphor-gypsum (14% S) were used as sources of nitrogen, phosphorus, potassium and sulphur respectively. Sugarcane variety, 'CoP 9301' was planted in the third week of February and harvested in last week of January during both the years. The total rainfall received during the crop season was 1435.5 mm in 2003-04 and 912.3 mm in 2004-05. The data were recorded on germination%, number of tillers, plant height and leaf area index at various stages of crop growth following the standard procedures. Finally the data were analysed as per the standard statistical methods.

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RESULTS AND DISCUSSION

Effect of phosphorus

The data on germination, number of tillers and plant height for both the years are presented in Table 1. Phosphorus fertilization did not cause significant variation on germination of cane at 30 and 45 days after planting during both the years. Germination count corresponding DAP indicated a mean values of 30.7 to 32.8% respectively during 2003-04 and 31.4 to 33.9% during 2004-05. Shukla (2007) also observed non-significant variation in germination of spring planted cane due to fertility level. Phosphorus fertilization (52.5 kg P/ha) recorded the highest number of tillers were 113000 and 113600/ha in first year at 65 and 95 DAP, respectively. The number of tillers in second year at these DAP were 166400 and 167300/ha. Phosphorus by way of being integral part of photosynthetic activities recorded significant increase in tiller production at each stage probably through the production of new meristem.

Application of phosphorus registered significant increase in plant height. The extent of increase in plant height under 52.5 kgP/ha over control treatment at 150, 180 and 210 DAP was to the extent of 19.2, 12.9 and 16.6%, respectively during 2003-04 and 19.2, 12.2 and 15.2% during 2004-05, respectively. Significant increase in plant height due to phosphate fertilization might be attributed to rapid elongation and multiplication of cells in the presence of large amounts of phosphorus and also to increase in phosphate constituents of cell sap in form of phosphor-proteins in the growing region of meristematic tissues. El-Talib *et al.* (2004), Bhatnagar and Saini (2005) and Prasad *et al.* (2008) have also reported significant influence of phosphorus fertilization on cane height.

Leaf area index increased markedly with increased levels of phosphorus at all the stages during both the years. LAI attained a peak at 230 DAP under 52.5 kg P/ha (4.24 and 4.25) during 2003-04 and 2004-05, respectively. Increase in LAI values owing to phosphorus nutrition was because of favourable synthesis of growth promoting constituents in plants as a result of better phosphorus supply which resulted in enlargement of leaf area. Higher values of LAI were also associated with higher number of tillers.

Effect of sulphur

There was no significant effect of Sulphur levels on cane germination. However, sulphur fertilization exhibited significant influence on tiller count at 65 DAP and maximum number of tillers (110400/ha in first year and 111300/ha in second year) were obtained with 120 kg S/ha, though it remained statistically at par with 80 kg S/ha and all of them were significantly superior to control treatment 98600/ha during 2003-04 and 99100/ha during 2004-05. Sulphur did not exhibit significant differences in number of tillers at 95 DAP during both the years. However, maximum number of tillers of 164600 and 165400/ha were recorded with 120 kg S/ha during first and second year, respectively.

Application of sulphur did not exhibit significant effect on plant height at 150 and 180 DAP in both the years (Table 1). At 150 DAP (mid July), the maximum plant height was

Table 1 Germination, number of tillers and plant height of sugarcane as affected by various levels of phosphorus and sulphur

Treatment	Germination (%)				Number of tillers ('000/ha)				Plant height (cm)					
	30 DAP*		45 DAP		65 DAP		95 DAP		150 DAP		180 DAP		210 DAP	
	03-04	04-05	03-04	04-05	03-04	04-05	03-04	04-05	03-04	04-05	03-04	04-05	03-04	04-05
P-level (kg/ha)														
0	32.8	33.9	43.1	43.8	94.3	95.5	149.5	150.3	93.6	95.4	145.2	147.5	170.6	173.9
17.5	31.3	32.8	43.8	43.1	104.7	105.5	158.9	159.4	103.8	105.9	156.2	157.8	191.3	193.3
35.0	30.7	31.4	41.6	41.8	111.2	111.7	165.0	165.8	110.0	112.1	162.4	163.8	197.3	198.6
52.5	32.1	32.3	42.4	42.4	113.0	113.6	166.4	167.3	111.6	113.7	163.9	165.4	198.9	200.3
SE m (±)	0.90	0.89	4.19	1.19	3.14	3.18	3.34	3.35	3.12	3.21	4.71	4.73	4.48	4.40
CD (P=0.05)	NS	NS	NS	NS	9.1	9.2	9.6	9.7	9.0	9.3	13.6	13.7	13.0	12.7
S level (kg/ha)														
0	33.0	34.0	44.0	44.0	98.6	99.1	152.8	153.7	97.8	99.7	149.9	151.7	175.2	177.3
40	31.2	32.7	43.0	43.0	104.6	105.4	158.8	159.4	103.8	105.9	156.1	157.7	191.2	193.2
80	32.0	32.2	42.4	42.4	109.5	110.3	163.6	164.4	108.2	110.2	160.5	162.0	195.5	197.3
120	30.7	31.3	41.5	41.8	110.4	111.3	164.6	165.4	109.2	111.3	161.2	163.1	196.1	198.3
SE m (±)	0.90	0.89	1.19	1.19	3.14	3.18	3.34	3.35	3.12	3.21	4.71	4.73	4.48	4.40
CD (P=0.05)	NS	NS	NS	NS	9.1	9.2	NS	NS	NS	NS	NS	NS	13.0	12.7

*DAP, days after planting

Table 2 Effect of various levels of phosphorus and sulphur fertilization on periodic leaf area index in sugarcane

Treatment	Leaf area index									Mean increase in LAI over control (%)		
	70 DAP			150 DAP			230 DAP			70 DAP	150 DAP	230 DAP
	2003-04	2004-05	Mean	2003-04	2004-05	Mean	2003-04	2004-05	Mean			
P-level (kg/ha)												
0	0.469	0.476	0.473	3.30	3.43	3.37	3.67	3.78	3.73	-	-	-
17.5	0.570	0.580	0.575	3.74	3.83	3.92	4.01	4.01	4.01	21.6	16.3	7.5
35.0	0.635	0.643	0.639	4.04	4.12	4.15	4.18	4.19	4.19	35.1	23.1	12.3
52.5	0.660	0.667	0.664	4.09	4.20	4.22	4.24	4.25	4.25	40.4	25.2	13.9
SE m (±)	0.0170	0.018	-	0.111	0.114	-	0.087	0.091	-	-	-	-
CD (P=0.05)	0.049	0.051	-	0.32	0.33	-	0.25	0.26	-	-	-	-
S level (kg/ha)												
0	0.494	0.503	0.499	3.53	3.53	3.69	3.85	3.86	3.86	-	-	-
40	0.566	0.575	0.571	3.74	3.81	3.91	4.00	4.01	4.01	14.4	6.0	3.9
80	0.632	0.635	0.634	3.93	4.08	4.09	4.10	4.15	4.13	27.1	10.8	7.0
120	0.642	0.653	0.648	3.98	4.15	4.16	4.16	4.21	4.19	29.9	12.7	8.5
SE m (±)	0.0170	0.018	-	0.111	0.114	-	0.087	0.091	-	-	-	-
CD (P=0.05)	0.049	0.051	-	0.32	0.33	-	NS	0.26	-	-	-	-

recorded with 120 kg S/ha followed by 80 kg S/ha. Similar was the trend at 180 DAP (mid August). Plant height recorded at 210 DAP (mid September) was maximum (196.1 and 198.3 cm) with 120 kg S/ha, which was statistically similar to 80 kg S /ha (195.5 and 197.3 cm) and 40 kg S/ha (191.2 and 193.2 cm) and all the S doses were significantly superior to control treatment. The significant increase in plant height with advancement in crop age of sugarcane is attributed to the sum total of better plant growth and increase in growth contributing characters due to sulphur fertilization. Shukla and Menhi Lal (2007) have also reported significant improvement in cane height due to sulphur nutrition.

During 2003-04 and 2004-05, leaf area index at 70 DAP was maximum with 120 kg S/ha (0.642 and 0.653) which was at par with 80 kg S/ha (0.632 and 0.635) and both were significantly superior to remaining of the treatments. Similarly, at 150 DAP, the maximum values of LAI were recorded with 120 kg S/ha (3.98 and 4.15) which was significantly superior to control treatment but statistically at par with 80 kg S/ha and 40 kg S/ha during 2003-04. However, during 2004-05, 120 kg S/ha (4.15 LAIs) was significantly superior to 40 kg S/ha. The maximum LAI was recorded with the application of 120 kg S/ha (4.16). The higher leaf area index at higher level of sulphur might be due to its role in enhancing chlorophyll synthesis and meristematic activity. Thus, plant well supplied with sulphur will have relatively larger photosynthesizing area, consequently accumulating higher quantities of photosynthates, which in turn will be translocated in to sink-site.

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Comparative performance of sugarcane varieties under waterlogged vis-à-vis upland conditions

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ABSTRACT

A field experiment of sugarcane was conducted under waterlogged (lowland) conditions at Pusa Farm of Rajendra Agricultural University, Bihar (Samastipur) during spring season of 2010-11. The soil of experimental field was calcareous in nature having pH 8.01 and EC 0.29 ds/m. The crop was planted on February 26, 2010 and harvested in 1st week of February 2011. Nine sugarcane varieties viz., 'BO 76', 'BO 91', 'BO 151', 'BO 146', 'BO 147', 'CoLk 94184', 'UP 9530', 'CoP 042' and 'CoSe 96436' were evaluated in randomised block design with 3 replications. Another set of the same experiment was planted under upland conditions on February 25, 2010 and harvested in the last week of January, 2011. The results indicated that all studied growth parameters were affected adversely due to water-logging conditions. The maximum number 89.23 x 10^3/ha of millable canes (NMC) was in variety 'BO 147'. The maximum reduction of 36% in NMC due to water-logging occurred in 'BO 76' (31.34 x 10^3/ha). The tangible differences among varieties in respect of single cane weight were not observed. The maximum single cane weight of 759 g was recorded in 'BO 147'. The reduction in single cane weight due to water-logging accounted for 49.2%. The per cent reduction of sucrose in juice at 330 DAP due to waterlogging, over normal conditions was 20.78% in variety 'BO 76' whereas the lowest reduction of 6.67% occurred in 'BO 151'. 'BO 147' significantly out yielded all the varieties. Maximum reduction in cane yield due to waterlogged conditions was recorded in 'BO 76' (68%) and the minimum of 20.1% in 'BO 147'. The overall reduction over the varieties was 41.31%. The commercial cane sugar percent in juice was found to be reduced due to water-logging in all varieties. Maximum reduction in CCS% due to waterlogged conditions occurred in 'BO 76' (23.12%), however, the lowest reduction was in 'CoLk 94184' (4.52%).

Key words: Sugar cane, Varieties, Waterlogged.

Sugarcane (*Saccharum spp* hybrid complex) is one of the most important agro-industrial crops of India. Most of the sugarcane areas in eastern Uttar Pradesh, Bihar and West Bengal get waterlogged which results in poor yield and sugar recovery. In Bihar sugarcane is cultivated in about 2.30 Lakh hectares out of that more than 75% area is concentrated in North Bihar, where all the working sugar factories are located. The North Bihar is the main sugarcane growing tract of Bihar where about 35-40 % of sugarcane remains waterlogged during monsoon season coinciding with the grand growth period of the crop. In waterlogged areas, cane yield generally declines by 15-20% (Zende 2002). The stress caused by water-logging, induces early flowering as well as maturity reducing cane yield. The prolonged water-logging deteriorates cane quality too.

Varieties differ in its degree of tolerance to waterlogging based on certain inherent genetic characteristics, age of the crop and other growing conditions. A large difference in varietal response to flooding in sugarcane has been reported by several scientists. The varieties which are doing comparatively well under water-logging conditions in Bihar are 'BO 91', 'CoSe 96436', 'CoLk 94184', 'BO 147' etc. The clonal differences in response to severe water-logging indicated that under artificially created conditions of prolonged water-logging *S. officinarum* clones were highly susceptible and did not survive whereas the clones of *S. barberi, S. sinense, Sclerostachya* and *Erianthus* survived. Hybrid complexes i.e., *Saccharum* spp. hybrid complex clones with waterlogging tolerant genes from tolerant species can do well in waterlogged conditions which requires systematic study on their comparative tolerance. Although the use of high yielding varieties coupled with waterlogging tolerance capacity contribute substantially to sugarcane production and productivity but still there is need to screen sugarcane varieties for tolerance to waterlogging in comparison to their performance under normal conditions for exploiting its better adaptability mechanisms under submerged conditions.

The present investigation was, therefore, planned to evaluate nine sugarcane genotypes for growth, yield and quality parameters under waterlogged conditions.

MATERIALS AND METHODS

A field experiment was conducted in waterlogged (low land) conditions during spring season of 2010-11 at Pusa Farm of

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Rajendra Agricultural University, Bihar. The soil was sandy loam with higher silt and clay contents, alkaline and calcareous in nature having pH 8.01 with EC of 0.29 ds/m. The soil was medium in fertility status in terms of organic carbon, available phosphorus and available potassium but low in available nitrogen. Nine sugarcane varieties viz., 'BO 76', 'BO 91', 'BO 151', 'BO 146', 'BO 147', 'CoLk 94184', 'UP 9530', 'CoP 042' and 'CoSe 96436' were evaluated in randomised block design with three replications. The crop was planted on February 26, 2010 and harvested in the 1st week of February 2011. The depth of water logging was recorded from July to October, 2010 at weekly interval which coincided with grand growth period of crop. The average depth of water in the crop field during the month of July, August, September and October 2010 was 157, 163.8, 293 and 50 cm, respectively. Hence, there was stagnation of water for about 110 days. Pre-monsoon tillers were counted 150 days after planting and number of millable canes (NMC) at harvest from net plot area of each plot. Single cane weight of 10 detopped and detrashed canes was taken randomly from each plot and averaged out. Sucrose in juice was estimated as pol% following standard method of estimation by polarimeter and Schimitz's table. Commercial cane sugar percentage (CCS %) was calculated at 330 DAP with the help of brix and pol recorded at this stage as per the formula given below:

$$CCS\ \% = [S-0.4\ (B-S)] \times 0.73$$

Where, S = Sucrose % of juice and B = Brix content of juice

RESULTS AND DISCUSSION

Yield and yield attributing characters

The perusal of data (Table 1) revealed that the highest number of pre-monsoon tillers at 150 DAP under lowland conditions was in sugarcane variety 'BO 91' (156.87 x 10^3/ha) which was closely followed by 'BO 147' (149.68 x 10^3/ha). The differences in number of tillers among 'BO 147', 'BO 146' and 'CoLk 94184' were however, not significant. The lowest plant population at this stage under waterlogged conditions was in variety 'UP 9530' (75.56 x 10^3/ha) being statistically at par with that of 'CoP 042', 'BO 76', 'BO 151' (91.86 x 10^3/ha). In almost all the varieties there was more reduction in plant population from pre-monsoon to number of millable cane. The over all reduction under upland situation and waterlogged was in the order of 27.9 and 39.8 % respectively. Under waterlogged situation, the reduction in number of millable canes from that of pre-monsoon tillers was in the range of 25.2% in ('UP 9530') to 50.6% in ('BO 91').

This seems to be major reason for reduction in yield due to water-logging as the late emerging tillers don't survive due to its poor growth caused by reduced nutrient uptake. The differences in plant population were also due to differential tillering behaviour of the genotypes and tiller survival while germination per se may not play important role in deciding the final plant population or NMC.

Another major yield contributing character i.e., single cane weight, measured at harvesting lucidly indicated (Table 1) that

Table 1 Varietal difference in sugarcane under waterlogged and upland conditions for yield attributes and quality traits

Varieties	Pre-monsoon tillers at 150 DAP ('000/ha)		No. of millable cane ('000/ha)		Single cane weight (g/plant)		Sucrose% in juice at 330 DAP		CCS% in juice at 330 DAP	
	Normal	Water-logged	Normal	Water-logged	Normal	Water-logged	Normal	Water-logged	Normal	Water-logged
'BO 76'	98.73	91.42	86.96	55.62	820	416	17.56	13.91	12.15	9.34
'BO 91'	165.80	156.87	84.04	77.46	650	503	17.79	16.45	12.36	10.36
'BO 151'	83.50	91.86	65.18	47.86	697	533	18.12	16.91	12.54	11.72
'BO 146'	138.86	123.79	101.28	81.54	718	603	16.79	14.67	11.59	9.82
'BO 147'	158.95	149.68	105.84	89.23	801	759	15.08	12.80	10.39	8.34
'CoLk 94184'	105.17	121.45	79.48	76.03	777	583	18.41	17.03	12.39	11.83
'UP 9530'	115.73	75.56	84.02	56.52	787	493	17.71	16.27	12.28	11.21
'CoP 042'	82.07	77.29	81.66	56.60	833	616	17.60	14.84	12.28	10.17
'CoSe 96436'	122.73	112.50	83.46	60.93	847	633	17.58	14.64	12.13	10.04
Mean	119.06	111.15	85.76	66.86	770	571	17.40	15.27	12.01	10.31
CD (P=0.05)	26.34	28.65	13.45	15.83	143	156	0.81	0.93	0.62	1.88
CV %	13.0	14.9	10.2	14.6	10.6	14.7	2.7	3.5	3.0	7.7

there were significant differences among the varieties. Under lowland conditions all the varieties showed relatively lesser single cane weight than that of upland condition. Under low land, the highest cane weight was recorded in 'BO 147' (759 g) which was at par with that of 'CoSe 96436' and 'CoP 042'. All the varieties except 'BO 76' and 'BO 147' were statistically at par to each other. The lowest cane weight of 416 g was in 'BO 76' which was at par with that of 'UP 9530', 'BO 91' and 'BO 151'. The overall reduction in single cane weight due to water-logging was 25.8%.

Juice quality

The highest pol% juice at 330 DAP under waterlogged conditions was for variety 'CoLk 94184' (17.03%) which was at par to that of 'BO 151', 'BO 91' and 'UP 9530'. Significantly lower pol% in juice (2.80%) was observed in 'BO 147'. In general, there was reduction in pol percent due to waterlogged conditions in all varieties.

On comparison of pol % in juice estimated under waterlogged conditions with that of upland it was observed that the maximum reduction in pol% juice was in 'BO 76' which was to the tune of 20.78% followed by 16.72% in 'CoSe 96436', 15.68% in 'CoP 042' and 15.11% in 'BO 147'. However, the lowest reduction in pol% juice was recorded in 'BO 151' which 6.67% only. Similar value was observed in 'CoLk 94184'. The overall reduction at this stage was 12.2%. Significant varietal differences in sucrose under waterlogged conditions have been reported by several workers (Malik and Tomer, 2003; Singh *et al.,* 2005).

Significantly highest CCS% in juice was observed in 'CoLk 94184' (11.83%) as compared to the remaining varieties except 'BO 151' (11.72%) and 'UP 9530' (11.21%). Variety 'BO 147' being at par with 'BO 76' registered significantly lower CCS% (8.34%) than other varieties.

The CCS% in juice was found to be reduced due to waterlogged condition in all varieties. Overall, CCS% was 12.01% under upland conditions against 10.31% under water-logging. Thus the reduction was of the order of 14.1% (Table 1). The maximum reduction in CCS% due to water-logging was in 'BO 76' (23.12%) followed by 'BO 147' (19.73%) and the lowest reduction occurred in 'CoLk 94184' (4.52%).

Cane yield (t/ha)

In case of lowland conditions, though the varietal differences were significant but the yield levels were quite low in all varieties, as compared to that of upland conditions (Table 2). However, variety 'BO 147' producing 67.70 t/ha significantly out yielded the remaining varieties. The yield level of 'BO 147' under both the conditions remained the highest. Variety BO146 gave a yield of 49.16 t/ha which was at par with that of 'CoLk 94184'. Marked differences amongst varieties 'CoLk 94184', 'BO 91', 'CoSe 96436' and 'CoP 042' were not observed. The lowest yield was in 'BO 76' having yield of 22.81 t/ha only which was statistically at par with 'BO 151' (26.07 t/ha) and 'UP 9530' (27.87 t/ha). Thus, it is inferred that the varieties, doing well in upland conditions, performed well in waterlogged conditions too.

Table 2 Cane yield of different sugarcane varieties grown under waterlogged and upland conditions and percentage reduction in yield due to waterlogging

Varieties	Cane yield (t/ha)		% reduction on yield due to waterlogging
	Normal	Waterlogging	
'BO 76'	71.31	22.81	68.0
'BO 91'	54.41	39.84	26.7
'BO 151'	47.96	26.07	47.6
'BO 146'	72.68	49.16	32.3
'BO 147'	84.74	67.70	20.1
'CoLk 94184'	61.73	44.48	27.9
'UP 9530'	66.13	27.87	57.8
'CoP 042'	69.52	34.94	49.7
'CoSe 96436'	69.17	38.93	43.7
Mean	66.40	39.08	41.31
CD (P=0.05)	19.35	9.03	-
CV %	16.8	13.4	-

The first top five varieties which performed well under waterlogged conditions were in order of 'BO 147', 'BO 146', 'CoLk 94184', 'BO 91' and 'CoSe 96436'. This confirms the findings of Singh (2008). However, the performance of 'BO 76' (22.81 t/ha), 'BO 151' (26.07 t/ha) and 'UP 9530' (27.87 t/ha) were not tangible.

The results clearly indicate that the effect of waterlogging was maximum in 'BO 76' where reduction in yield was found to be in order of 68% followed by 'UP 9530' (57.8%), 'CoP 042' (49.7%) and 'BO 151' (47.6%). The variety which was least affected by waterlogging was 'BO 147' where yield reduction was 20.1% followed by 'BO 91' (26.7%), 'CoLk 94184' (27.9%). Considering the yield and per cent reduction due to waterlogging, sugarcane varieties 'BO 147', 'CoLk 94184', 'BO 91' and 'BO 146' seem to be doing well under waterlogged conditions. The reduction in yield due to waterlogging was also reported by several scientists (Zende, 2002; Patil *et al.* 2008 and More *et al.* 2009).

Irrespective of sugarcane varieties the overall reduction in cane yield due to waterlogging was of the order of 41.31%. Patil *et al.* (2008) also reported 38.5% reduction due to waterlogging whereas Yadav *et al.* (2010) reported that the waterlogging created for 30 days and 60 days reduced the cane yield by 86.52 t/ha and 74.67 t/ha, respectively.

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Interpreting phenotypic stability in sugarcane using different parametric models

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ABSTRACT

The trial was carried out during 2005-08 to predict the phenotypic stability of 10 sugarcane (*Saccharum* spp hybrid complex) genotypes using different parametric models for cane yield, CCS yield and fibre content in plant as well as ratoon crops under four environments. G x E (linear) component of variance was significant for traits under study. The AMMI model analysis for cane yield indicated presence of higher magnitude (76 %) of principal component 1 (non linear interaction) than that of linear regression model in sugarcane. AMMI was found to be linear for CCS (t/ha) and fibre content (%). Genotype 'CoLk 9705' showed least deviation from regression (-0.039) with regression at unity (bi= 1.01) and found to be most stable for sugar yield (8.41 t/ha) in all the parametric models Tai (α= 0.013), Shukla (s^2 = -0.049) and Wricke's ecovalence (W^2 = 0.135). The deviation from regression and regression by linear model of Perkins and Jinks, Eberhart and Russel and low Wricke's ecovalence (66.12) and Hanson DI (3.24) indicated that the genotype 'CoLk 9705' was the most stable with higher cane yield (73.08 t/ha) over the population mean (65.48 t/ha). 'CoLk 9705' was found to be stable with Eberhart and Russel, Wricke's ecovalence and Perkins and Jinks' parameters for sugar yield (t/ha). Genotype 'CoLk 04237' was found to be stable for fibre content (11.11%) by Eberhart and Russel, Perkins and Jinks, Hanson (DI) and Tai (α = 0.677) models.

Key words: GxE interaction, Parametric models, Stability, Sugarcane.

Sugarcane being second most important commercial crop next to cotton plays a vital role in the Indian economy. It occupies about 5.08 million hectare area that produces about 347.9 million tonnes of sugarcane annually with the national average productivity of 68.4 t/ha. About 50 million farmers are dependent for their livelihood on sugarcane and in addition roughly equal numbers of agricultural labourers earn their living working for cultivation. Sugarcane is the primary raw material for all sugar mills as well as *Gur* and *Khandsari* units, an important cottage industry in India. It also serves the purpose of other related industries like distillery, paper, power cogeneration etc.

Ratooning is an important means of achieving cost effectiveness in sugarcane production. The important advantage of ratooning lies with saving in cost of production to an extent of 20-30 % in terms of saving seeds, cost of preparatory tillage and planting. Ratoon matures early with shorter crop cycle with higher recovery during early crushing season that extends milling period. In India particularly in sub-tropical parts, only one ratoon is taken and almost 50% area is occupied by ratoon crop. Adaptation of any new variety among the farmers now depends very much on its ratooning potential.

In most of the crops, relative performance of genotypes differs in different environments. Such G x E interaction reduces the efficiency of selection and increase the size of selection programme. Sugarcane is a clonally propagated and long duration crop. Its different growth phases pass through varying growing environment that require buffering capacity to greater extent. Hence, stability in performance in plant as well as ratoon crops over environments is one of the most desirable properties of genotypes to be released as a variety for wide cultivation. The differential response of cultivars from one environment to another can be interpreted by different statistical models. The present study was, therefore, undertaken to (i) study the genotype x environment interaction in sugarcane under different environments, (ii) make comparison of different parametric models to identify stable genotypes.

MATERIALS AND METHODS

The experimental material consisted of ten genotypes of sugarcane (*Saccharum* spp. hybrid complex) namely 'CoLk 9709', 'CoLk 99271', 'CoLk 04237', 'CoLk 9705', 'CoLk 04238', 'CoLk 97147', 'CoLk 94184' including three standards *viz*., 'CoJ 64', 'CoS 96268' and 'CoS 767'.The experiment was conducted in Randomized Block Design in three replications over four environments *viz.,* first plant crop (2005-06), ratoon of first plant crop (2006-07), second plant crop (2006-07) and ratoon of second plant crop (2007-08) at the main research farm of the Indian Institute of Sugarcane Research, Lucknow, situated at $26^0 56'$ N and $80^0 52'$ E and 111 m above mean sea level. Each genotype was planted with four cane setts (three budded) per metre of row length. The plot size consisted of four rows of 6 m length spaced at 75 cm

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apart. The recommended agronomic package of practices was followed to raise good plant as well as ratoon crops. Observations were recorded on cane yield (t/ha), commercial cane sugar (CCS) yield (t/ha ha) and fibre content (%). Ten randomly selected canes were used for juice analysis and estimation of fibre content (%), cane and CCS yields were estimated on plot basis. The mean data were used to analyze stability parameters using models proposed by Eberhart and Russel (1966), Perkins and Jinks (1968), Shukla's stability variance (1972), Tai's statistics (1971), Wricke's equivalence (1962) and AMMI Model (Gauch and Zobel 1988) using Indostat software.

RESULTS AND DISCUSSION

The analysis of variance for cane yield, sugar yield and fibre content by Eberhart and Russel's model is presented in Table 1. The analysis of variance for these three traits indicated significant differences among the genotypes. Mean sum of squares due to genotype x environment interaction (GEI) were highly significant for the traits under study when tested against pooled error. Further, Environment + genotype x environment interaction were significantly different in pooled analysis of variance for these traits by Eberhart and Russel's model as well as Perkins and Jinks' model. On partitioning of GEI into linear and non-linear (pooled deviation) components, both were significant indicating their significance in the inheritance of traits. Although, both linear and non-linear components contributed towards GEI variance, yet linearity was more pronounced for cane yield (65.4%), sugar yield (65.3%) and fibre content (66.9%) indicating that the regression coefficients on environmental index were important for these traits and their performance could be predicted to some extent. Portion of environmental (linear) was substantially higher than GxE

Table 1 Analysis of variance for stability of cane yield, CCS yield and fibre content in sugarcane by Eberhart and Russel's model

Source	Degrees of freedom	Cane yield (t/ha)	CCS (t/ha)	Fibre content (%)
Total	39	444.25	6.24	2.88
Genotypes	9	415.32**	5.64**	9.81**
Environments + (Genotype x Environment)	30	452.93**	6.39**	0.80**
Environments	3	3444.78**	47.68**	5.22**
G x E interaction	27	120.50*	1.80*	0.31*
Environments (Linear)	1	10334.34**	143.05**	15.67**
G x E (Linear)	9	236.32**	3.53**	0.62**
pooled Deviation	20	56.33**	0.85**	0.14
Pooled Error	72	19.38	0.10	0.20

* and ** at 5 % and 1% level of Significance

Table 2 Analysis of variance for stability of cane yield, CCS yield and fibre content in sugarcane by Perkins and Jinks model

Source	Degrees of freedom	Cane yield (t/ha)	CCS (t/ha)	Fibre content (%)
Total	39	444.25	6.22	2.88
Genotypes	9	415.32**	5.64**	9.81**
Environments + (Genotype x Environment)	30	452.93**	6.39**	0.80**
Environments	3	3444.78**	47.68**	5.22**
G x E interaction	27	120.50	1.80	0.31
G X E regression	9	236.32**	3.53**	0.62**
Remainder	18	62.59**	0.94**	0.15
Pooled Error	72	19.38	0.10	0.20

* and ** at 5 % and 1% level of Significance

(linear) for all the traits indicating high predictability of the performance of genotypes in different environments. Kumar *et al.* (2007) reported significant GxE (linear) for cane yield and sugar yield. Stability of all the genotypes except 'CoLk 9709' and 'CoLk 9705' for cane yield could not be predicted due to their significant deviation from regression. The over all performance of the clones for cane yield and sugar yield was better in first plant crop. The effects of genotypes and environments are not always additive due to the presence of genotype and environment interaction (GEI) and are measured as inconsistent performance of genotype across environments. The additive main effects and multiplicative interaction (AMMI) model was also used to compare the stability of genotypes but AMMI was found to be linear for CCS yield (t/ha) and fibre content (%). The first two IPCAs of the AMMI of GEI accounted for 95.83% of this variation for cane yield, whereas, PCA I alone contributed 74.76% of variation for this trait (Table 3). The genotypes with IPCA I scores near zero ('CoLk 94184') and ('CoLk 99271') were treated as stable in

Table 3 AMMI analysis of variance for cane yield in sugarcane

Source	Degrees of freedom	MS
Total	39	444.25
Genotypes	9	415.32**
Environments	3	3444.78**
G x E interaction	27	120.50**
PCA I	11	221.11**
PCA II	9	76.18*
PCA III	7	19.36
Pooled residual #	7	19.38

* and ** at 5 % and 1% level of Significance

Fig 1 AMMI-1 biplot for cane yield presenting 10 sugarcane genotypes tested under four environments

comparison to other genotypes by this model. A biplot showing main effect means on the abscissa and IPCA-1 value as the ordinates (Fig 1). In this biplot genotypes or environments that appeared almost on a perpendicular line had similar means and those appeared on a horizontal line had similar interaction patterns. For example, genotypes 'CoLk 04237', 'CoLk 94147', and 'CoS 96268' had similar main effect as well as interaction pattern. AMMI-I biplot revealed that the genotypes 'CoLk 99271', 'CoLk 9705' and 'CoLk 94184' with IPCA I scores near zero and high mean cane yield were treated as stable in comparison to other genotypes by this model. These genotypes had little interaction across the environments (Zobel *et al.* 1988). Further interaction biplot for AMMI-II model can also be prepared where IPCA-1 scores on abscissa and IPCA-2 scores on the ordinates are plotted. This biplot showed that genotype 'CoLk 94184' was stable. Kumar *et al.* (2009) study indicated that biplot between IPCA I and IPCA II is way to take care of non linear interaction and to catch the most stable genotype.

Analysis of stability for cane yield using Wricke's ecovalence (W^2) gives the relative contribution of each genotype in evaluation of total GxE interaction, Shukla's stability variance (s^2) is an unbiased estimate of the variance of a genotype across environment. Phenotypic index (PI) gave similar results to the Eberhart and Russel's as well as Perkins and Jinks' parameters (Table 4). Shukla's stability variance (s^2) being an unbiased estimate of the variance of a genotype across environment, for cane yield was found to be highly significant indicating none of the genotypes could be categorized as stable for this trait. However, least Shukla's stability variance (s^2) was recorded for genotype 'CoS 96268' by his method. Table 5 shows the ranking based on these parameters were very high (score less than 3) for genotype 'CoLk 9705'. Thus, genotype 'CoLk 9705' can be considered as stable for cane yield. Comparing the parameters of Tai's (α) and Hanson's (DI), 'CoLk 97147' exhibiting high ranking (1) was rated as stable by these parameters. For cane yield, correlation between regression coefficient (bi) and deviation from regression (S^2di) was numerically positive significant (0.083). Similarly, correlation between deviation from regression and Shukla's stability variance (0.649) were significant and positive for this trait. However negative correlation (-0.336) between regression coefficient (bi) and Shukla's stability variance was noticed. High correlation

Table 4 Estimates of different stability parameters for cane yield of sugarcane genotypes

Genotype	Cane yield (t/ha)	PI	bi	S^2Di	α	λ	s^2	W^2	DI	PJ bi	PJ S^2Di
'CoLk 9709'	74.82	9.34	0.420*	4.403	-0.582	1.61	145.79**	366.791	1.64	-0.580*	4.403
'CoLk 99271'	80.59	15.11	1.31	14.436*	0.311	2.6	50.53**	138.167	4.328	0.310	14.436*
'CoLk 04237'	60.87	-4.61	0.921	107.045**	-0.079	16.71	89.05**	230.63	3.455	-0.079	107.045**
'CoLk 9705'	73.08	7.6	1.241*	-2.036	0.242	0.41	20.51**	66.12	3.24	0.241*	-2.0036
'CoLk 04238'	72.53	7.05	1.433	90.267**	0.434	12.19	153.05**	384.21	4.730	0.433	90.267
'CoLk 97147'	58.18	-7.3	1.652	108.51**	0.653	13.5	270.43**	665.93	6.254	0.652	108.51**
'CoLk 94184'	68.78	3.3	1.231	27.43**	0.231	4.43	42.97**	120.01	4.854	0.231	27.431**
'CoS 96268'	59.8	-5.68	1.121	18.33*	0.121	3.3	18.75**	61.89	3.852	0.121	18.335
'CoJ 64'	46.54	-18.94	0.348	105.13**	-0.654	19.04	268.05**	660.22	1.989	-0.652	105.127**
'CoS 767'	59.56	-5.92	0.325	38.97**	-0.677	7.65	226.1**	559.54	1.219	-0.675	38.974**
GM	65.48										

* and ** at 5 % and 1% level of Significance

PI= Phenotypic index; bi= Regression coefficient by Ebarhart and Russel's model; S^2Di = Deviation from regression by Ebarhart and Russel's model; α = Tai's statistics; λ = Tai's statistics; s^2 = Shukla's stability variance; W2 = Wricke's ecovalence; DI = Hanson's statistics; PJ bi= Regression coefficient by Perkins and Jinks' model; PJ S^2Di = Deviation from regression by Perkins and Jinks' model

Table 5 Ranking sugarcane genotypes grown based on estimates of different stability parameters for cane yield

Genotype	Cane yield (t/ha)	PI	bi	S^2Di	α	λ	s^2	W^2	DI	PJ bi	PJ S^2Di
'CoLk 9709'	2	2	8	2	8	9	5	7	10	7	2
'CoLk 99271'	1	1	4	3	3	8	4	4	3	5	3
'CoLk 04237'	**6**	**6**	**1**	**9**	**7**	**2**	**6**	**5**	**7**	**1**	**9**
'CoLk 9705'	**3**	**3**	**5**	**1**	**4**	**10**	**2**		**5**	**4**	**1**
'CoLk 04238'	4	4	6	7	2	4	7	6	2	6	7
'CoLk 97147'	9	9	7	10	1	3	10	10	1	8	10
'CoLk 94184'	5	5	3	5	5	6	3	3	4	3	5
'CoS 96268'	**7**	**7**	**2**	**4**	**6**	**7**	**1**	**1**	**6**	**2**	**4**
'CoJ 64'	10	10	9	8	9	1	9	9	8	9	8
'CoS 767'	8	8	10	6	10	5	8	8	9	10	6

between parameters of Wricke's ecovalence (W^2) and deviation from regression by Eberhart and Russel and between parameters of Wricke's ecovalence (W^2) and Perkins and Jinks was observed. This indicated that Eberhart and Russel and Perkins and Jinks models have little difference as far as grouping of genotypes for stability is concerned. Strong significant positive correlation between Wricke's ecovalence (W^2) and Shukla's stability variance (s^2) was observed for this trait which indicated that stability variance is a coded value of ecovalence. Kang *et al.* (1987) also suggested that Wricke' ecovalence (W^2) and Shukla stability variance (s^2) were gave the same result. Similar finding was reported by Dehgani *et al.* (2008) in stability anlysis for grain yield in lentil. Bilbro and Ray (1976) reported that value of regression coefficient indicates the adaptation of the genotypes to the environment, while high coefficient of determination (R^2) indicates stability. Considering this fact, S^2d and R^2 were taken into consideration.

For CCS yield, stability parameters and ranking of genotypes using these parameters for different methods have been presented in Table 6 and 7, respectively. Ranking of

Table 6 Estimates of different stability parameters for CCS yield of sugarcane genotypes

Genotype	CCS (t/ha)	PI	bi	S^2Di	α	λ	s^2	W^2	DI	PJ bi	PJ S^2Di
'CoLk 9709'	9.55	1.49	0.54	0.235*	-0.464	2.59	1.457**	3.75	1.641	-0.463	0.235
'CoLk 99271'	9.87	1.81	1.29	0.099	0.294	1.6	0.578**	1.64	4.328	0.293	0.099
'CoLk 04237'	7.45	-0.61	0.95	1.457**	-0.053	11.07	1.213**	3.16	3.455	-0.053	1.456
'CoLk 9705'	8.42	0.36	1.01	-0.04	0.113	0.465	-0.049	0.14	3.240	0.013	-0.039
'CoLk 04238'	8.45	0.39	1.32	1.42**	0.325	10.08	1.7895**	4.55	4.730	0.324	1.417
'CoLk 97147'	7.21	-0.85	1.74	1.64**	0.742	10.64	4.61**	11.32	6.254	0.740	1.637
'CoLk 94184'	8.92	0.86	1.43	0.15	0.433	1.63	1.213**	3.17	4.854	0.431	0.146
'CoS 96268'	7.34	-0.72	1.15	0.6*	0.148	3.19	0.413**	1.24	3.852	0.148	0.360
'CoJ 64'	6.05	-2.01	0.41	1.45**	-0.596	12.07	3.30**	8.17	1.989	-0.595	1.449
'CoS 767'	7.36	-0.7	0.16	0.63**	-0.84	5.99	4.70**	1.54	1.219	-0.838	0637
GM	8.06										

Table 7 Ranking sugarcane genotypes grown based on estimates of different stability parameters for CCS yield

Genotype	CCS (t/ha)	PI	bi	S^2Di	α	λ	s^2	W^2	DI	PJ bi	PJ S^2Di
'CoLk 9709'	2	2	8	4	8	7	6	6	9	4	7
'CoLk 99271'	1	1	4	2	4	9	3	3	4	2	4
'CoLk 04237'	6	6	2	9	7	2	5	5	6	9	2
'CoLk 9705'	**5**	**5**	**1**	**1**	**6**	**10**	**1**	**1**	**7**	**1**	**1**
'CoLk 04238'	4	4	5	7	3	4	7	7	3	7	5
'CoLk 97147'	8	8	7	10	1	3	9	9	1	10	9
'CoLk 94184'	3	3	6	3	2	8	4	4	2	3	6
'CoS 96268'	7	7	3	5	5	6	2	2	5	5	3
'CoJ 64'	10	10	9	8	9	1	8	8	8	8	8
'CoS 767'	9	9	10	6	10	5	10	10	10	6	10

genotypes by different methods namely Eberhart and Russel, Perkins and Jinks, Shukla's s^2 and Wricke' ecovalence (W^2) parameters revealed that genotypes 'CoLk 9705' had the highest scores (1) and could be considered as the most stable variety. This genotype showed lowest variance for CCS yield in all the methods tested except Tai' statistics and Hanson (DI). Analysis of association between Shukla stability variance (s^2) and deviation from regression (0.568), between Hanson (DI) and regression (bi) Perkins and Jinks (0.983) and between Wricke ecovalence (0.249) and regression (bi) Perkins and Jinks (0.983) for this trait indicated that these methods were comparable to each other for the purpose of interpreting stability of genotypes for CCS yield. Stability parameters and ranking of genotypes for fibre content (%) by different methods given in Table 8 and 9 clearly indicated that genotypes having low mean fibre % value and high scores of ranking could be grouped as stable. Genotype 'CoLk 04237' showed the lowest mean fibre % with high scores of stability parameters by Eberhart and Russel, Tai (α, λ), Hanson (DI) and Perkins and Jinks and was found to be most stable. In addition, genotype 'CoLk 97147' showed the highest ranking (1) by Shukla s^2 and Wricke' ecovalence (W^2) with fibre% ranking (5) and could be rated as stable for this trait. In conclusion, Single location tests over the years, gives temporal stability which could be

Fig 2 AMMI-2 biplot for cane yield showing IPCA-1 and IPCA-2 for genotypes and environments

Table 8: Estimates of different stability parameters for fibre content of sugarcane genotypes

Genotype	Fibre content (%)	PI	bi	S^2Di	α	λ	s^2	W^2	DI	PJ bi	PJ S^2Di
'CoLk 9709'	13.19	0.3	-0.032	-0.083	-1.035	0.409	0.761**	1.867	0.446	-1.032	-0.083
'CoLk 99271'	14.43	-0.94	0.705	-0.165	-0.296	0.079	0.056	0.175	0.942	-0.295	-0.163
'CoLk 04237'	11.10	2.39	1.675	-0.032	0.677	0.603	0.406*	1.014	2. 205	0.675	-0.032
'CoLk 9705'	11.77	1.72	1.375	0.344	0.377	2.123	0.514*	1.274	2.039	0.375	0.344
'CoLk 04238'	14.77	-1.28	1.051	-0.062	0.051	0.489	0.085	0.246	1.442	0.051	-0.062
'CoLk 97147'	13.36	0.13	1.133	-0.139	0.133	0.179	0.031	0.116	1.488	0.133	-0.139
'CoLk 94184'	16.70	-3.21	1.746	-0.121	0.748	0.248	0.398	0.995	2.252	0.746	-0.121
'CoS 96268'	13.53	-0.04	0.817	-0.113	-0.184	0.285	0.063	0.193	1.126	-0.183	-0.113
'CoJ 64'	12.40	1.09	0.031	-0.156	-0.972	0.109	0.618**	1.523	0.243	-0.969	-0.156
'CoS 767'	14.16	-0.67	1.499	-0.065	0.501	0.995	0.351	0.884	2.041	0.499	0.056
GM	13.49										

* and ** at 5 % and 1% level of Significance

Table 9 Ranking sugarcane genotypes grown based on estimates of different stability parameters for fibre content

Genotype	fibre content (%)	PI	bi	S^2Di	α	λ	s^2	W^2	DI	PJ bi	PJ S^2Di
'CoLk 9709'	4	4	10	3	10	5	10	10	9	4	10
'CoLk 99271'	8	8	3	9	8	10	2	2	8	9	4
'CoLk 04237'	**1**	**1**	**7**	**1**	**2**	**3**	**7**	**7**	**2**	**1**	**7**
'CoLk 9705'	2	2	5	10	4	1	8	8	4	10	5
'CoLk 04238'	9	9	1	3	6	4	4	4	6	2	1
'CoLk 97147'	5	5	4	7	5	8	1	1	5	7	2
'CoLk 94184'	10	10	8	6	1	7	6	6	1	6	8
'CoS 96268'	6	6	2	5	7	6	3	3	7	5	3
'CoJ 64'	3	3	9	8	9	9	9	9	10	8	9
'CoS 767'	7	7	6	3	3	2	5	5	3	3	6

useful in identifying genotypes for wider adaptability under multi location testing. Different stability statistics that were used in the present study quantified stability of genotypes with respect to cane yield, sugar yield and fibre% in sugarcane. Thus, both mean performance of yield and stability of performance should be considered simultaneously to predict the useful effect of GxE Interaction and to select suitable genotype more precisely. Genotype 'CoLk 9705', 'CoLk 94184' could be used for commercial exploitation. In AMMI model, the genotypes 'CoLk 99271', 'CoLk 9705' and 'CoLk 94184' with IPCA I scores near zero and high mean cane yield were treated as stable. 'CoLk 9705' for cane yield and CCS yield and 'CoLk 04237' for fibre % were found to be stable by other parametric models.

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Short Communication

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Sugarcane (*Saccharum officinarum* L.) - a new host of skipper, *Telicota* sp. (Lepidoptera: Hesperiidae) in Gujarat region

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Sugarcane crop was reported to be damaged by the attack of skipper larvae at NAU farm, Navsari of Gujarat state. The larvae were found to be infesting the expanding leaves of the young cane shoot, by cutting its margins. The larvae remain hidden under the leaf margin fold. The appearance of the larvae and damage pattern resemble with that of rice skipper, *Pelopidas mathias*, which is the most dominant pest of rice in the region. The larvae were collected and reared in the laboratory, theadult emerged were identified as *Telicota* sp.

Telicota ancilla was recorded as pest of bamboo, *Oryza* spp. and *Saccharum* spp. in India (Kaunte and Gadgil 1956). Blyth 1957 also reported that the *Astychus augius* (L.) feeds on sugarcane and the genera *Astychus* was considered as form of *Telicota ancilla* Mabille. Thus, it seems that the *Telicota* sp. has been recorded for the first time in Gujarat as a pest of sugarcane.

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INDIAN JOURNAL OF SUGARCANE TECHNOLOGY

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