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

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Ensuring remunerative price to sugarcane growers: Institutional innovations and way ahead

A K SHARMA*, R L YADAV, RAJESH KUMAR and A D PATHAK

ICAR-Indian Institute of Sugarcane Research, Lucknow-226 002 (U.P.)

ABSTRACT

Ensuring remunerative price of sugarcane crop to growers in India is one amongst several ways to achieve the objective of doubling sugarcane farmers' income by 2022. The fulfillment of this objective envisages a paradigm shift in agriculture (or sugarcane) policies and programmes. Though number of reforms have already been carried out in Indian sugar sector, the time has come to open the sugar sector to market forces, and to bring about significant changes in sugarcane production and productivity. The inefficiency in sugarcane marketing could be reduced by more institutional reforms, and by strengthening existing marketing arrangements and institutions like cooperatives, contract farming and FPOs in coordinating cane supply from small holders and reducing transaction costs. New market architecture is needed, and for that heavy investment in creating market infrastructure (like processing, utilization of by-products, storage, cold chains, transport and packaging) is required, and the private sector needs to be efficiently engaged. Efficient market institutions (institutions for collective action in production, transport and marketing such as cluster farming and contract farming) also need to be developed to help in getting improved technologies for cost reduction, better prices, and to ensure market stability. Specifically, the paper highlights that innovations in the form of structural improvement in sugar mill operations to utilize idle capacity and process by-products, introduction of technological innovations such as sugarcane harvesters, maturity based sugarcane harvesting, and the use of ICT and digitization of cane production and marketing operations are required for generating technology-led income growth in Indian sugar sector. Strong and facilitating institutions like contract farming in sugarcane also need to be popularized in India to set the stage for large scale adoption of innovations in sugar farming of India, and ensure higher returns to farmers. Contract between the sugar mills and the sugarcane growers for supply of cane and the payment of the cane price be developed with specific focus on provisions for managing the crisis situation too. Institutional arrangements for putting in place a rigorous system to decide the proportion of cane to be used for sugar production be also developed.

Keywords: Cost of cultivation, Prices, Sugarcane marketing, Institutional innovations, Digitization, Contract farming, Collective action, Farm-Factory relations and Sugar mill viability.

Sugarcane cultivation in India is carried out by 6.26 million cane growers in around 5.12 million ha area, and its cultivation provides raw material to around 493 operational sugar mills (out of 732 registered till date) with installed sugar production capacity of around 33.4 million tonnes per year. The highest sugar production which was up to 28.3 million tonnes so far 3 years back, has achieved new high level estimated at around 32 million tonnes of sugar (ISMA 2018). The installed capacity also results in the production of 2186 million litres of ethanol and 4654 MW of surplus power through cogeneration (Sharma *et al.* 2015). Sugarcane production also supports jaggery production (around 5 million tonnes) through around 50 thousands jaggery making units. Besides, there are number of other by-product based industries. The value of output of sugarcane has been estimated at around ₹110 thousand crores at current market rates.

Despite significant contribution to the economy, the sugar sector in India is coupled with controls across the entire value-chain of sugar production and sale, and is characteristically quite fluctuating and unpredictable in sugar production (GoI 2013). Even the current production of sugar is around 12 million tonnes more compared to the previous year (highest jump in any single year), and even 7 million tonnes more compared to the sugar consumption level of 25 million tonnes per year. Under the regulatory provisions, sugar and sugarcane marketing in India has become very cumbersome. The issue of sugarcane pricing has become a major crisis with farmers demanding a higher price for their produce and sugar mills reluctant to give in to their demand. The role of government in balancing the conflicting interests of the farmers, millers and the consumers in terms of considering CACP recommendations while fixing the cane price and by enforcing number of other regulatory provisions has not been found successful in providing the sustainable growth to the sugar sector in India. State level additional regulations in sugarcane price fixing has also led to litigation and developing bitter farm-factory relations,

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

much to the disadvantage of sugarcane farming in general and the sugarcane farmers (cane price arrears) in particular.

Number of improvements in sugarcane marketing and price fixing mechanism were carried out since Independence to make the sugar and sugarcane marketing more efficient. The recent (2017 and 2018) measures comprise doubling of farmers' income by 2022, the acceptance of the recommendations of Dr. Swaminathan Committee Report, and making budgetary (Union Budget 2018) provisions to pay at least 50% higher price compared to the cost of production (GoI 2018). It means that the Government will consider Cost A2+family labour (FL), which covers the cost of production, interest on working capital, and the imputed value of the family labour while deciding the fixation of the new price or the FRP of sugarcane. These price-led income growth measures seem to have a paradigm shift in transforming policies and programmes on all aspects production to income generation of farmers including sugarcane growers. Ensuring remunerative price to the farmers and the development of the associated mechanism to facilitate its efficient execution are a few moves in this direction. Under the present regulatory regime, the sugarcane prices offered to growers, though, are more competitive compared to other crops, but the production, marketing and processing arrangements for sugarcane crop (by virtue of various enactments in sugarcane marketing and price fixation) are costly, very complex and are beset with the problems of accumulation of cane price arrears every 2 or 3 years, leading to substantial income loss to the sugarcane growers. Hence, the price-led income growth alone may not be sustainable in the long run. Institutional innovation and technology led income growth may be more sustainable in sugarcane. The present communication is an attempt to analyze the implications of institutional and technological innovations carried out in recent past. Attempt has also been made to analyze these implications with special focus on Uttar Pradesh, the largest cane growing state in India.

The paper is based on the information from secondary published sources such as Indian sugar, CACP price policy reports, and various acts and regulations enacted for regulation of cane procurement and marketing in the country. Aspects of sugarcane production and marketing innovations mentioned in the paper have been analyzed as separate socio-economic research work or carried out as impact assessment studies by the first author. Farmers' friendly approach mentioned in the paper has been generated keeping in view the missing links of the institutional aspects of sugarcane production and marketing scenario analyzed by the authors.

The main concern in sugarcane cultivation, at present, is the increasing cost of cultivation and the decreasing benefit: cost ratio over time. With increasing costs of inputs and stagnant yields during the last 15-20 years, the margins in sugarcane cultivation have been squeezed in spite of the increase in procurement price (Yadav *et al*. 2008). Despite these developments, sugarcane is still the most profitable crop in the country *vis-à-vis* its competing crops like wheat, paddy and cotton. The net returns per ha as percent of cost C2 are more than 50 percent in sugarcane (CACP 2016) at all India level compared with paddy (12 percent), cotton (15 percent) and wheat (27 percent). However, in terms of net returns per tonne of sugarcane production, the FRP of sugarcane for 2017-18 sugar season at ₹255 per quintal was only 26% higher over Cost C2. This price at 9.5% recovery rate translates for UP, TN and Haryana states at just 9%, 21% and 15% over Cost C2. With budgetary provisions to pay at least 50% higher price compared to the cost of production (GoI 2018), the price of sugarcane will increase significantly resulting in the improvement of farmers' margins. The incentives to sugarcane growers for increasing the area under sugarcane will also be very high. However, the incentives for area switch-over will depend upon the margins for the competing crops like rice and wheat, as the margins for these MSP crops will also increase more proportionally towards these crops compared to sugarcane crop, at least for few initial post-budget adjustment years. The incentives to sugarcane growers will also depend upon the global sugar supply and price scenario and volatility. The scenario of price crash in 2 to 3 years may not be ignored if the adequate regulatory and monitoring measures are not implemented in time. For sustainable development of the Indian sugar sector in the emerging scenario, institutional innovations are required to be carried out to provide overall stability to the sector. These innovations are required to reduce the cost of sugarcane cultivation to ensure higher margins to growers on one hand, as well as to ensure sugar price stability and the viability of the sugar mills on the other. There is also a need for such institutional arrangements which may facilitate the implementation of technological innovations also in a better way and at a faster speed. Following institutional innovations are required to be effected for efficient sugarcane production and marketing in the emerging scenario.

1. At the first instance, structural improvement in sugar mills is of crucial importance in ensuring mill viability (GoI 2004, GoI 2013) as well as in timely disposal and processing of sugarcane. About 74% operational sugar mills are of less than 5000 TCD (tonnes of cane crushed per day) capacity including 22% sugar mills of less than 2500 TCD capacity (GoI 2013). Most of these low capacity sugarmills are in cooperative sector. Low capacity sugar mills are having obsolete machinery and are less efficient. Sugar recovery levels achieved are also less compared to 5000 and higher TCD capacity sugarmills. In order to ensure viability of sugar mills, integrated sugar complexes built on the concept of using all its by-products effectively have been encouraged. Around 111 sugarmills, out of 163 new sugar mills in various stages of development, are sugar complexes integrated with an in-built mechanism for producing cogeneration and

distilleries. In case of UP state, all cooperative and public sector sugar mills below 5000 TCD capacity are being modernized to 5000 TCD level. New sugar mill below 5000 TCD is also not being approved.The sugar recovery levels achieved in higher TCD sugarmills in UP State are around 10.5% or even up to 11.5% under efficient mill management conditions. These levels are just 8 to 9% in low capacity sugar mills. At a sugar mill level, if the sugar recovery increases by 0.1 per cent unit (from 10.5 to 10.6%), an individual sugar mill gains, on an average, by ₹4.0 crores. Hence, efficient mill management has the potential to sugar mill viability and prompt payment of all cane price to the farmers. Innovations in sugarcane processing sphere has increased the demand for sugarcane not only for sugar production but also for ethanol and power generation (Sharma *et al.*2015). Now any sugarcane variety with high fibre percentage and low sugar content could be better utilized for power generation. The demand for ethanol production directly from cane juice is emerging from sugar mills when the sugar prices are low, as existing regulatory arrangements allow ethanol production only via molasses route and not directly from cane juice. The following institutional arrangements now need to be introduced to manage the crisis situations and ensure stability in production and prices. These are:

a) To strengthen sugar mill viability, emphasis must be on efficient management at mill level. Losses and idle capacity during off-season be managed and put to some best alternative uses. Learning from the historic perspective of running the sugar and the neel (dye) industry from the same sugar plant, sugarcane and sugar beet industry (as in Amritsar in Punjab) or sugarcane processing and food processing (of potato and tomato) be encouraged to exploit idle capacity as well as to ensure viability under market glut or price crisis situations. Integrated sugar and food processing complexes for sugarcane, potato and tomato may be established.

b) For sugar sector crisis management, efficient provisions for allowing sugarcane marketing for ethanol production, though on limited scale, are required. Arrangements may be made to allow sugar mills to crush a fixed quantum of cane for ethanol production, may be in early crushing season when the sugar recovery levels are low. Alternatively, institutional arrangements may be made for restricting or dis-incentivizing lower TCD mills having low sugar recovery levels from manufacturing sugar, more so during sugarcane surplus season. These may be allowed to crush cane for juice and its sale to ethanol producing units.

c) Instead of whole cane crushing, the facility for the billet type cane crushing be developed to facilitate the use of sugarcane harvesters.

2. Secondly, the innovations in institutional arrangements for cane procurement and marketing have a great role in overall cane development activities. Due to the nature of the crop, sugarcane has both elements of perishability and bulkiness. Sugarcane being a perishable crop and raw material, it must be crushed at the earliest after harvesting as it rapidly deteriorates with the passage of time converting sucrose into invert sugars which are non-crystallisable. Hence, unlike most of other agriculture commodities, the harvesting of sugarcane is closely associated with its marketing, as the cane harvesting has to be scheduled in such a way as to ensure a dedicated supply of the fresh crop to the mill in order to obtain good sugar recovery levels. Harvesting is an operation that is generally considered as the component of production and hence, included in the cost of production. However, in case of sugarcane, it is closely linked with its marketing. Consequently, in many states, the implementation of this operation has been taken over by the sugar mills or the processors, and has not been left to the mercy of the growers (as in Maharashtra). For these considerations, *inter alia*, the sugarcane grower is obliged to supply sugar cane to a particular mill. The number of farmers supplying cane to a particular sugar mill varies from region to region and also from factory to factory in a country, for example, about 30-50 thousand small cane growers in UP State. Accordingly, a large variety of marketing methods have evolved to coordinate sugarcane supply deliveries to the mills. Two types of systems have been evolved in India depending upon the degree of integration of mills and the growers. These are the use of co-operatives as the contact point in tropical part (as in Maharashtra, Gujarat and parts of Karnataka) or the use of farmers' associations/unions as the contact point in sub-tropical part (as in sub-tropical states like UP, Punjab, Haryana and Bihar). On the other hand, as per Sugarcane Control Order, 1966, State Govt. has to ensure requisite supply of sugarcane to sugar mills. To ensure the requisite quantum of the sugarcane production, sugarcane area is assigned by the State Govt. to each sugar mill. In true sense, it is quantum of the sugarcane production from the assigned area, that is reserved and not the area under sugarcane in itself. Norms of cane area reservation and minimum distance criteria were thus emerged to process the perishable and bulky crop as well as to ensure viability of the sugar mill. In other words, the degree and nature of integration between the millers and numerous sugarcane farmers in India could be seen as a successful

example of contract farming existing in traditional Indian agriculture system, though a loose form of contract farming. The existing sugarcane marketing provisions under these arrangements, wherein raw material is provided at the mill gate or any designated point by the farmers (in small lots of 3 to 10 tonnes at a time) to a particular sugar mill identified by state (without entering into market yard) at pre-specified time and for which the pre-determined price is obtained after 14 days of the supply. The sugar mills in turn arrange for quality seed cane (much to their own advantage for obtaining high sugar recovery), and also in arranging fertilizers and chemicals (especially by cooperative sector sugar mills). These aspects need to be revisited into to address the missing links, and carry out innovations in production as well as on marketing side. In actual practice, most of the sugar mills do not carry requisite development of the allotted area. As per one estimate, most of sugar mills in UP are still spending less than 1% of their gross revenue on cane development activities in sharp contrast to most of the sugar mills in South India who are facing open competition and spending up to 4-5% on cane development activities (Yadav and Sharma 2007). While in South India, cane area is allotted to sugar mills for 2 to 3 years, in UP, it is allotted for one year only. During this year (2017-18), innovation in the form of allocation of cane area for 2 years have been made in UP too. The following institutional innovations may be encouraged to have better farm-factory relations, development of cane command area and prompt payment of cane prices.

a) Long term agreements between farmers and the millers or the contract farming between sugar mills and the farmers instead of yearly assignment by the state government need to be encouraged. Contract farming, if implemented effectively, ensures better prices to the farmers. Contract farming also helps in getting improved technologies and better prices. High influx of sugarcane machinery especially the use of sugarcane harvesters and loaders under Indian conditions and introduction of new crops like sugar beet in cane command areas may be possible under contract farming. A model format for agreement terms or contract farming between sugar mills and the farmers needs to be designed. The Govt. of India has also prepared a model Contract Farming Act to overcome various problems in contract farming and protect the interest of the farmers. Government role in price fixation be reduced over a period of time. Gradual phasing out of norms of cane area reservation (Rangarajan 2012) and minimum distance criteria be carried out for encouraging more competitive sugarcane marketing. Better farm-factory relations be encouraged by developing mutually beneficial terms of contract, with minimum involvement of the government.

b) The existing institutions of cooperative marketing societies of sugarcane growers be strengthened to work on pure business lines to reduce transaction costs and receive timely payments. These institutions need to be better linked and equipped to take decisions for crisis management. These institutions also need to be strengthened to make significant investments in marketing and post-harvest management infrastructure development.

c) Sugar mills responsibility need to be redefined to ensure the requisite development of the cane command area. Adequate resources at every sugar mill level need to be earmarked for cane development activities and in introducing new innovative measures. Provision for financing demand based research requirements of the sugar industry from the contribution of the sugar industry be also made.

d) Complete review of regulatory regime governing sugarcane production and processing to price payment is required to give way to innovative and well defined contract farming mode of sugarcane cultivation.

3. Thirdly, the innovations in the harvesting aspect of sugarcane have a great role to play in efficient sugarcane marketing (Sharma and Prakash 2014), as sugarcane has still remained as most labour intensive and least mechanized crop in India. However, numbers of innovations including development of heavy sugarcane planting and harvesting machinery have occurred by the pioneering efforts by some sugar mills in tropical states of TN, Maharashtra and Karnataka (Singh 2017). Harvesting of sugarcane is very labour intensive operation requiring 70 to 100 labours per ha and at present constitutes about 40-50% of the total operational cost of sugarcane cultivation (Sharma and Prakash 2011). The mechanization of the cane harvesting operation has been initiated by these sugar mills to cope up with the challenge of labour scarcity. Compared to manual harvesting, mechanized harvesting has reduced cost of cultivation and resulted in uniform ratoon growth if wider row spacing is adopted while planting sugarcane (Shanthy and Antony 2017). In tropical states, harvesting is done by sugarmills, and it is carried out on maturity basis to achieve higher sugar recovery levels, a factor considered important for viability of sugar mills. However, where harvesting is done by the growers (as in all other states, particularly sub-tropical ones), it is not on maturity basis but on the basis of purchase slips issued by the sugar mills to thousands of farmers on equity considerations. In these states, under the existing arrangements for

harvesting, sugar mills have no compulsion to carry out harvesting of sugarcane, and thus no incentives to them to invest on cane harvesters. Further maturity based harvesting is not followed in sub-tropical part resulting in less than expected sugar recovery levels. In these states, a single plot of the farmer is harvested in a piecemeal manner resulting in non-uniform stand of ratoon crop or delay in the planting of the next crop. There must be a reduction in harvesting cost of sugarcane to reduce the overall cost of sugarcane cultivation. The use of innovative technological interventions in the form of use of cane harvesters would be beyond the reach of an average sugarcane farmer of around 0.71 ha cane farm size, and very difficult under piecemeal harvesting provisions existing in sub-tropical states. The use of these new but costly innovations and machinery in sugarcane farming would be ensured if sugar mills play an active participatory role in providing/introducing these machines. If suitable institutional arrangements are made for taking over the cane harvesting operations by sugar mills in sub-tropical states or by encouraging contract sugarcane farming, these would help in increasing mechanization of harvesting, and other planting operations as well.These new innovations have the potential to reduce the labour requirement significantly, and perform labour intensive operations easily and in time. These innovations will also help in reducing per ha operational cost, and result in higher profit margins in sugarcane farming. It is also expected that with the gradual growth in contract farming, use of sugarcane harvesters and the maturity based harvesting will get encouraged to achieve higher sugar recovery levels.

4. The fourth major innovation is in terms of digitization of cane marketing operations. An innovative model of cane procurement system, Sugarcane Information System (SIS), based on information technology (IT) network was developed by UP Sugarcane Department in 2010 to overcome the problems associated with the existing cane supply arrangements to sugar mills in the state. A general lack of transparency in issuance of time and number of cane supply tickets to the growers (as in sub-tropical India), weighing of cane, and payment of cane price etc, were the factors leading to unhealthy farm-factory relations in cane marketing. The other problems faced by the farmers were wastage of time and money to get the information for the disposal of the cane to the mill. SIS accomplished the gigantic task of making online around 150 million annual transactions/ interactions between 3.0 million sugarcane farmers, 116 sugar mills and 168 cane cooperative societies engaged in the marketing of sugarcane in UP. On an average, 53 different types of interactions (relating to survey of area estimation under sugarcane, number of supply tickets, weight of sugarcane supplied, payment made etc.) took place between an average farmer and the sugar mill to organize his cane supply and receive price payments (Sharma *et al*. 2012b). At sugar mill level, the total number of interactions with the farmers go to around 13 lacs on an average. The innovation provided instantaneous (within seconds of the transaction), accurate and valuable information about these interactions to the farmers. This innovation impacted significantly on 3 fronts, *viz.*,i) the benefits to sugarcane farmers to the tune of ₹67.62 Million at mill level ii) benefits to sugar mills to the tune of ₹63.77 million, and iii) efficiency enhancement of the Cane Department (Sharma *et al.* 2012a and 2012b). The use of GPS in sugarcane area surveys and estimation resulted in efficient and accurate estimation of sugarcane plant and ratoon area on farmers' fields separately, and eliminating duplicity in reporting as well as the fast redressal of grievances of the growers (Sharma *et al.* 2016). Following measures be ensured to strengthen the digitization of operations in sugar sector.

a) More transparency is also desired on the mill operations. Digitization of complete transactions (of inflows and outflows) of sugar mills and its accessibility to policy planners, research centres or for the general public are desired to have transparency and in assessing in what ways a tonne of a sugarcane crushed in a sugarmill has contributed.

b) Periodic monitoring of the progress of the implementation of digitization moves such as SIS, use of GPS *etc.*by a third party be ensured and corrective measures be carried out.

5. The fifth major institutional innovation could be in the form of a collective action. In addition to cooperatives societies, SHGs and FPOs, other potential areas also exist to act as a decentralized and competitive private sector. Conducive and welfare oriented rather than exploitative private sector may be nurtured. Members of sugarcane cooperative societies or the agricultural graduate wards of sugarcane growers having interest in sugarcane cultivation and related business be encouraged to have MBA degree from IIMs and to run cooperative societies, FPOs or even the sugar mills on pure business lines on their own. These graduates if supported with the financial assistance worth ₹2 Crores per graduate under a pilot project, around 500 graduates under collective action or as FPO will be able to invest ₹1000 Crores for establishing a sugar mill of their own. Such collective action innovations in transport, retail, food processing within the sugar mill, and exports are also needed to be nurtured for a more decentralized form of future sugar sector of India.

6. Last but not the least, the sixth aspect is the development of the farmers' friendly policies. CACP methodology in devising cost estimates also need to be improved upon. The estimates of cost of cultivation used by CACP represents an average scenario of the crop cultivation. It fails to represent the improved and efficient crop cultivation scenario wherein the use of innovations and improved technology has been made. There remains an inbuilt dis-incentive to the users of new technology in the announced price despite the fact that these technologies have the potential to be recommended as innovative methods of cultivation. Cost estimates for more efficient scenario of crop cultivation, especially in major cane growing states like UP need to be generated. Pro-farmer trade policies also need to be implemented for better price realization. In order to clear the market out of the surplus situation, export and import provisions be made and announced in time. Niche markets for Indian sugar be identified to tap global opportunities. Different possibilities of clearing the surplus domestic sugar market be explored and a mechanism comprising potential buyers be put in place for advance sugar purchases in order to reduce the sugar supply in the market.

Concluding remarks and the Way Ahead

Though various interventions and improvements in sugarcane procurement and marketing carried out after Independence are justified as the sugar sector was gradually growing, at present the sugar industry is quite developed and well-set to modernize and diversify its operations to utilize all by-products of sugar mill operations. The sugar production capacity has also increased substantially in the country. Now, the time has come to open the sugar sector to market forces,and to bring about significant changes in sugarcane production and productivity. It is not possible for the government to procure the sugarcane at the announced price, therefore institutional innovations, market and processing infrastructure, and the private sector (sugar mills) will have to play an important role in the emerging scenario. Innovations in institutional arrangements pertaining to sugarcane production and marketing such as structural improvement in sugar mill operations to utilize idle capacity, introduction of technological innovations such as sugarcane harvesters, contract farming, maturity based sugarcane harvesting, and the use of ICT and digitization of cane production and marketing operations if popularized in India will help reduce farmers' cost of cultivation significantly, and ensure them higher returns per unit production. The following suggestions are made to strengthen the government policies for assuring better realization of sugarcane prices to the farmers.

1. Private sector (sugar mill) viability may be ensured by providing flexibility in sugar or ethanol production at the sugar mill level. As in practice in Brazil, the GOI also need to fix a minimum or the maximum limit for sugar production as well as for ethanol production for each sugar mill. A rigorous system needs to be put in place to decide the proportion of cane to be used for sugar production well in advance, and allow the sugar mills to go for ethanol production for the rest of the cane. In order to manage the Indian sugar sector crisis situation when sugar prices are low due to domestic sugar production much above the consumption level (as during the year 2018, domestic sugar production is about 28% higher than the consumption level), the extra production of sugarcane could be routed for ethanol production directly from the cane juice in 3 different ways. This could be done by fixing a quantum of cane to be crushed for ethanol production directly from the cane juice. The second option is to fix a time frame (such as in the beginning of the crushing season when sugar recovery levels are low) to crush sugarcane only for ethanol production. The third option is to demarcate some areas or sugar mills (having low sugar recovery levels) for ethanol production.
2. The existing institutional arrangements and the resultant innovations offer a built-in mechanism to encourage contract farming in sugarcane cultivation. The implementation of the proposed Contract Farming Act could be effected with much ease in sugarcane crop compared to any other crop. This, in turn, will reduce the dependence on the government in sugarcane price fixation, and in encouraging better farm-factory relations. Hence, for ensuring sustainable development of sugarcane farming, innovations like contract farming (instead of existing regulations) are required wherein sugarcane growers and the sugar mills may enter into direct contact with each other as bipartite or as a tripartite agreement if the government role is also desired. Contract between the sugar mills and the sugarcane growers for supply of cane and the payment of the cane price be developed with specific focus on provisions for managing the crisis situation as well.Introduction of contract farming is expected to set the stage for large scale adoption of innovationsin sugar farming of India. A paradigm shift in sugarcane production practices is also expected with the use of these innovations.
3. Collective action innovations in the form of cooperative societies, FPOs or agricultural graduates as entrepreneurs in sugarcane processing, food processing, sugar transport, and exports needto be nurtured for a more vibrant form of future sugar sector of India, and for generating technology-led income growth in Indian sugar sector.

NOTES:

1 Under regulatory framework, Sugar Industry is a schedule-1 industry, and is regulated by GOI under the

Essential Commodity Act (ECA), 1955. Further, agriculture (or sugarcane agriculture) being in the Concurrent List, both the Centre as well as the State Govts. are empowered to legislate on this subject. The Govt. of India had the jurisdiction to fix the sugarcane price under the Sugarcane (Control) Order, 1966 promulgated in terms of powers conferred by ECA (Mishra, 2009). The Central Govt. fixes Fair and Remunerative Price, FRP (earlier Statutory Minimum Price, SMP) of sugarcane in terms of Clause 3 of the Sugarcane (Control) Order, 1966 for each sugar season, based on CACP recommendations and consultations with State Governments, sugar industry & farmers' associations. The state governments then fix state advised prices (SAP) which are influenced by political compulsions and sometimes are much higher than FRP.

2 The improvements in the sugar sector of India came from the recommendations of various committee reports/ working groups constituted for the cause. The major change came from the study and recommendations of Sen Commission (1965), Bhargava Committee Report (Sugar Inquiry Commission Report 1974), Mahajan Committee Report (1998), Tuteja Committee Report (2004), Cabinet Committee on Economic Affairs, CCEA note (2008), Thorat working Group (2009), and Rangarajan Committee Report (2012). In addition there are other committee reports, not specific to sugarcane, but pertaining to overall agriculture in general such as Swaminathan Committee Report (2006) to bring in more efficiency in agriculture sector, and ensure more income to farmers.

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Cane and sugar yields of promising sugarcane varieties as affected by row width and within-row spacing among seedlings

MOHAMED O A GALAL

Sugar Crops Research Institute, Agricultural Research Center, Giza, Egypt

ABSTRACT

The present investigation was carried out in El-Mattana Research Station (latitude of 25.25°N and longitude of 32.31°E), Luxor Governorate, Egypt, during 2015/2016 (plant cane) and 2016/2017 (1st ratoon). The study aimed to find out the appropriate row width and within-row spacing for growing some promising sugarcane varieties using seedlings to get the highest cane and sugar yields. This work included eighteen treatments representing the combination between three sugarcane varieties [two promising ones ('G.2003-47' and 'G.2003-49') and the commercial variety 'G.T.54-9'] under three row spacing (80, 100 and 120 cm) and using seedlings transplanted at two within-row distances (30 and 40 cm). The obtained results showed that the plant crop tillers population was the highest at150 days after transplanting (DAT) while ratoon crop tillers were maximum at 60 days after ratooning (DAR). Planting sugarcane at 80cm inter-row spacing gave the highest values of all studied traits in plant and 1st ratoon crops except for tiller production in the plant cane where planting at 100cm produced the highest values. Moreover, insignificant difference was found between 80 and 100cm inter-row spacing in the sugar yield in 1st ratoon crops. Transplanting sugarcane at 30cm inter-seedlings gave the highest values of all studied traits in the plant and 1st ratoon crops. Commercial variety 'G.T.54-9' surpassed the other two varieties significantly in cane and sugar yields, as well as number of tiller and millable canes in the plant and 1st ratoon crops. While promising variety 'G.2003-47' gave the highest values of number of tiller and millable canes in the 1st ratoon crop. Under the conditions of this work, the second order interaction among the studied factors, growing any of the two varieties; the commercial 'G.T.54-9' or the promising one 'G.2003-47' using seedlings transplanted at 30cm within-rows of 80cm can be recommended to obtain the highest cane and sugar yields/ha in the plant cane and its 1st ratoon crop.

Key words: Sugarcane, Transplanting, Row space, Seedling space.

In Egypt, sugarcane plant crop is harvested at age of twelve months, while ratoon crop matures and harvested earlier. Tillering starts early in ratoons and is more synchronous than that of plant crop due to increasing bearing higher number of buds in stubble as compared to the three bud setts of plant cane crop. Because germination and emergence takes almost 6-8 weeks in plant cane crop, the ratoon crop has the advantage of early establishment. More profuse tillering and quick production of tillers is a characteristic of ratoons (Verma *et al.* 2009).

In sugarcane, tillering is a critical physiological phase. It contributes mainly to cane population at harvest, final cane yield and quality. Stalk population and cane yield are positively correlated, especially in sub-tropical cane growing areas. Stalk population is governed mainly by the variety grown, row spacing and seed rate. Row spacing has a direct influence on plant population. It plays a distinct role in determining the amount of intercepted solar radiation, and hence crop canopy development, which in turn affects photosynthesis and ultimately the dry matter produced by plant. In addition, it may affect stalk population and cane weight that contributes to cane yield. Better tiller survival is produced by planting sugarcane in wider row spacing than narrow one as reported by Rizk *et al.* (2004) and El-Shafai and Ismail (2006). However, El-Lattief (2016) revealed that the narrow row spacing (100 cm) gave the highest number of millable stalks and cane yield per ha. On the other hand, wide row spacing (140 cm) gave the highest values of stalk weight. Ahmed *et al*. (2011) showed that the examined enter-row spacing (80,100 and 120 cm) significantly affected the number of millable canes/ha and cane and sugar yields/ha. The closest enter-row spacing (80 cm) gave the highest values of all studied traits. Moreover, insignificant difference was found between 80 and 100 cm inter-row spacing in the number of millable cane/ha and sugar yield. Okaz *et al*. (2011) indicated that planting sugarcane at 80 cm inter-row spacing recorded the highest values of number of millable canes and cane yield/ha compared to 100 and 120 cm inter-row spacing. Vasantha *et al*. (2014) found that narrow row spacing (75 cm) produced higher tiller population, number of millable canes and cane yield/ha compared to 90 and/or 150 cm inter-row spacing.

Growers who have small land tenure in Middle and Upper Egypt maximize their economic return through growing sugarcane preceded by some winter crops as wheat or faba

E-mail: maweias2007@gmail.com

beans to satisfy their food and social needs. However, it was found that sowing such crops delays planting of spring-planted sugarcane to May or June, which negatively reflected in a substantial reduction in growth characters as well as cane and sugar yields. Applying transplanting technique in planting of sugarcane can solve this problem by establishing a nursery, which can be done by several methods including using single bud cane sets grown in March in a trench or plastic bags to produce healthy tillered seedlings to be transplanted to the permanent field at different spacing after harvesting any winter crop. Lal (1997) reported that maximum numbers of tillers, millable stalks, cane and sugar yields were produced from transplanting into rows at 90 cm inter-row and 30 cm intra-row spacing. Ramanand *et al*. (2007) transplanted cane at spacing of 90*45, 90*60, 90*90 or 120*60 cm. They reported that number of tillers, number of millable canes and cane yield were greatest under a spacing of 90*60 cm. Galal *et al*. (2017) reported that growing sugarcane using seedlings transplanted at 45 cm resulted in the highest values of number of millable canes as well as cane and sugar yields/ha compared with that planted using seedlings transplanted at 35 cm.

Many investigators found differences among the evaluated sugarcane varieties in their productivity and quality parameters (Ahmed *et al.* 2011; Shukla and Singh 2011; Galal *et al*. 2015; Galal *et al.* 2017 and Mehareb and Galal 2017).

This work was aimed to find out the appropriate row width and inter-row spacing for planting sugarcane varieties 'G.2003-47', 'G.2003-49' and 'G.T.54-9' grown with seedlings to get the highest cane and sugar yields.

MATERIALS AND METHODS

The present work was carried out in El-Mattana Research Station (latitude of 25.25° N and longitude of 32.31° E), Agricultural Research Center, Luxor Governorate, Egypt on a plant cane in 2015/2016 and its 1st ratoon in 2016/2017 to study the effect of row spacing (80, 100 and 120 cm) and two transplanting distances between cane seedlings within rows (30 and 40 cm) as well as their combinations on yield and its components of three sugarcane varieties 'G.2003-47', 'G.2003-49' and the commercial variety 'G.T.54-9'. Seedlings were produced by planting single-bud cane setts in a nursery in mid March and were transplanted in the field in mid-May and harvested on the 1st of April, in the 1st season and kept as a 1st ratoon, in the 2nd season. Experiment was laid out in split-split plot design under three replications. Row spacings were arranged in the main plots, while seedling distances were randomly distributed in the sub-plots. Sugarcane varieties were distributed in the sub-sub plots. The sub-sub-plot area was 60 m^2 (including 15, 12 and 10 rows in case of spacing 80, 100 and 120 cm spacings, respectively and 5 m in length).

Nitrogen fertilizer was applied as urea (46% N) which was split into three doses in the plant cane (at the nursery when the seedlings aged a month, after the 1st and 2nd hoeing, *i.e.* 45 and 75 days from planting).

The recorded data

1. Tiller production:

It was found that tiller population reached its maximum (T_{max}) at 150 days after transplanting of the plant cane and 60 days after harvesting it (in the 1st ratoon). Tiller population was counted per plot then converted into 1000/ha.

2. Number of millable canes/plot was counted and converted into thousand/ha at harvest.

3. Cane yield/ha (ton) was determined from the weight (kg) of millable canes of each plot, which was converted into tons/ha.

4. Sugar yield/ha (ton) was estimated as follows:

Sugar yield (ton) = cane yield (ton) x sugar recovery %.

Where:

- Sugar recovery percentage was calculated as follows:

Sugar recovery % = richness % x purity %,

Where: richness = (sucrose in 100 x factor)/100. Factor = 100 - [fiber% + physical impurities% + percent water free from sugar].

- Sucrose/100 cm^3 juice was determined using Saccharimeter according to A.O.A.C. (1995).

- Juice purity % was determined as follows:

Juice purity % = sucrose / brix % x 100

- Brix percentage (total soluble solids, TSS %) in juice was determined using Brix Hydrometer, standardized at 20^o C.

Statistical analysis:

The collected data were statistically analyzed according to the procedures outlined by Snedecor and Cochran (1981). Means of significant variance were compared using LSD test at 5% level of probability.

RESULTS AND DISCUSSION

Tiller production

Tiller population was recorded at different dates in the plant cane and 1st ratoon crops. In the plant crop, tiller population was the highest at 150 days after transplanting (DAT), while in ratoon crop it reached its maximum at 60 days after ratooning (DAR). The peak of tiller production in ratoon crop showed earliness by about 60 days as compared to plant crop. Canopy development in ratoon crop is more rapid than that of the plant cane crop (Thompson 1988) because more buds are available to produce primary shoots and the buds are closer to the surface than that of plant crop.

Data in Table 1 show that row width significantly affected tiller population in plant and its 1st ratoon cane crops. Transplanting sugarcane in rows of 100 cm apart resulted in 11.38 and 55.53 thousand stalks/ha higher than that found in rows of 80 and/or 120 cm width, successively, in the plant cane. However, decreasing row width to 80 cm led to 46.72 and 111.48 thousand tillers higher, compared to that counted in rows of 100 and/or 120 cm, respectively, in the 1st ratoon cane crop. These results could be referred to higher number of number of seedlings/ha transplanted in case of 80 and/or 100 cm, than those grown in rows of 120 cm. Similar results were obtained by Vasantha *et al*. (2014).

Growing sugarcane using seedlings transplanted at 30 cm produced 9.83 and 7.99 thousand tillers/ha higher than that grown at 40 cm, in the plant and 1st ratoon cane crops, respectively. The superiority of the narrower inter-row spacing in this growth trait was probably due to higher number of seedlings/ha. These results were in accordance with those reported by Lal (1997).

The tested sugarcane varieties varied significantly in tiller population number. The results in Table 1 cleared that 'G.2003-47' sugarcane variety gave the highest tiller population in the plant cane, producing 21.29 and 5.36 thousand canes/ha higher than that given by the commercial variety ('G.T.54-9') and the promising one ('G.2003-49'), respectively. However, the commercial variety recorded the highest number of tillers, where it attained 8.14 and 11.60 thousand stalks/ha over that of 'G.2003-47' and 'G.2003-49', in 1st ratoon cane crop. It was found that the difference in this trait between 'G.2003-47' and 'G.2003-49' was insignificant, in plant and its1st ratoon cane. Varietal differences in number of tillers were reported by Shukla and Singh (2011). Sugarcane genotypes followed polynomial trend in tiller emergence.

Tiller population was significantly affected by the interactions between the studied factors in the plant and 1st ratoon cane crops (Table1). Regarding the interaction between row width and transplanting spacing, it was found that the difference in the number of tillers/ha was insignificant, when seedlings were grown at 30 and 40-cm spacing in rows of 80-cm width, with a significant variance between seedling spacing in rows of 100 and/or 120 cm, in the plant cane.

As for the interaction between row spacing and sugarcane varieties, the results showed insignificant variance between 'G.2003-47' and 'G.2003-49' in tiller number in sugarcane grown in rows spaced at 100 cm, in the plant cane as well as at 80 and 100 cm, in the 1st ratoon crop. However, the difference between the two varieties was significant under conditions of 120 cm spacing in both crops.

Concerning the interaction between seedling spacing and sugarcane varieties, there was insignificant variance between 30 and 40 cm seedling spacing within rows in their influence on tiller population of 'G.T.54-9'. However, the variance between the two seedling spacings reached the level of significance with higher number of tillers of 'G.2003-47' and 'G.2003-49' varieties planted with seedlings spaced at 30 cm, in the 1st ratoon cane crop.

In respect to the 2nd order interaction of the studied factors, insignificant difference was detected in tiller number in the plant cane, when 'G.T.54-9' variety was planted with seedlings spaced at 40 cm in rows of 80 and/or 100 cm, with a significant variance with that grown at 40 cm in rows of 120 cm. The

Table 1 Tiller production (thousand canes/ha) of the tested sugarcane varieties as affected by row width, seedling within-row spacing and their interactions, in the plant cane and its 1st ratoon crop

Seasons		Plant cane (2015-2016)				First ratoon (2016-2017)			
		Sugarcane variety				Sugarcane variety			
Row Width	Seedling within-row spacing	'G.T.54-9'	'G2003-47'	'G.2003-49'	Mean	'G.T.54-9'	'G.2003-47'	'G.2003-49'	Mean
80 cm	30	173.00	222.30	189.24	194.85	470.04	457.79	472.14	466.66
	40	172.14	214.82	183.28	190.08	479.81	456.25	453.06	463.04
	Mean	172.57	218.56	186.26	192.46	474.92	457.02	462.60	464.85
100 cm	30	204.05	211.20	209.60	208.28	422.80	425.82	416.76	421.79
	40	168.00	218.88	211.36	199.41	430.08	407.84	405.46	414.46
	Mean	186.02	215.04	210.48	203.85	426.44	416.83	411.11	418.12
120 cm	30	148.67	151.33	168.72	156.24	364.00	360.53	355.11	359.88
	40	148.96	124.00	148.20	140.39	345.44	355.09	340.03	346.85
	Mean	148.81	137.67	158.46	148.31	354.72	357.81	347.57	353.37
Overall Mean	30	175.24	194.94	189.19	186.46	418.94	414.71	414.67	416.11
	40	163.03	185.90	180.95	176.63	418.44	406.39	399.52	408.12
	Mean	169.14	190.42	185.07	181.54	418.69	410.55	407.09	412.11
LSD at 0.05 level for:									
Row width (A)					8.85				5.98
Seedling within-row spacing (B)					3.48				2.77
Cane varieties (C)					6.75				3.45
A x B					6.02				4.80
A x C					11.69				5.97
B x C					NS				4.88
A x B x C					16.53				8.44

highest number of tillers was obtained by transplanting seedlings of 'G.2003-47' variety at 30 cm in rows of 80-cm width in the plant cane, while the highest tiller population was produced by G.T.54-9 previously transplanted at 40 cm in rows of the same width.

Number of millable canes

Data in Table 2 show that row width significantly affected number of millable canes in the plant and 1st ratoon cane crops. Transplanting sugarcane in rows of 80 cm apart increased the number of millable canes/ha by 16.09 and 41.20 thousands over that gained in case of growing sugarcane in rows of 100 and/or 120 cm width, respectively, in the plant cane, corresponding to 35.27 and 50.09 thousand millable canes/ha in 1st ratoon cane. More number of millable canes at narrow row spacing can be referred to more number of tillers per unit area and the maintenance of a large number of them until harvesting. Similar results were obtained by Okaz *et al.* (2011) and El-Lattief (2016).

The results revealed that transplanting of sugarcane at 30 cm within row produced 2.68 and 12.43 thousand millable canes/ha higher than that grown with seedlings transplanted at 40 cm in plant and 1st ratoon cane crops, respectively. These results may be attributed to higher number of seedlings and consequently higher tillers/ha. These results are in agreement with those reported by Lal (1997) and Ramanand *et al.* (2007).

The tested sugarcane varieties differed markedly in the number of millable canes. The results in Table 2 manifested that 'G.2003-47' sugarcane variety gave the highest number of millable canes/ha in the plant cane, without appreciable variance with that produced by 'G.2003-49' in this trait. Moreover, it can be noticed that the difference in millable cane number/ha between 'G.2003-47' and the commercial variety ('G.T.54-9') was insignificant, in the plant cane crop. In the 1st ratoon, the commercial variety succeeded to overcome the other two sugarcane varieties, recording 15.66 and 17.14 thousand millable canes/ha over that of 'G.2003-47' and 'G.2003-49'. Meanwhile, insignificant difference in this trait between 'G.2003-47' and 'G.2003-49' was detected. Varietal differences in number of millable canes were reported by Ahmed *et al.* (2011) and Galal *et al.* (2017).

Number of millable canes was significantly affected by the interactions between row width and transplanting within-row spacing in the plant cane crop, where it was found that the difference in the number of millable canes/ha was insignificant, when seedlings were transplanted at 30 and 40-cm spacing in rows of 80-cm width, with significant variance between seedling spacing in rows of 100 and/or 120 cm.

The interaction between row spacing and sugarcane varieties affected the number of millable canes/ha in the plant cane. The results showed insignificant variance between 'G.2003-47' and 'G.2003-49' in number of millable canes when they were planted in rows spaced at 100 and/or 120 cm.

Table 2 Number of millable canes (thousand canes/ha) of the tested sugarcane varieties as affected by row width, seedling within-row spacing and their interactions, in the plant cane and its 1st ratoon crop

Seasons		Plant cane (2015-2016)				First ratoon (2016-2017)			
Row	Seedling	Sugarcane variety				Sugarcane variety			
Width	within-row spacing	'G.T.54-9'	'G2003-47'	'G.2003-49'	Mean	'G.T.54-9'	'G.2003-47'	'G.2003-49'	Mean
80 cm	30	146.27	151.96	147.9	148.71	201.66	207.77	213.01	207.48
	40	141.17	157.08	146.00	148.08	227.70	178.20	162.00	189.30
	Mean	143.72	154.52	146.95	148.40	214.68	192.99	187.51	198.39
100 cm	30	121.60	136.73	131.20	129.84	179.33	172.80	154.18	168.77
	40	135.52	137.60	131.20	134.77	159.12	146.88	166.40	157.47
	Mean	128.56	137.16	131.20	132.31	169.22	159.84	160.29	163.12
120 cm	30	118.80	107.87	113.47	113.38	177.60	142.80	136.20	152.20
	40	102.00	100.00	101.07	101.02	139.80	142.80	150.60	144.40
	Mean	110.40	103.93	107.27	107.20	158.70	142.80	143.40	148.30
Overall Mean	30	128.89	132.18	130.86	130.64	186.20	174.46	167.80	176.15
	40	126.23	131.56	126.09	127.96	175.54	155.96	159.67	163.72
	Mean	127.56	131.87	128.47	129.30	180.87	165.21	163.73	169.94
LSD at 0.05 level for:									
Row width (A)					0.89				6.08
Seedling within-row spacing (B)					2.24				6.22
Cane varieties (C)					3.61				6.00
A x B					3.88				NS
A x C					6.26				NS
B x C					NS				NS
A x B x C					NS				14.69

However, the difference between the two varieties reached the level of significance under conditions of 80 cm spacing.

In respect to the significant 2nd order interaction of the studied factors on this trait in the 1st ratoon crop, insignificant difference was recorded between 'G.2003-47' and 'G.2003-49' in case of growing them using seedlings spaced at 30 cm in rows of 80 and 120 cm width, with a significant variance between these two varieties at the same transplanting spacing, in rows of 100 cm. The highest number of millable canes/ha was produced by 'G.T.54-9' transplanted at 40 cm within-row spacing in rows of 80 cm apart, in the 1st ratoon cane crop.

Cane yield

Data in Table 3 show that cane yield ton/ha was significantly affected by row width in the plant and its 1st ratoon cane crops. Growing sugarcane in rows of 80 cm produced 2.35 and 10.03 ton of canes/ha higher than that of 100 and/or 120 cm width, respectively, in the plant cane, corresponding to 10.82 and 19.04 ton of canes/ha in the 1st ratoon cane crop. A linear increase in cane yield with narrow row spacing has also been reported by Rizk *et al.* (2004) and Ahmed *et al.* (2011).

Growing sugarcane using seedlings transplanted at 30 cm produced 5.00 and 10.90 tons of canes/ha higher than that transplanted at 40 cm in the plant and 1st ratoon cane crop, successively. The superiority of the narrower within-row spacing in cane yield was probably due to higher number of millable canes/ha. Similar results were obtained Lal (1997) and Ramanand *et al.* (2007).

The results in Table 3 indicate that the evaluated sugarcane varieties varied significantly in cane yield/ha. Planting the commercial variety ('G.T.54-9') produced 8.84 and 10.81 tons/ha as well as an increase of 13.42 and 23.35 tons/ha, over that gained from 'G.2003-47' and'G.2003-49', in the plant cane and 1st ratoon, respectively. The difference among the tested sugarcane varieties is probably attributed to their genetic structure. However, the difference between the two promising varieties namely 'G.2003-47' and 'G.2003-49' in cane yield was insignificant, in plant cane. Differences among cane varieties in cane yield were reported by Galal *et al*. (2015) and Mehareb and Galal (2017).

The interaction between row width and transplanting spacing had a significant influence on cane yield in plant and 1st ratoon cane crops (Table 3). The difference in cane yields/ha obtained from canes grown with transplants spaced at 30 and 40 cm in rows of 100-cm width was insignificant, while the variance between the two transplanting spacing in their effect on cane yield was significant in case of growing canes in rows of 80 and 120 cm, in the plant cane. In the 1st ratoon cane crop, the difference in cane yields/ha between 30 and 40 cm transplanting spacing in rows of 80 and 100-cm was insignificant, with a significant difference between the two transplanting spacing in cane yield in case of growing canes in rows of 120 cm.

As for the interaction between row spacing and sugarcane varieties, the results showed insignificant variance between

Table 3 Cane yield (t/ha) of the tested sugarcane varieties as affected by row width, seedling within-row spacing and their interactions, in the plant cane and its 1st ratoon crop

Seasons		Plant cane (2015-2016)				First ratoon (2016-2017)			
Row	Seedling	Sugarcane variety				Sugarcane variety			
Width	within-row spacing	'G.T.54-9'	'G2003-47'	'G.2003-49'	Mean	'G.T.54-9'	'G.2003-47'	'G.2003-49'	Mean
80 cm	30	130.30	125.06	117.85	124.40	165.19	156.70	126.78	149.56
	40	119.28	112.83	111.29	114.47	160.40	147.62	132.00	146.67
	Mean	124.79	118.94	114.57	119.43	162.80	152.16	129.39	148.12
100 cm	30	127.13	113.66	111.02	117.27	158.22	134.53	125.81	139.52
	40	123.51	112.75	114.45	116.90	141.83	126.46	136.92	135.07
	Mean	125.32	113.21	112.73	117.09	150.03	130.50	131.37	137.30
120 cm	30	116.07	110.43	108.78	111.76	156.18	136.55	132.57	141.77
	40	114.86	103.37	102.92	107.05	120.69	120.15	108.33	116.39
	Mean	115.47	106.90	105.85	109.41	138.44	128.35	120.45	129.08
Overall Mean	30	124.50	116.38	112.55	117.81	159.87	142.60	128.39	143.62
	40	119.22	109.65	109.55	112.81	140.98	131.41	125.75	132.71
	Mean	121.86	113.02	111.05	115.31	150.42	137.00	127.07	138.16
LSD at 0.05 level for:									
Row width (A)					1.19				4.97
Seedling within-row spacing (B)					1.14				4.63
Cane varieties (C)					2.40				3.83
A x B					1.98				8.02
A x C					NS				6.64
B x C					NS				5.42
A x B x C					NS				9.39

'G.2003-47' and 'G.2003-49' in cane yield in case of growing sugarcane in rows spaced at 100 cm, in the 1st ratoon cane crop. However, the difference between the two varieties was significant under conditions of 80 and 120 cm spacing.

Concerning the interaction between seedling spacing and sugarcane varieties, there was insignificant variance between 30 and 40 cm seedling spacing within rows in their influence on cane yield of 'G.2003-49'. However, the variance between the two seedling spacings reached the level of significance with higher cane yield of 'G.T.54-9' variety planted with seedlings spaced at 30 cm in, 1st ratoon cane crop.

In respect to the 2nd order interaction of the studied factors in the 1st ratoon cane crop, insignificant difference in cane yield/ha between 'G.T.54-9' and 'G. 2003-47' was detected when they were transplanted at 30 cm within rows of 80-cm width and 40 cm within rows of 120-cm width, with significant variance between the two varieties at the same spacing of transplanting in narrower rows of 80 and/or 100 cm.

Sugar yield

Data in Table 4 indicate that sugar yield/ha was substantially affected by row width in the plant and 1st ratoon cane crops. Widening row spacing in which sugarcane is grown from 80 to 100 and 120 cm was accompanied with a reduction in sugar yield/ha amounted to 0.40 and 0.95 ton, in the plant cane, corresponding to 0.68 and 1.53 ton, in the 1st ratoon cane crop, successively. The difference between 80 and 100 cm in their influence on sugar yield/ha was insignificant, in 1st ratoon cane crop. The superiority of decreasing row width to 80 cm over the other two wider ones could be due to higher cane yield (Table 3), which is the essential component in sugar yield. These results were in agreement with those reported by Ahmed *et al*. (2011).

Growing sugarcane using seedlings transplanted at 30 cm resulted in a significant increase of 0.82 and 0.62 ton of sugar/ ha higher than that grown at 40 cm in the plant and 1st ratoon cane crop, successively. The superiority of the narrower within-row spacing in sugar yield was probably due to higher cane yield/ha (Table 3). The results are quite in line with those found by Lal (1997).

The results in Table 4 show that the commercial sugarcane variety ('G.T.54-9') significantly surpassed the other two varieties in sugar yield, producing 0.67 and 0.91 ton of sugar higher than that obtained from 'G.2003-47' and'G.2003-49', respectively, in the plant cane, corresponding to 0.59 and 2.08 tons sugar/ha, in the 1st ratoon. These results could be attributed to higher cane yield recorded by 'G.T.54-9' variety (Table 3). Meantime, there was insignificant difference in sugar yield obtained from 'G.2003-47' and 'G.2003-49' grown as a plant cane crop. Such varietal differences were reported by Shukla and Singh (2011) and Galal *et al.* (2017).

Sugar yield was significantly influenced by the interactions between row width and transplanting within-row spacing in plant and 1st ratoon cane crops (Table 4). In the plant cane, it

Table 4 Sugar yield (t/ha) of the tested sugarcane varieties as affected by row width, seedling within-row spacing and their interactions, in the plant cane and its 1st ratoon crop

Seasons		Plant cane (2015-2016)				First ratoon (2016-2017)			
Row	Seedling	Sugarcane variety				Sugarcane variety			
Width	within-row spacing	'G.T.54-9'	'G2003-47'	'G.2003-49'	Mean	'G.T.54-9'	'G.2003-47'	'G.2003-49'	Mean
80 cm	30	13.50	13.50	12.58	13.19	17.43	17.93	13.60	16.32
	40	12.57	11.19	12.02	11.93	17.27	16.92	14.67	16.29
	Mean	13.04	12.34	12.30	12.56	17.35	17.43	14.14	16.30
100 cm	30	12.96	12.40	11.43	12.27	17.60	14.63	15.18	15.80
	40	12.41	11.77	11.98	12.05	15.35	15.30	15.65	15.44
	Mean	12.69	12.08	11.71	12.16	16.47	14.97	15.42	15.62
120 cm	30	12.60	12.21	11.49	12.10	16.79	15.29	14.44	15.51
	40	11.76	10.75	10.81	11.11	14.32	15.12	12.70	14.05
	Mean	12.18	11.48	11.15	11.60	15.56	15.21	13.57	14.78
Overall Mean	30	13.02	12.70	11.83	12.52	17.27	15.95	14.41	15.88
	40	12.25	11.24	11.61	11.70	15.65	15.78	14.34	15.26
	Mean	12.63	11.97	11.72	12.11	16.46	15.87	14.38	15.57
LSD at 0.05 level for:									
Row width (A)					0.14				0.81
Seedling within-row spacing (B)					0.11				0.56
Cane varieties (C)					0.29				0.57
A x B					0.18				NS
A x C					NS				0.98
B x C					0.42				0.80
A x B x C					NS				1.39

was found that the difference in sugar yield/ha between 30 and 40 cm transplanting spacing was more distinguished (1.26 and 1.00 ton/ha, in rows of 80 cm and 120 cm, respectively) compared with that grown in rows of 100 cm width (0.21 ton). In the 1st ratoon, the interactions between row width and transplanting within-row spacing were insignificant.

The interaction between row spacing and sugarcane varieties had a significant effect on sugar yield/ha in the 1st ratoon. The results showed insignificant variance between the commercial variety 'G.T.54-9' and promising variety 'G.2003-47' in sugar yield in sugarcane grown in rows spaced at 80 and 120 cm. However, the difference between the two varieties was significant under conditions of 100 cm spacing.

Sugar yield/ha was significantly affected by the interaction between seedling spacing and sugarcane varieties in both seasons. The difference between 'G.T.54-9' and 'G.2003-47' in sugar yield/ha was insignificant when they were planted with seedlings spaced at 30 cm in the plant cane and 40 cm in1st ratoon, with a significant variance between these two cane varieties at the other transplanting spacing.

In respect to the 2nd order interaction of the studied factors in the 1st ratoon cane crop, insignificant difference in sugar yield/ha between 'G.T.54-9' and 'G.2003-47' was detected when they were transplanted at 30 and/or 40 cm within rows of 80-cm width, with significant variance between the two varieties at the same spacing of transplanting in rows of 100 cm.

CONCLUSION

Under the conditions of this work, the second order interaction among the studied factors, growing any of the two varieties; the commercial 'G.T.54-9' or the promising one 'G.2003-47' using seedlings transplanted at 30 cm within-rows of 80 cm can be recommended to obtain the highest cane and sugar yield/ha in the plant cane and its 1st ratoon crop.

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Biometric markers for nitrogen use efficiency (NUE) *vis-à-vis* productivity and quality of early maturing sugarcane genotypes grown with and without organics, under Indian sub-tropics

A K SINGH*, A D PATHAK, R L YADAV, ARCHANA SUMAN and EKTA SINGH

ICAR-Indian Institute of Sugarcane Research, Lucknow-226 002 (U.P.)

ABSTRACT

Field experiments were conducted for three consecutive years (two plant-ratoon cycles) during 2008-09 to 2010-11, starting from February, 2008 at the Research Farm of Indian Institute of Sugarcane Research, Lucknow. The soil of experimental site is categorized in order *inceptisol* under the group *Udic Ustochrepts,* neutral in reaction (pH 7.4), low in organic carbon (0.34%) and available N (158.5 kg/ha), medium in available P (16.6 kg/ha) and K (265.9 kg/ha). The treatments consisted of eight early maturing genotypes *viz.,* 'CoS 95270', 'CoS 96258', 'CoH 92201', 'BO 130', 'CoS 96268', 'CoPant 98224', 'BO 128' and 'CoLk 94184' in main plots and four nitrogen levels *viz.,* control, 150 kg Nha^{-1}, Farm Yard Manure (FYM) @ 10t ha^{-1} and 150 kg N ha^{-1} +FYM 10t ha^{-1} under subplots in split plat design replicated thrice. The genotypes were planted in furrows at 75 cm row spacing during spring season in the month of February. The highest nitrogen use efficiency (NUE) was observed with 'CoLk 94184' (206.6 kg cane/kg N applied) at 150 kg N ha^{-1}. Its NUE was further enhanced by application of organics (260.9 kg cane/kg N applied). The genotype 'CoLk 94184' grown with 150 kg N + 10 t farm yard manure (FYM) ha^{-1} yielded 82.3 t/ha followed by 'CoS 95270'. However, overall productivity of 'BO 128' was found better as compared to 'CoS 95270'.The biometric markers identified for higher NUE showed positive responses and measured strong relations. The quality parameters were improved by application of organic manure. The NUE is directly correlated with the number of tillers produced and thus with number of millable canes. Root volume of the genotypes also showed the strong correlation (R^2=0.816) with nitrogen use efficiency. The high tillering genotypes with high root volume and broader feeding zone can be tagged for higher nitrogen use efficiency.

Key words: Apparent N recovery, Biometric markers, Early maturing genotypes, Millable canes, NUE, N-uptake, Sub-tropics.

Sugarcane occupies an important position in agrarian economy of India. About 7 million farmers, their dependents and large number of agricultural laboures are involved in the cane cultivation. Being an important agro- industrial crop sugarcane involves more than 50 million skilled and unskilled workers for various activities. Competing sinks of vegetative growth, fibre and stored sucrose in sugarcane undergo complex physiological regulations that largely depends on crop nutrition. Sugarcane is a high biomass-producing crop that requires substantial quantities of nitrogen from soil (Singh and Yadav 1992; Peter *et al.* 2005). The primary function of nitrogen in sugarcane is to increase the photosynthetic apparatus like tiller formation, leaf development and leaf expansion. It increases the leaf surface area and functional duration of leaves. The yield potential of different genotypes varies with their inbuilt characters. Consequently the uptake of nitrogen by different genotypes also varies.

Sugarcane being a long duration and huge biomass accumulating crop removes substantial amount of plant nutrients from the soil. As reported from IISR, Lucknow, a crop of 100 t/ha exhausts 208 kg N, 53 kg P and 280 kg K besides 3.4 kg Fe, 1.2 kg Mn, 0.6 kg Zn, 0.2 kg Cu and 30 kg S (Lal and Singh 2002). On the other hand, Indian soils are universally deficient in N except in some parts of north eastern region. Nearly 50 per cent soils are deficient in P and 20% in K. Sulphur has become critical in low organic matter coarse textured soils under S exhausting oilseed based cropping systems. Simultaneously, low fertilizer N recovery has been reported from many sugarcane areas of the world (Hartemink 2008). More so, modern agriculture is concerned with yield, nutritional quality and the environmental impact of crop production. Efficient use of fertilizers N is, therefore, critical (Uribelarrea *et al.* 2006). All these point out to greater opportunity for using more balanced fertilizers for enhancing cane yield, improving produce quality and maintaining system sustainability.

The 'Soil-Cane-Sugar' system operates in an interlinked manner under two biological sub-systems *viz.*, 'Soil-Cane' and 'Cane-Sugar' which determine the efficacy of 'Produce to Product Chain'. Therefore, the production of sugar in terms of 'sugar bags' in factories depends upon the quantity and quality of sugarcane produced in the fields. The statement 'sugar is manufactured in the field and not in the factory' or 'sugar is synthesized in the field and recovered in the factory' clearly

*Corresponding author's E-mail: shantaanil@yahoo.com

brings out this fact. More so, the fertilizers account for lion's share among the external production inputs.

Productivity and quality of different sugarcane varieties are largely dependent upon the quantity and quality of millable canes. Studies have recorded a direct contribution of 40% of the number of millable canes to the agronomic yield of sugarcane crop followed by the weight (30%), length (27%) and girth (3%) (Yadav and Shrama 1978). Contribution of these yield attributing characters are mainly the function of nutrients. Varying N use efficiency coupled with the various biometrical characters of different genotypes necessitated to identify some markers which are responsible for high nitrogen recovery, so, that the fertilizer N can be efficiently utilized. Considering these points in view the present investigation was undertaken to find out suitable biometric markers responsible for high nitrogen use efficiency of different early maturing sugarcane genotypes.

MATERIALS AND METHODS

Experimental site

Field experiments were conducted for three consecutive years (two plant-ratoon cycles) during 2008-09 to 2010-11, starting from February, 2008 at the Research Farm of ICAR-Indian Institute of Sugarcane Research, Lucknow located at 26^o50^I N latitude, 80^o52^I E longitude and 111 m above mean sea level in central part of Uttar Pradesh falling in subtropical belt of sugarcane cultivation. The soil of experimental site is categorized in order *inceptisol* under the group Udic *Ustochrepts,* neutral in reaction (pH 7.4), low in organic carbon (0.34%) and available N (158.5 kg/ha), medium in available P (16.6 kg/ha) and K (265.9 kg/ha). Texture of experimental field was sandy loam (15.2 % clay, 21.4 % silt and 63.4 % sand) of Gangetic alluvial origin. The depth of the soil is about 2.6 metres, well drained and well levelled (slope is about 1 %). The climate of the location (Lucknow) is semi-arid subtropical with dry hot summers (April to June) and cold winters (November to January). The average annual rainfall is 987 mm and nearly 85% of the total rainfall is received through south-west monsoon during second fortnight of June to mid-September. The average monthly minimum and maximum temperatures fluctuate from 6.8 to 7.9 and 20.4 to 22.8^{o}C in winter and from 22.3 to 25.5 and 39.8 to 41.7^{0}C in summer, respectively.

Treatments and their execution

The experimental treatments consisted of eight early maturing genotypes *viz.,* 'CoS 95270', 'CoS 96258', 'CoH 92201', 'BO 130', 'CoS 96268', 'CoPant 98224', 'BO 128' and 'CoLk 94184' in main plots and four nitrogen levels *viz.,* control, 150 kg Nha^{-1}, Farm Yard Manure (FYM) @ 10t ha^{-1} and 150 kg N ha^{-1} + FYM 10t ha^{-1} in sub-plots in split plot design replicated thrice. The field was prepared by tilling with cultivator and harrows twice each after pre-planting irrigation followed by running of the wooden plank to conserve soil moisture. The genotypes were planted in 10 cm deep furrows at 75 cm row spacing opened by tractor drawn furrow opener during spring season in the month of February.

About 47000 three bud cane setts ha^{-1} (7.0 t ha^{-1}) were placed horizontally end to end in these furrows. The fertilizer was placed in the furrows below the setts. Nitrogen was applied as per the treatments through urea (46.6% N). The recommended doses of P and K were 60 kg P_2O_5 and K_2O ha^{-1} each. The sources of P and K were Diammonium Phosphate-DAP (18% N and 46% P_2O_5) and Muriate of Potash (60% K_2O). Full amount of P and K fertilizers and 1/3rd N were applied as basal. Remaining amount of the nitrogen was applied in two equal splits at initial (60days after planting) and final (120 days after planting) stages of tillering in sugarcane.

The crop was grown under assured irrigation supply. Six pre-monsoon irrigations were given in addition to pre-planting irrigation. One post-monsoon irrigation in the month of September in first year and two irrigations during September and October in the second year were given. The harvesting of crop was done manually during third week of January in both the years with the help of spade followed by detrashing and detopping using sickle.

Soil and plant sampling and Analysis

Initial soil samples were collected before commencement of the experiment in February 2008 for 1st crop cycle and 2009 for 2nd crop cycle. Soil samples were collected from 0-20 and 20-40 cm profile depth from four places in the experimental field using a core sampler of 8 cm diameter for determining soil physical properties (Singh 2001). For chemical properties, samples from 0-20 cm profile depth were taken and analysed for organic carbon (Walkley and Black 'S rapid titration method), available N (alkaline $KMNO_4$ method), available P (0.5 M $NaHCO_3$, pH 8.5 extractable) as described by Olsen and Sommers (1982) and extractable K using NH_4OAC (1:6 soil: solution) following Page *et al.* (1982).

Three healthy clumps (stools) per treatment were selected for root studies. Each stool was dugout carefully making all efforts to minimize loss of roots. The entire stool was then suspended in a water tank to wash-off the clinging soil. The horizontal and vertical spread of roots was measured from the base. Thereafter, the root mass was separated from the stalk and the fresh weight of the roots was recorded. The measurement of root spread (vertical/horizontal) led to derivation of a cone shaped 'feeding zone' and was calculated by the volume of a cone represented as

$$\text{Feeding zone} = 1/3\pi h^2V \qquad \text{(i)}$$

(Where h = one way (1/2 of the diameter) horizontal spread from the core/stalk base to the tip of longest lateral root and V is the vertical spread)

'Root intensity' which encompasses vertical and horizontal spread of the roots and the roots mass was calculated on fresh weight basis as:

$$\text{Root intensity} = \frac{\text{Root mass}}{\text{Feeding zone}} \qquad \text{(ii)}$$

The ratio of above ground plant weight to the weight of below ground plant part (i.e. root mass) was taken as measure of shoot:root ratio and also termed as 'root efficiency' computed as:

$$\text{Root efficiency} = \frac{\text{Above ground plant fresh weight}}{\text{Below ground plant fresh weight}} \quad \text{(iii)}$$

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

Juice purity (%) = Sucrose (%) in juice/corrected brix x 100 (iv)

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

Where S is sucrose % in juice, and B is corrected brix (%) determined as per the method of Meade and Chen (1977)

The apparent N recovery and Nitrogen Use Efficiency have been envisioned by Yadav *et al.* (1997):

$$\text{Apparent N recovery, } AR_n = \frac{N_t - N_c}{N_a} \quad \text{(vi)}$$

$$\text{Nitrogen Use Efficiency, NUE } = \frac{y_n - y_c}{N_a} \quad \text{(vii)}$$

Where:

N_t = N uptake in treated plot

N_c = N uptake in control plot

y_n = cane yield kg ha^{-1} in treated plot

y_c = cane yield kg ha^{-1} in control plot

N_a = applied N, kg ha^{-1}

Statistical analysis and calculation

Computing the ratio of the mean square concerned to the error mean square did the comparison of the treatments. The F-test was used, following the procedures of split plot design (Cochran and Cox 1957). The data were statistically analyzed for various characters as described by Panse and Sukhatme (1985). The standard error of mean is determined by dividing standard error by number of observations entered into the calculation of the mean. The standard error of difference multiplied further by "2 and t value (at 5% level of significance) at error degree of freedom gives the value of CD for statistical interpretation.

RESULTS AND DISCUSSION

The highest nitrogen use efficiency (NUE) was observed with 'CoLk 94184' (260.9 kg cane/kg N applied) at 10 t FYM + 150 kg N application. Similar trend was also observed with N uptake. It was followed by N use efficiency of genotype 'CoS 95270' (Table 1). Significantly highest N uptake (99.9 kg/ha) was recorded by 'CoLk 94184' followed by 'CoS 95270'. Apparent N recovery was observed to be the highest in 'CoS 95270' followed by 'CoLk 94184'.

The root spread, feeding zone and root intensity also varied for different genotypes. Maximum root spread (25.3 cm) and feeding zone (0.023 m^3 $stool^{-1}$) was observed for the genotype 'BO 128', however, highest root intensity (25296.8 g m^{-3}) was observed for genotype 'CoH 92201'. Sugarcane genotype 'CoLk 94184' produced bulky (root volume: 71.9 cc) longer (root length: 33.09 cm) roots and higher number of hairs (915.9 hairs cm root length $^{-1}$ clump $^{-1}$) bearing roots (Fig. 1a & b and Table 1).

Table 1 Nitrogen uptake, use efficiency, apparent recovery and root characters of different sugarcane genotypes

Genotypes	*N uptake (Kg/ha)	*NUE (Kg cane /Kg N)	*Apparent N recovery (%)	Root spread (cm)	Feeding zone (m^3/stool)	Root Intensity (g/m^3)	Number of root hairs/cm root length/clump
'CoS 95270'	95.20	220.77	33.08	23.9	0.020	13049.2	529.83
'CoS 96268'	76.60	201.84	25.53	23.2	0.017	15559.3	284.87
'CoH 92201'	49.19	169.25	18.72	21.3	0.010	25296.8	317.02
'BO 130'	59.72	156.96	15.51	22.4	0.015	16297.6	283.74
'CoS 96268'	81.08	199.70	24.22	24.1	0.017	15642.6	393.97
'CoPant 98224'	73.89	166.81	23.98	19.8	0.012	19673.8	291.24
'BO 128'	81.50	161.81	25.11	25.3	0.023	11581.7	694.77
'CoLk 94184'	99.97	260.99	31.63	20.9	0.016	16012.6	915.95
CD (P=0.05)							263.8
N levels							
0- control				20.6	0.014	19053.1	383.80
150 kg N /ha				23.2	0.015	17853.1	482.64
10 t FYM				21.8	0.018	14742.0	473.03
150kg N +10 t FYM				24.8	0.019	14908.5	516.23
CD (P=0.05)							118.6

* observed at 10 t FYM/ha + 150Kg N/ha

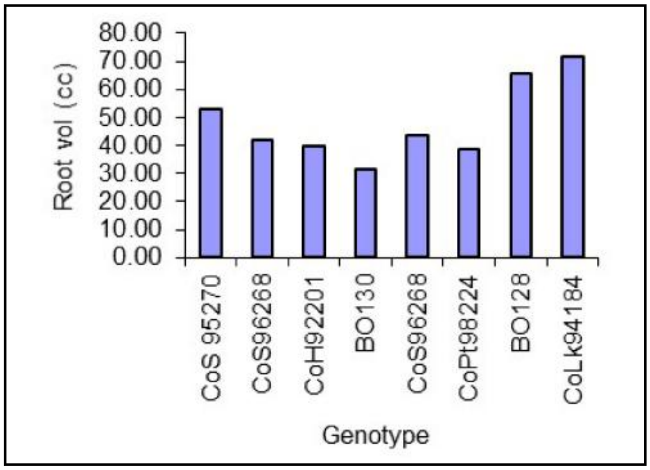

Fig. 1a: Root volume of genotypes

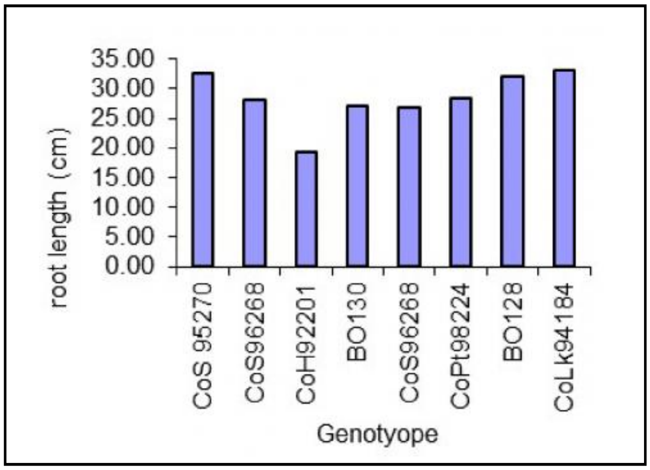

Fig. 1b: Root length of genotypes

There was significant variation in the germination of the genotypes with highest value in 'CoLk 94184' followed by 'CoS 96258' (Table 2). Highly significant and large variations were recorded among the genotypes with respect to their tillering pattern. Genotypes 'CoLk 94184', 'CoS 96258', 'CoPant 98224', 'CoS 96258', were reckoned as high order tillering genotypes while 'CoH 92201', 'BO 130' and 'BO 128' were of shy tillering type. The number of millable canes which is the exact measure of tiller performance also showed the significant variation. Significantly highest number of millable canes (NMC) were recorded by 'CoLk 94184' (133.6 thousand/ha). Increase in the number of tillers and number of millable canes were recorded with the application of fertilizer nitrogen and its fortification with organic manure (FYM).

Yield variability among the genotypes were highly significant at Pd"0.05. The genotype 'CoLk 94184' yielded 66.1 t/ha followed by 'BO 128'. In general the productivity of sugarcane also enhanced at 150 kg N + 10 t FYM/ ha.

Significant genotypic variations were recorded in the quality parameters of sugarcane like pol, purity and commercial cane sugar. Similar pol (%) were observed for the genotypes 'CoS 95270' and 'CoLk 94184'. Genotypes 'CoLk 94184', 'CoS 95270', 'CoS 96258', 'CoH 92201' and 'CoS 96268' were having statistically similar sucrose content. The significantly highest sugar yield (8.35 t/ha) was recorded by 'CoLk 94184', which was comparable to 'CoS 95270' and 'BO 128'. The sugar yield was enhanced by N application along with FYM.

Highest root dry matter (Table 3) was partitioned by 'CoH 92201' (5.91 %) followed by 'CoLk 94184' (4.91%). In green leaf the portion of dry matter by 'CoH 92201' showed an edge over others. Dry matter harnessed as above ground part (AGP) for the genotype 'CoPant 98224' (95.99 %) was higher as compared to others.

Table 2 Growth, yield and quality of different sugarcane genotypes and effect of N levelss

Treatment Genotype	Germination (%)	No. of tiller (000/ha) May	June	July	Aug.	NMC (000/ha)	Yield (t/ha)	^{o}brix	Pol (%)	Purity (%)	CCS (%)	CCS t/ha
'CoS 95270'	35.52	102.37	125.35	190.90	188.93	89.85	58.83	20.86	18.15	87.07	12.46	7.34
'Co S96268'	38.44	128.98	135.53	208.18	190.95	87.46	45.83	20.58	18.13	88.09	12.51	5.74
'CoH 92201'	23.11	72.01	105.13	155.43	151.78	67.81	40.44	20.52	17.89	87.19	12.29	4.94
'BO 130'	25.61	79.74	117.80	174.83	165.20	73.35	48.14	20.89	17.84	85.49	12.14	5.85
'CoS 96268'	36.78	133.25	136.28	218.95	196.00	95.06	54.22	20.95	18.23	87.00	12.52	6.73
'CoPant 98224'	35.93	126.46	120.33	154.50	158.00	101.93	49.31	21.13	17.54	83.12	11.75	5.81
'BO 128'	35.41	101.78	127.40	165.78	156.93	112.63	60.22	20.40	17.40	85.35	11.82	7.15
'CoLk 94184'	42.12	144.56	144.20	220.98	210.88	133.66	66.10	20.33	18.15	89.31	12.61	8.35
C D (P=0.05)	3.97	13.65	14.24	18.63	20.65	12.97	8.17	NS	0.46	1.36	0.63	2.05
N levels												
0- control	33.81	85.91	98.14	142.66	139.44	75.46	37.54	20.76	17.80	85.77	12.13	4.54
150 kg N /ha	33.07	123.98	143.09	214.06	199.08	103.56	59.56	20.42	17.64	86.45	12.07	7.20
10 t FYM	34.87	94.26	108.23	153.23	150.93	84.63	48.07	20.89	18.10	86.69	12.39	5.95
150kg N +10t FYM	34.72	140.43	156.55	234.81	219.89	117.23	66.38	20.75	18.13	87.40	12.47	8.27
CD (P=0.05)	NS	7.86	8.92	10.21	9.86	7.31	5.46	NS	NS	0.82	NS	1.25

Tiller and millable cane population exhibited positive correlation with NUE at both 150 kgN/ha and 150 Kg N + 10 t FYM (Fig. 2a, b, c & d). The root characters such as number of root hairs (Fig. 3a & b), root vol. (Fig. 3c & d) and length of roots (Fig. 3e & f) were found directly related to increase in NUE with R^2 values varies from 0.26 to 0.48 with both organic and inorganic N application. The feeding zone (Fig. 3g & h) and root biomass (Fig. 3i & j) also showed positive correlation with NUE at N with organic manure application. The AGPDM and yield of sugarcane also correlated positively in increasing the nutrient use efficiency (Fig. 4a & b).

The physiological observations like photosynthetic rate, stomatal conductance, and transpiration rate and leaf area index also varied significantly both by genotypic variations and nitrogen application (Table 4 and 5). At grand growth phase which commence in the month of August maximum photosynthetic rate (28.06 µ mole/m²/S), stomatal conductance (254.68 µ mole/m²/S), transpiration rate (2.45 µ mole/m²/S) and Leaf Area Index (7.47) were recorded by genotype 'CoLk 94184', followed by 'BO 128' and 'CoS 95270'.The above parameters were significantly increased by application of FYM with inorganic fertilizer. These parameters were found directly correlated with increase in NUE (Fig. 6a, b,c,d,e & f).

The results of the study showed very large genetic variation for NUE, germination, tillering pattern, dry matter partitioning, root characteristics and crop physiology in early genotypes. Photosynthesis, growth and yield are strongly linked to N availability in grass crops (Ranjith and Meinzer 1997). The increase in NUE of the genotypes due to application of FYM was on account of improvement in soil conditions (Singh *et al.* 2007). The number of root hairs in upper and lower portion of roots may also play an important role in increasing the NUE. However, the germination percentages of the genotypes are only due to genotypic variation (Singh *et al*. 2002).

Tillers are the basis for optimizing the plant density and ultimately contributing to number of millable canes (NMC). Higher tillering in the genotype 'CoLk 94184' might be due to its high NUE capability which also enhanced the photosynthetic rate, stomatal conductance, transpiration ratio and leaf area index.

In the grass crops like sugarcane yield is function of tillering. Tillers in sugarcane are stalk or shoots arising from the base of the plant grouped under tufted grasses (Nickell 1984). In tufted grasses which include sugarcane, the under ground branching is limited and is followed by formation of a number of erect stalks (Shoots), which makes individual plants (Yadav

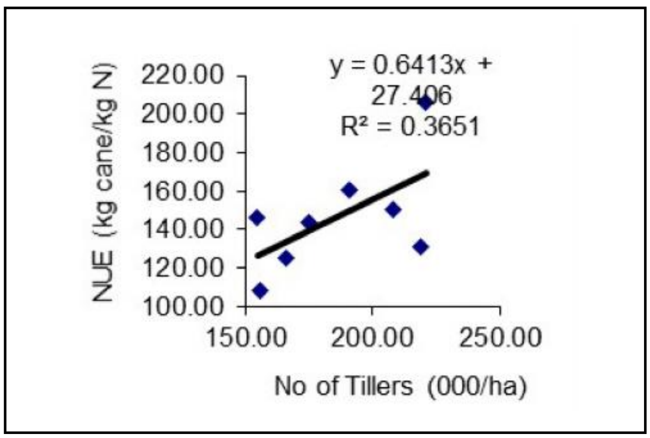

Fig. 2a. Tiller *vs* NUE (150kg N/ha)

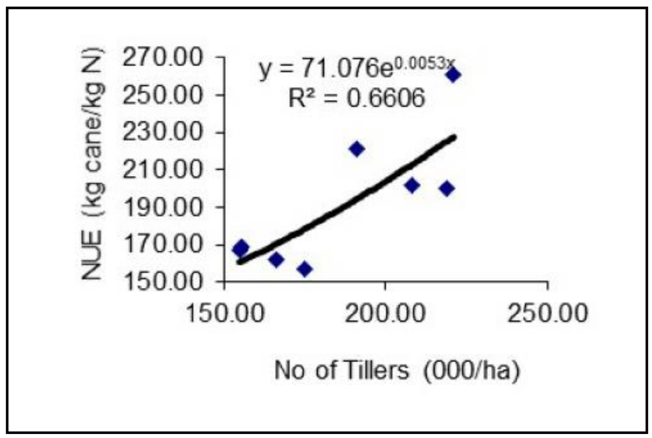

Fig. 2b. Tiller *vs* NUE (10 t FYM+ 150kg N/ha)

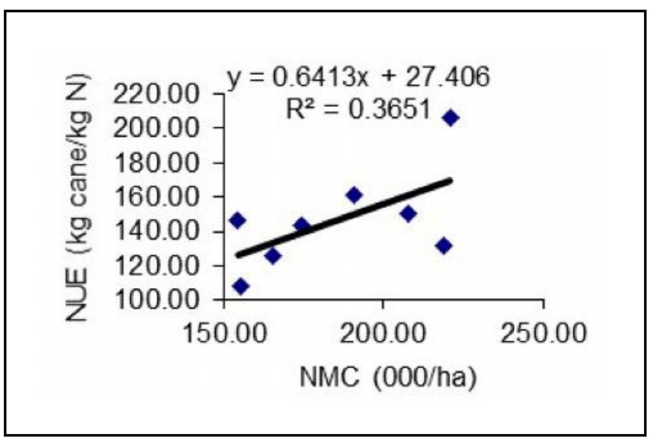

Fig. 2c. NMC *vs* NUE (150kg N/ha)

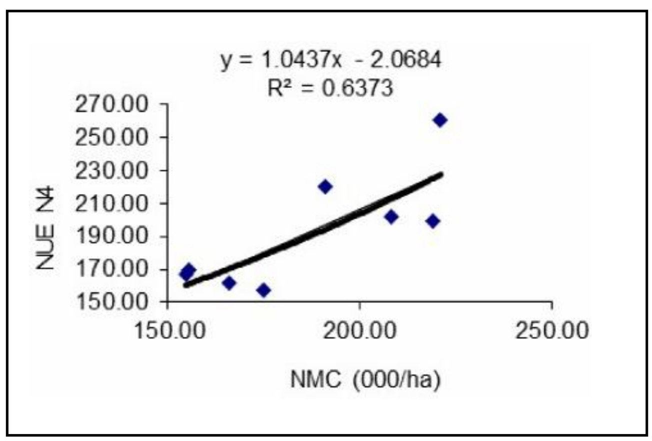

Fig. 2d. NMC *vs* NUE (10 t FYM+ 150kg N/ha)

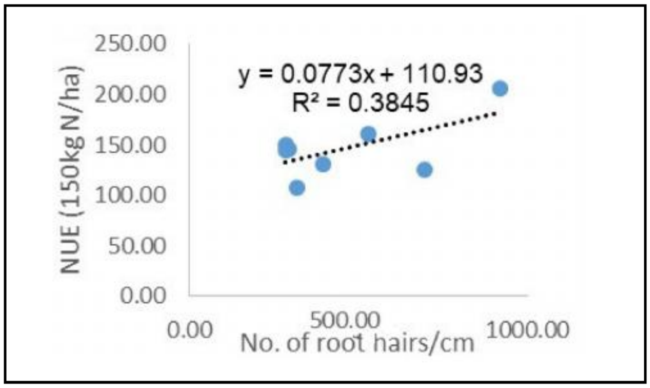

Fig. 3a. Root hairs *vs* NUE (150kg N/ha)

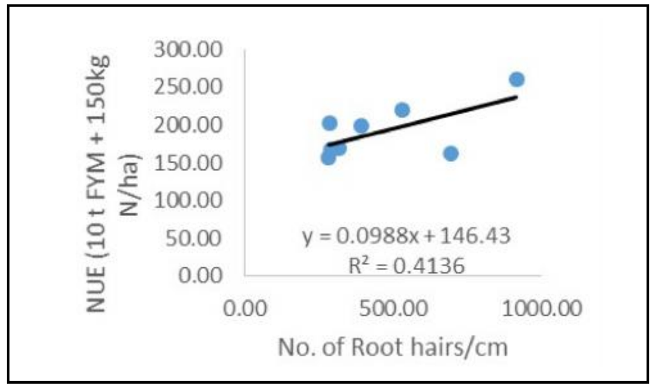

Fig. 3b. Root hairs *vs* NUE (10 t FYM+ 150kg N/ha)

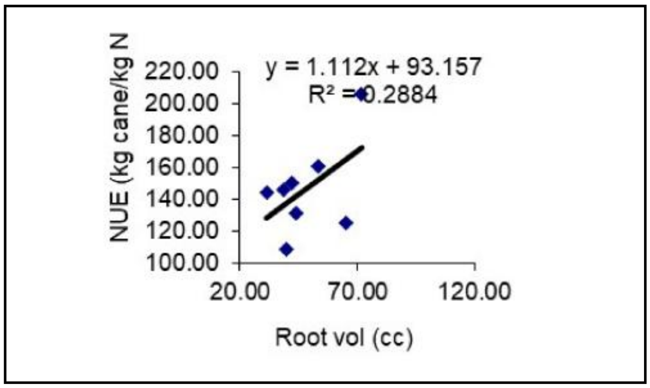

Fig. 3c. Root volume *vs* NUE (150kg N/ha)

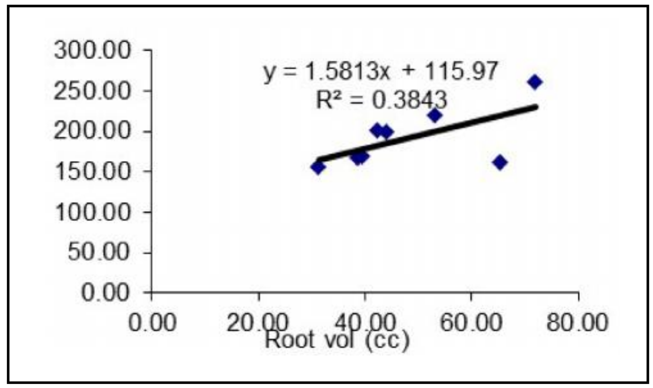

Fig. 3d. Root volume *vs* NUE (10 t FYM+ 150kg N/ha)

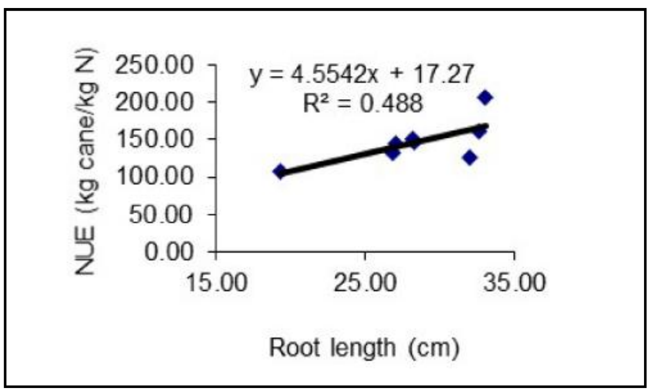

Fig. 3e. Root length *vs* NUE (150kg N/ha)

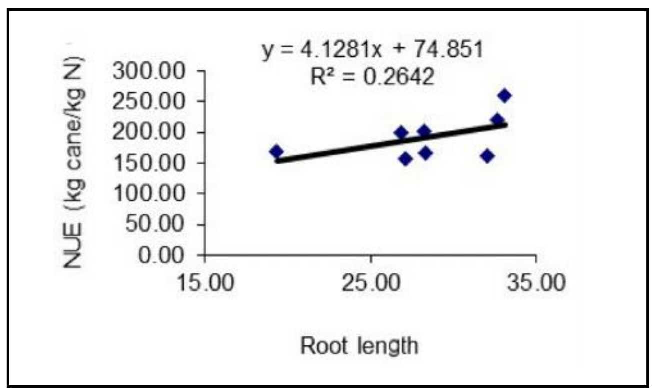

Fig. 3f. Root length *vs* NUE (10 t FYM+ 150kg N/ha)

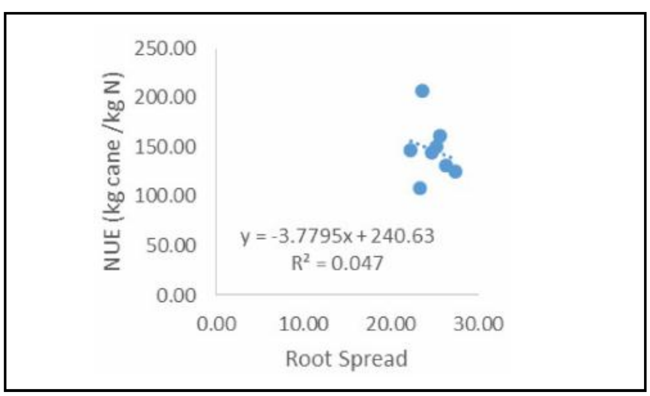

Fig. 3g. Root spread *vs* NUE (150kg N/ ha)

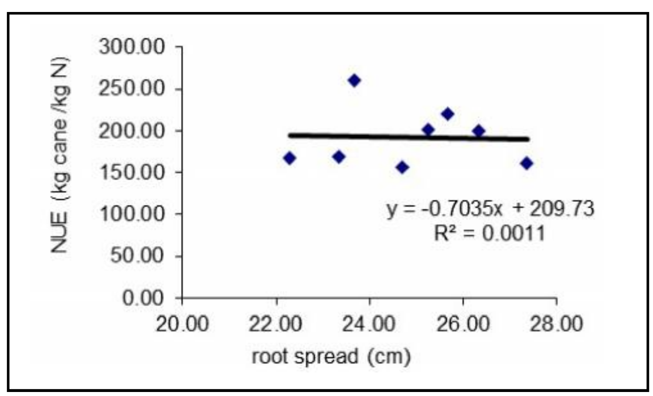

Fig. 3h. Root spread *vs* NUE (10 tFYM+150kg N/ ha)

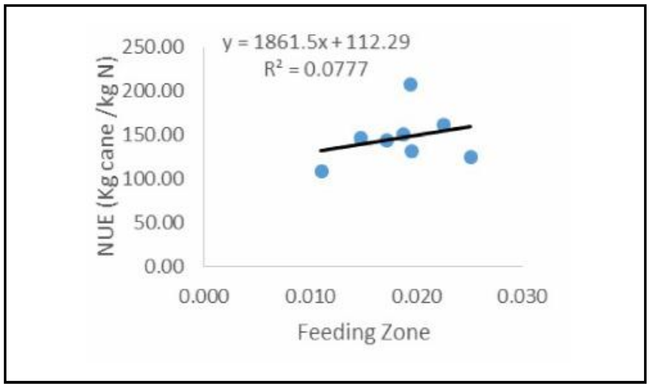

Fig. 3i. Feeding zone *vs* NUE (150 kg N /ha)

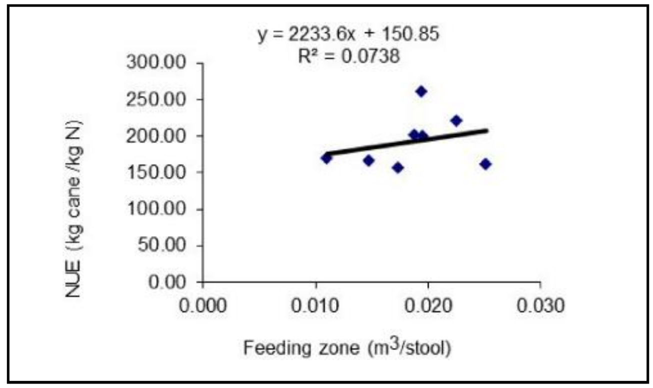

Fig. 3j . Feeding zone *vs* NUE (10 t FYM+150 kg N /ha)

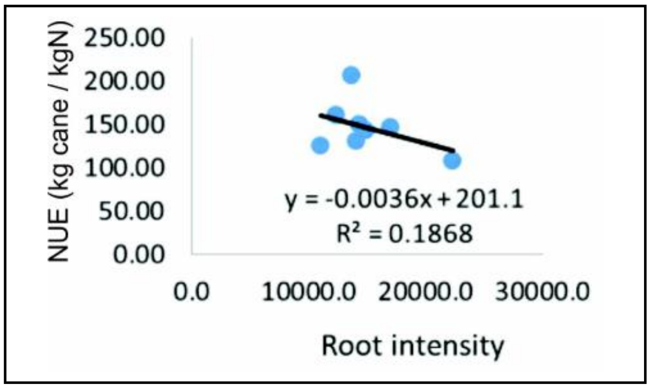

Fig. 3k. Root Intensity *vs* NUE (150 kg N/ha)

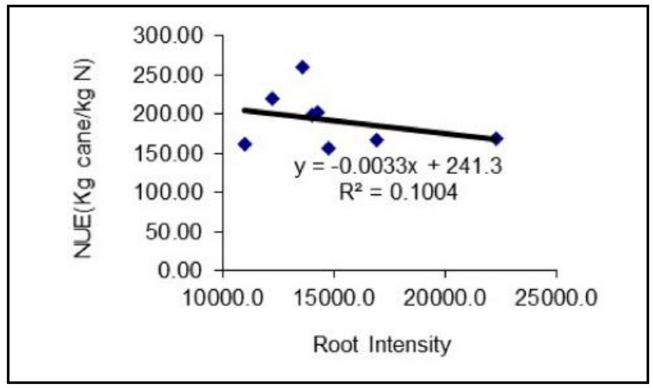

Fig. 3l. Root Intensity *vs* NUE (10 t 150 kg N/ha)

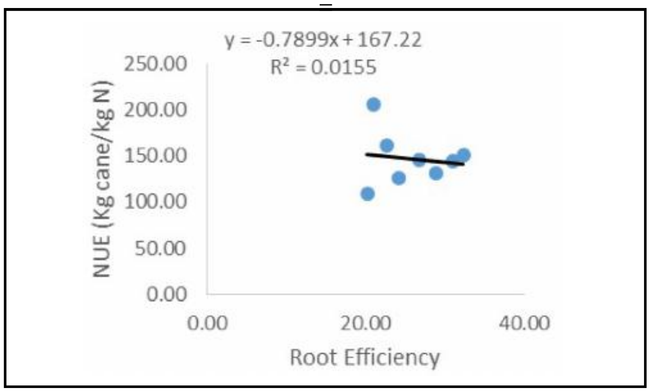

Fig. 3m. Root efficiency *vs* NUE (150kg N/ha)

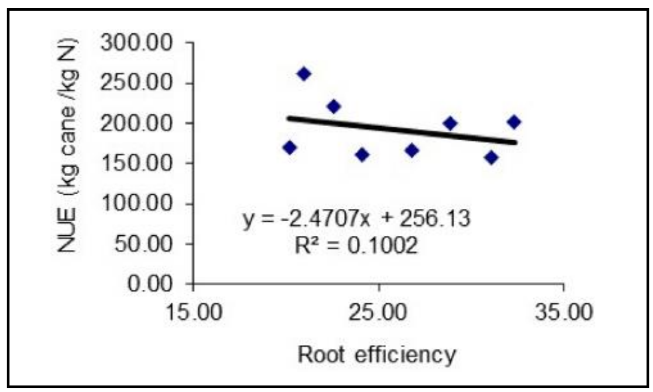

Fig. 3n. Root efficiency *vs* NUE (10 t FYM+150kg N/ha)

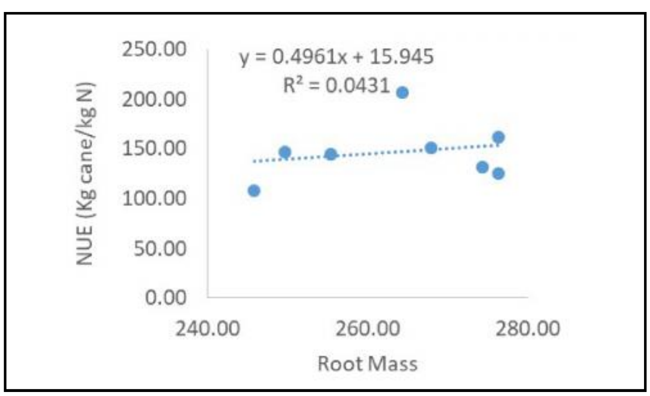

Fig. 3o. Root mass *vs* NUE (150kg N/ha)

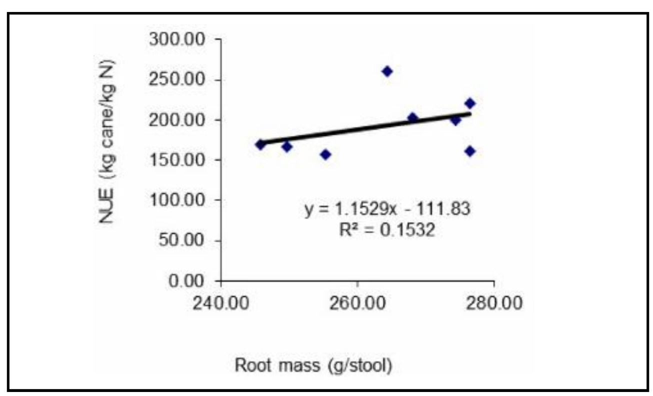

Fig. 3p. Root mass *vs* NUE (10 t FYM +150kg N/ha)

Table 3 Dry matter production of sugarcane genotypes and effect of N levels at harvest

Treatment	Dry matter production (t/ha)					Dry matter partitioning (%)				
Genotype	Root	Green leaf	Dry leaf	Stalk	AGP	Root	Green leaf	Dry leaf	Stalk	AGP
'CoS 95270'	1.06	5.19	4.05	12.58	21.83	4.63	22.70	17.70	54.97	95.37
'CoS 96268'	0.78	4.01	2.83	9.24	16.08	4.60	23.81	16.77	54.82	95.40
'CoH 92201'	0.76	3.18	2.27	6.59	12.05	5.91	24.85	17.76	51.47	94.09
'BO 130'	0.69	4.08	2.93	9.86	16.86	3.91	23.22	16.69	56.18	96.09
'CoS 96268'	0.76	4.44	3.20	10.42	18.06	4.03	23.60	17.00	55.37	95.97
'CoPant 98224'	0.70	3.37	2.96	10.53	16.86	4.01	19.18	16.83	59.98	95.99
'BO 128'	0.96	4.19	3.97	12.38	20.53	4.48	19.50	18.45	57.57	95.52
'CoLk 94184'	1.14	4.95	4.37	12.76	22.08	4.91	21.31	18.83	54.95	95.09
C D (P=0.05)	0.37	0.86	1.16	3.54	7.31	-	-	-	-	-
N levels										
0- control	0.83	3.22	2.06	7.05	12.32	6.35	24.44	15.63	53.58	93.65
150 kg N /ha	0.83	4.76	3.71	11.94	20.41	3.93	22.41	17.45	56.21	96.07
10 t FYM	0.82	4.30	2.91	9.15	16.36	4.78	25.01	16.93	53.28	95.22
150kg N +10t FYM	0.93	4.43	4.61	14.03	23.08	3.88	18.46	19.22	58.44	96.12
CD (P=0.05)	NS	0.49	0.77	2.35	4.25	-	-	-	-	-

Table 4 Photosynthetic rate and stomatal conductance of different genotypes and effect of N levels

Treatment	Photosynthetic rate (u mole/m^2/s)				Stomatal conductance (millimole/m^2/s)			
Genotype	May	June	July	Aug	May	June	July	Aug
'CoS 95270'	23.55	19.75	24.80	23.34	187.80	225.45	254.08	234.93
'CoS 96268'	21.32	21.14	23.77	20.39	159.45	202.95	239.23	210.03
'CoH 92201'	20.23	21.41	21.24	20.34	162.45	205.88	246.63	217.65
'BO 130'	20.05	21.58	21.38	20.85	167.85	212.28	254.90	223.00
CoS 96268'	22.08	21.34	23.97	21.89	144.65	213.50	258.70	228.68
CoPant 98224'	20.83	20.64	22.83	21.51	176.30	214.60	266.70	235.9
'BO 128'	23.12	24.00	25.74	24.42	201.13	233.25	279.18	244.65
'CoLk 94184'	26.39	24.35	29.45	28.06	209.45	245.48	295.65	254.68
C D (P=0.05)	3.41	2.26	2.80	5.69	14.36	15.25	18.86	17.68
N levels								
0- control	19.80	19.18	22.39	19.74	169.81	199.51	240.91	218.38
150 kg N /ha	23.60	23.23	25.02	24.07	184.26	230.05	274.50	235.94
10 t FYM	20.52	20.18	22.61	21.21	172.34	205.11	244.84	221.3
150kg N +10t FYM	24.87	24.51	26.56	25.37	178.13	242.01	287.28	249.14
CD (P=0.05)	2.26	1.87	1.63	2.85	7.28	8.76	10.28	10.20

Table 5 Transpiration rate and LAI of different genotypes and effect of N levels

Treatment	Transpiration rate (millimole/m^2/S)				Leaf Area Index			
Genotype	May	June	July	Aug	May	June	July	Aug
'CoS 95270'	3.00	2.32	2.60	2.19	2.77	3.72	5.52	6.87
'CoS 96268'	2.20	1.90	2.36	1.96	2.63	3.50	5.22	6.67
'CoH 92201'	2.13	1.64	2.16	1.82	2.48	3.16	4.76	6.14
'BO 130'	2.44	1.79	2.34	1.99	2.53	3.63	5.02	6.32
'CoS 96268'	2.35	2.07	2.52	2.11	2.68	3.81	5.00	6.66
'CoPant 98224'	2.32	1.89	2.30	1.94	2.72	3.84	5.15	6.93
'BO 128'	3.04	2.50	2.64	2.36	3.01	4.18	5.85	7.27
'CoLk 94184'	3.16	2.59	2.82	2.45	3.07	4.29	6.17	7.47
C D (P=0.05)	0.76	0.56	NS	NS	0.46	0.78	1.12	0.85
N levels								
0- control	2.35	1.90	2.20	1.90	2.27	3.37	4.60	6.30
150 kg N /ha	2.67	2.17	2.59	2.18	3.01	3.99	5.73	7.11
10 t FYM	2.49	1.97	2.29	1.97	2.40	3.60	4.84	6.42
150kg N +10t FYM	2.81	2.31	2.78	2.36	3.25	4.10	6.17	7.32
CD (P=0.05)	0.36	0.33	0.35	0.42	0.49	0.67	1.05	0.59

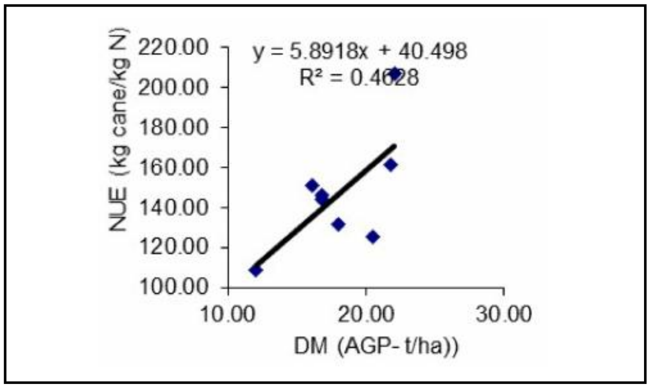

Fig. 4a. DM *vs* NUE (150kg N/ha)

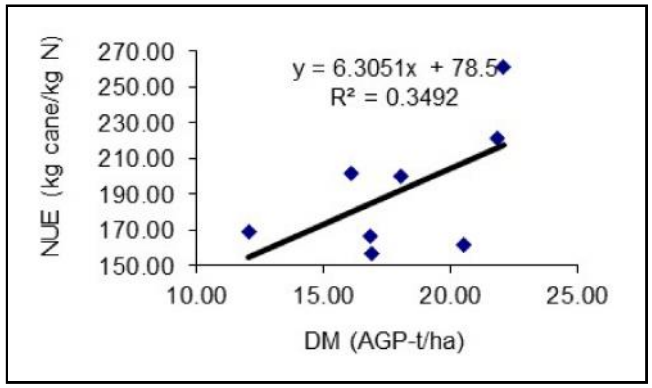

Fig. 4b. DM *vs* NUE (10 t FYM+ 150 kg N/ha)

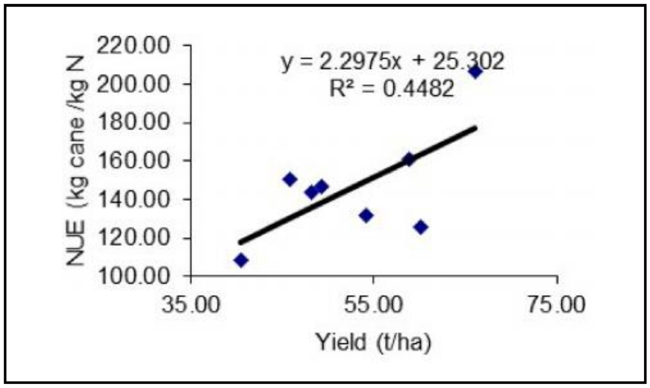

Fig. 5a. Yield *vs* NUE (150kg N/ha)

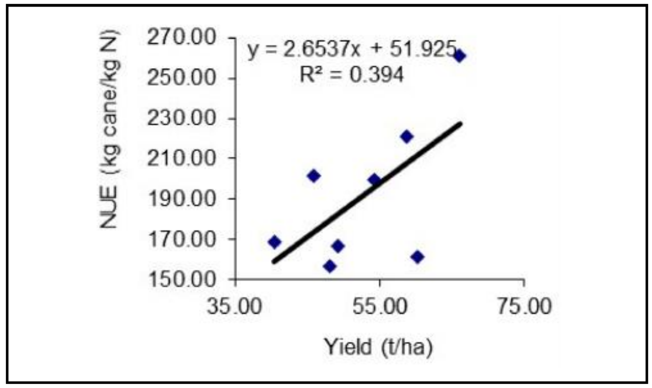

Fig. 5b. Yield *vs* NUE (10 t FYM+ 150 kg N/ha)

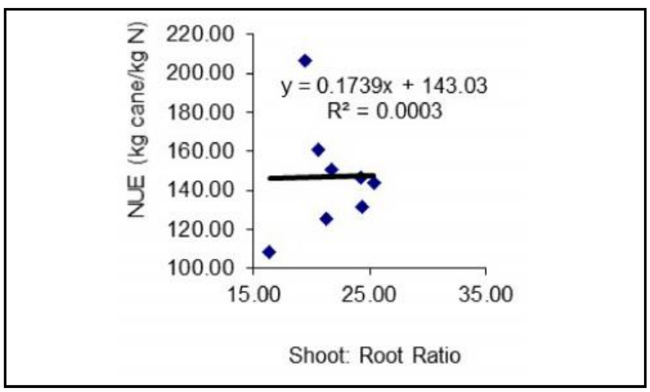

Fig. 6a. Shoot : Root *vs* NUE (150kg N/ha)

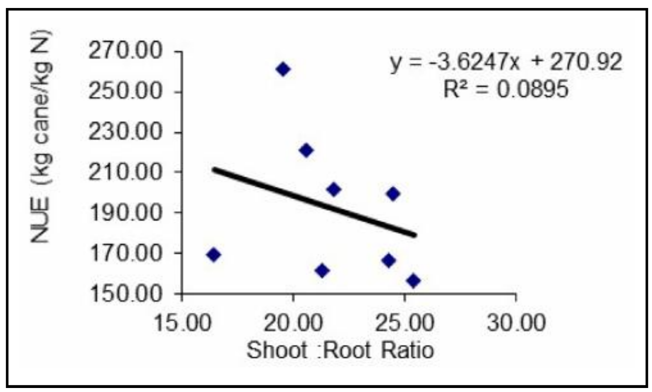

Fig.6b. Shoot : Root *vs* NUE (10 t FYM+ 150kg N/ha)

1993). So the higher number of tillers followed by higher NMC are responsible for targeted yield of the genotype types 'CoLk 94184' and 'BO 128'.

The quality parameters of the genotypes were again a part of varietal character. Sugar yield is a function of CCS% and cane yield. The higher sugar yield of the genotype 'CoLk 94184' and 'CoS 95270' were due to higher CCS% and cane yield. The increase in root length may be due to higher apparent recovery. The root biomass is observed to be the function plant genotype and management factor.

Sugarcane prefers N in NO_3 form and also takes the NH_4 form. The latter is subject to microbial attack that depletes NH_4–nitrogen. The response of sugarcane to applied N is almost universal and several attempts were made to express this relationship mathematically. The inverse – yield concept, Mitschlich equation, exponential function, square root and second degree polynomial equations were employed to predict N need of sugarcane (Hunsigi 1993). But the quadratic equation seems to predict the N need of cane more satisfactorily.

Yadav *et al.* (1997) demonstrated that the responses and N recovery declined sharply as the N dose increased from 75 to 300 kg/ha to sugarcane grown in subtropical region. The highest response and N recovery are obtained at lower level

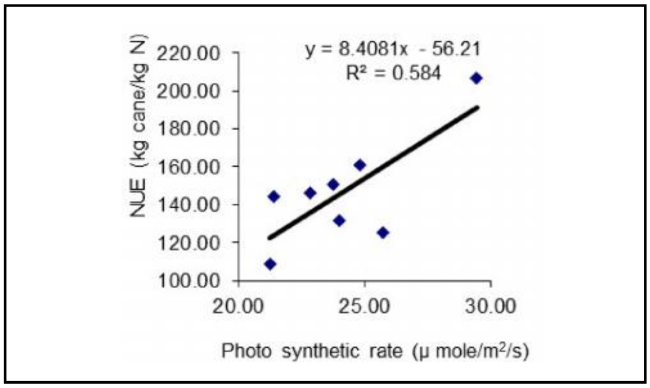

Fig. 7a. Photosynthetic rate (PR) *vs* NUE (150kg N/ha)

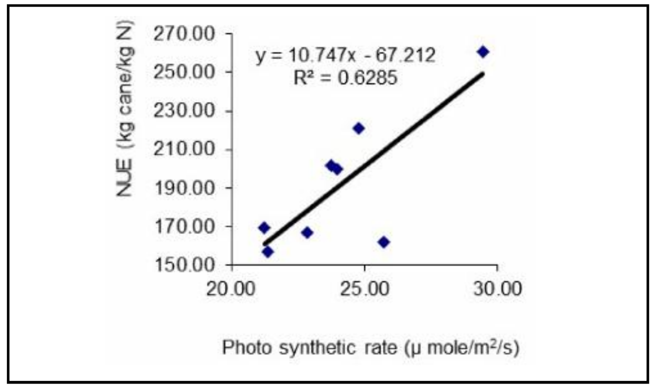

Fig. 7b. PR *vs* NUE (10 t FYM+ 150 kg N/ha)

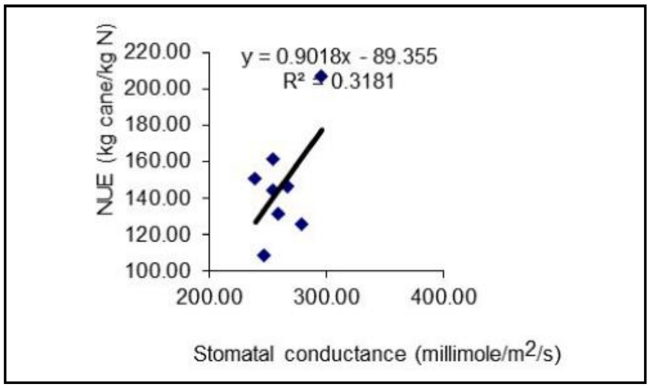

Fig. 7c. Stomatal conductance (SC) *vs* NUE (150kg N/ha)

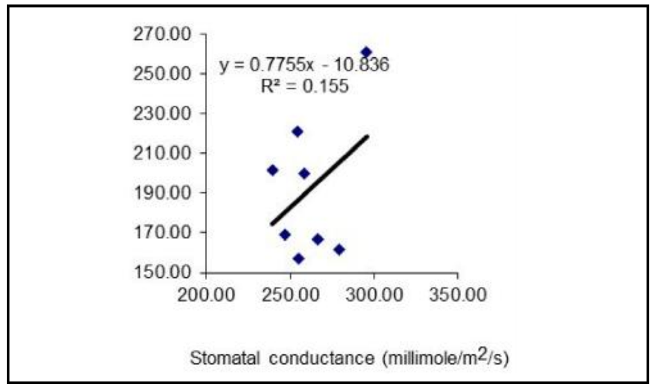

Fig. 7d. SC *vs* NUE (10 t FYM+ 150 kg N/ha)

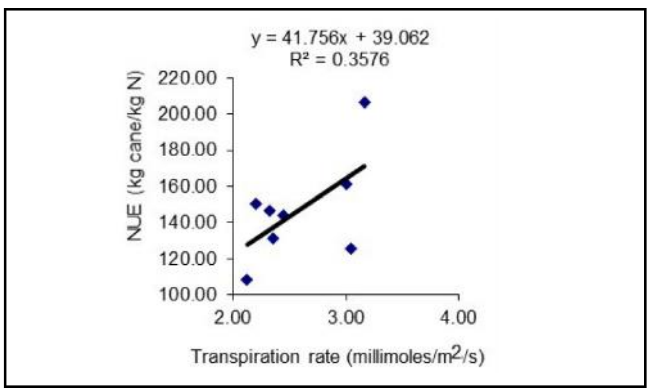

Fig. 7e. Transpiration rate (TR) *vs* NUE (150kg N/ha)

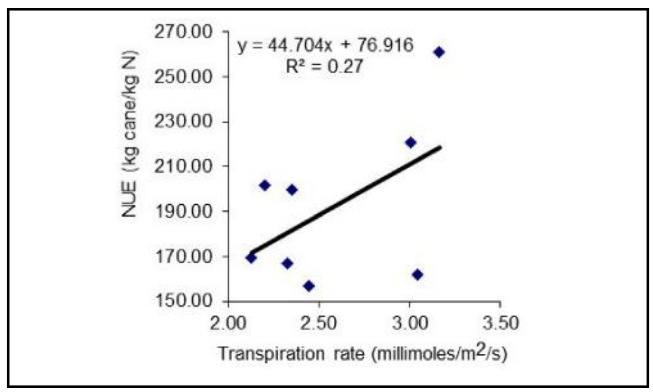

Fig. 7f. TR *vs* NUE (10 t FYM+ 150 kg N/ha)

of N dose (75 kg/ha). Nitrogen recovery barely exceeds 30 to 40 %. After application, a part is used by plants, a part rest in the soil, and rest is depleted through gaseous loss and leaching. Applied nitrogen to soil whether cropped or uncropped may be lost through leaching, NH_3 volatilization, nitrification, denitrification, run-off, NH_4 fixation, biological immobilization including the uptake of nitrogen by plants, weeds and microbes.

The magnitude of nitrogen loss through a particular mechanism depends on soil conditions, agricultural practices, agroclimatic conditions, type of fertilizer used and also method of their application. The data from lysimeter experiments in the United States and United Kingdom as reviewed by Allison (1955) revealed a N recovery of 21-79%. Values of 60% and above were obtained when grasses such as Sudan grass and timothy were used. Ranjith and Meinzer (1997) have given convincing evidence that NUE of cane be improved and N is partitioned in favour of photosynthetic apparatus such as chlorophyll and RUBISCO (Ribulose, 1, 5, bisphosphate carboxylase – oxygenase). Similar observations were made by Abrol *et al*. (1999).

The key results in this investigation were the very large biometric characters that revealed for nitrogen use efficiency in sugarcane. These characters were apparent in genotypes representative. Some biometric characters like tiller population, number of millable canes, AGPDM and photosynthetic rate were identified as highly responsive for nitrogen use efficiency. NUE measurement across the genotypes also demonstrated a high level of repeatability in relation to different biometric markers with and without organic manure application. The results collectively illustrate a high potential of varieties to affect the NUE. It is important that the results obtained relating to impact of biometric markers of varieties and N fertilizer on NUE are interpreted in terms of likely impact on agronomic efficiency before application in breeding programmes. In estimating these impacts it is important to consider two issues, (i) effect on NUE with N application alone and (ii) effect of organic manure modulated biometric parameters on NUE.

Photosynthesis, growth and yield are strongly linked to N availability particularly in grass crops. N is required in large amount relative to other nutrients, maximizing photosynthesis and dry matter production in relation to N fertilizer inputs. Nitrogen use efficiency based on photosynthesis or dry matter production is widely reported to be higher in C_4 plants (Brown 1978; Schmitt and Edwards 1981; Li 1993). The superior NUE in C_4 species is generally through the consequence of their CO_2 concentrating system (Sage *et al.* 1987). The physiological observations like photosynthetic rate, stomatal conductance and transpiration rate of different genotypes are the basis for variation in NUE under the study. Higher NUE of the genotypes might be associated with maintenance of higher plant hydraulic conductance and high water potential.

The biometric markers such as root length and transpiration rate were identified for higher NUE. Genotypic differences in nutrient absorption, content and use are known to exist widely in different crops (Batten 1992 and Fageria *et al.* 1988). Tolerance to mineral stress as a genetic trait is usually termed as "nutrient efficiency" (Batten 1992). A tolerant plant may have a lower nutrient requirement per unit time and/ or ability to extract more nutrient from the soil.

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Performance of new sugarcane clones for yield and its components during two different crop cycles

FARRAG F B ABU-ELLAIL[1*], MOHAMED I MASRI[2] and ASHRAF B A EL -TAIB[3]

[1-]*Breeding & Genetics Dept., Sugar Crops Research Institute. ARC, Giza, Egypt.*
[2-]*Agronomy Depart. Fac. Agric., Cairo Univ., Giza, Egypt*[3]
[3-]*Agronomy Dept. Fac. of Agric. and Natural resources, Aswan Univ., Aswan, Egypt.*

ABSTRACT

The experiment was conducted at Shandweel Agricultural Research Station, Sohag Governorate, Egypt during 2012/ 2013 and 2013/ 2014 harvesting seasons. The objective of this study was to evaluate for yield and quality traits in plant cane (PC) and first ratoon crop (FR) at the first clonal selection stage under Upper Egypt conditions. The selected sugarcane clones along with two check cultivars (‘GT54-9’ and ‘Ph8013’) were planted in Randomized Complete Block Design with three replications. Results indicated significant differences among evaluated clones for stalk length, stalk diameter, stalk weight, number of stalks/fed 01 feddan = 4200.8 m^2, cane yield, Brix%, sucrose%, purity%, sugar recovery% and sugar yield in plant cane, first ratoon and across crops. Genotype × crops-year interaction was highly significant for all traits, except cane yield (ton/fed) and Brix% which were insignificant. Across plant cane and first ratoon the clones, ‘G2009-30’ (67.17 ton/fed), ‘G2009-7’ (64.41 ton/fed), ‘G2009-10’ (63.49 ton/fed) and ‘G2009-18’ (62.41 ton/fed), respectively, surpassed the two check cultivars for cane yield, while, the highest sugar yield was recorded with clones, ‘G2009-10’ (9.02 ton/fed), ‘G2009-27’ (8.25 ton/fed), ‘G2009- 2’ (8.25 ton/fed) and ‘G2009-21’ (8.17 ton/fed), respectively, indicating that they have potential to be evaluated in subsequent regional selection programs under different maturity groups.

Key words: Sugarcane *Saccharum*, Plant cane, Ratoon crops, Clones.

The biggest challenge being faced by the sugar industry in Egypt is that, more than 95% of the cultivated area depending only on one cultivar ‘GT 54/9’. Therefore, the goal of sugarcane breeding program in Egypt is to develop new cultivars with improved cane and sugar yields and quality traits as well as disease resistance through selection of genotypes (clones) obtained from fuzz (true seeds) that is derived from the classical hybridization of superior parents. Sugarcane is being grown on 136.6 thousand ha with total annual production of 15.7 million tons (Annual Report of Sugar Crops Council 2017). Sugarcane (S*accharum spp*. L) is the major cash and industrial crop in Egypt. Kimbeng and Cox (2003) reported that sugarcane breeding programs typically commence by evaluating a large number of seedlings derived from true seeds. Sugarcane clones obtained from the same cross show heterogeneity in F_1 generation and the breeders exploit the variability in making selection. Masri (2004) found at early selection stages of sugarcane that stalk diameter and stalk weight decreased with advancing generations while stalk number, cane yield, juice quality traits and sugar yield increased with generations. Tahir *et al.* (2014) evaluated 28 sugarcane genotypes including two checks in plant cane and ratoon crops for yield and important characters. They reported significant differences among evaluated genotypes, crops and their interaction for stalk diameter, stalk weight, cane yield, Brix and sugar recovery. The contrast for plant cane versus ratoon crops was significant for all studied traits, except stalk diameter. Evaluation of sugarcane clones performance in breeding cane quality attributes, decreased time to identify superior clones, to know the performance in different locations and support the selected sugarcane clones to next selection stage of program (Musa *et al*. 1997, Mohamed and El-Taib 2007 and Bell *et al.* 2008). The objective of this study to evaluate the yield and quality performance of some new sugarcane clones under two different crop cycles; plant cane (PC), and first ratoon (FR) at the first clonal selection stage.

MATERIALS AND METHODS

In mid April, 2011 sugarcane seedlings of 6 bi-parental crosses (Table 1) at the age of 3 months were transplanted in the breeding nursery of Sugar Crops Research Institute, Giza Governorate for evaluation in a single stool stage. Each cross (family) was represented by 50 clones (seedlings). After 10 months from seedling transplanting, data on stalk length, stalk diameter, stalk weight and hand refractometer brix were recorded. (Data are not presented). According to the measurements of stalk weight and brix, the best 5 clones of each cross were selected (10% selection intensity) for evaluation in the first clonal selection stage. Therefore, a total of selected 30 sugarcane genotypes and the two check

*Corresponding author’s E-mail: farrag_abuellail@yahoo.com

cultivars; ‘Ph 8013’ and ‘G T 54/9’ were grown in 5m x 3 row plots with 1.0 m spacing between rows, thus plot size was 15 m^2. The experimental design was Randomized Compete Block Design with three replications. Planting was done during March, 2012 season at Shandweel Agricultural Research Station, Sohag Governorate. Planting was done by placing fifteen 3-budded cane pieces in each row. Field was irrigated right after planting and all other agronomic practices were carried out as recommended. Plant cane was allowed to ratoon after harvest, which took place after 12 months from planting. Harvesting of ratoon crop was done after 12 month of cutting of plant cane crop.

At harvest, the following traits were measured:

A. Cane yield and its contributing traits:

A sample of twenty stalks from each plot was harvested to measure stalk length, stalk diameter and stalk weight.

1. Stalk length (cm) was measured from soil surface to the top most visible dewlap.
2. Stalk diameter (cm) was measured at mid stalk with no reference to the bud groove.
3. Number of millable stalks/fed was calculated on the plot basis.
4. Stalk weight (kg) was calculated by dividing cane yield per plot by number of stalks per plot.
5. Cane yield (ton/fed) was calculated on the plot basis.

B. Juice quality traits and sugar yield (ton/fed)

Juice of twenty stalk sample from each plot was analyzed for determining the following traits:

1. Brix (percent soluble solids) determined with a hydrometer.
2. Sucrose percentage of clarified juice was determined by using automated Saccharimeter according to A.O.A.C. (1980).
3. Purity [(Sucrose / Brix) x 100].
4. Commercial Cane Sugar% (CCS) (rendement) was calculated according to the formula described by Yadav and Sharma (1980): [Sucrose % - 0.4 (Brix – Sucrose %)] x 0.73.
5. Sugar yield (ton/fed) was estimated by multiplying net cane yield (ton / fed) by CCS%. Separate and combined analyses of variance for collected data were performed according to Gomez and Gomez (1984). The comparison among means was done using the least significant difference test (LSD) at 5% level of probability. The thirty sugarcane clones that were selected from six bi-parental crosses used in this study are listed in Table 1.

Table 1 Sugarcane hybrids and number of their clones

Cross	Hybrid name ♀		♂	Number of clones
1	‘EH94-181-1’	X	‘EH94-119-72’	1-5
2	‘MEX58-1866’	X	‘PH8013’	6-10
3	‘79D1’	X	‘PH8013’	11-15
4	‘F153’	X	‘BO3’	16-20
5	‘Co 622’	X	‘G85-37’	21-25
6	‘Co1075’	X	‘CP31-294’	26-30
	Total			30

EH and D = Hoamdea, Egypt; MEX= Mexico; Phil= Philippines; F= Formosa, Taiwan BO= Bihar–Orissa, India ; Co= Coimbatore , India; CP= Canal point, Florida, USA; G =Giza, Egypt and GT= Giza, Egypt seed from Taiwan

RESULTS AND DISCUSSION

The results of the conducted experiments are as below:

Stalk length and stalk diameter

Data in Table 2 revealed that evaluated genotypes varied significantly for stalk length and stalk diameter in the plant cane, first ratoon and across crops. For stalk length, the genotype No.4 recorded the highest mean stalk length in the plant cane (288.33 cm), while, in the first ratoon and across crops, the highest mean stalk length (330.00 cm and 300.83 cm, respectively) was recorded by the genotype No.27. Across crops; the genotype No.27 significantly exceeded the check variety ‘Ph8013’ but was lower than that of the check variety ‘G.T.54-9’. These results are in harmony with those reported by Mohamed and El-Taib (2007) and Masri *et al.* (2014), who, found significant differences among genotypes and the interaction between genotypes and crops-year for stalk length. For stalk diameter, the genotype No.7 recorded the highest mean stalk diameter in the plant cane (2.90 cm), while, in the first ratoon, the highest mean stalk diameter (2.70 cm) was recorded by genotype No.3, moreover, across crops; the highest mean stalk diameter (2.68 cm) was recorded by the genotype No.23. Across crops; the genotype No.23 surpassed the check variety Ph8013 but was lower than that of the check variety ‘G.T.54-9’. These results are in agreement with those reported by Bissessur *et al. (*1999) and Jamoza *et al*. (2014) who found significant differences among genotypes and the interaction between genotypes and crop-year for diameter. On the contrary, Tahir *et al*. (2014) reported in significant differences among genotypes for stalk diameter.

Stalk weight and number of stalks/ fed

Means listed in Table 3 indicated that stalk weight (kg) and number of stalks/fed varied significantly among evaluated genotypes in the plant cane, first ratoon and across crops.

For stalk weight (kg) the genotype No.7 recorded the highest mean stalk weight in plant cane (2.19 kg), first ratoon, (1.42 kg) and across crops (1.81 kg). Across crops; the same genotype exceeded the check varieties ‘Ph8013’ and ‘G.T.54-9’ by 0.79 kg. Similar results were obtained by El-Taib (1999) and Masri *et al.* (2014), who found significant differences among genotypes and significant interaction between genotypes and crops-year for stalk weight. For number of stalks/fed, the genotype No.16 recorded the highest mean number of stalks/ fed in the plant cane (76.10 thousand stalks/fed), while in the

Table 2 Mean performance of sugarcane genotypes for stalk length (cm) and stalk diameter (cm) in plant cane, first ratoon and across crops during 2012-2014 seasons

Genotype	Stalk length (cm)			Stalk diameter (cm)		
	Plant cane	First ratoon	Across crops	Plant cane	First ratoon	Across crops
1	246.67	301.33	**274.00**	2.40	2.27	**2.33**
2	255.00	270.00	**262.50**	2.17	2.17	**2.17**
3	228.33	255.00	**241.67**	2.37	2.70	**2.53**
4	288.33	271.67	**280.00**	1.80	2.23	**2.02**
5	251.33	232.67	**242.00**	2.30	2.60	**2.45**
6	225.00	237.33	**231.17**	2.30	2.17	**2.23**
7	230.00	258.33	**244.17**	2.90	2.20	**2.55**
8	285.00	296.67	**290.83**	2.43	2.67	**2.55**
9	247.67	295.00	**271.33**	2.27	2.30	**2.28**
10	241.67	249.33	**245.50**	2.70	2.27	**2.48**
11	265.00	245.00	**255.00**	2.67	2.47	**2.57**
12	241.67	263.33	**252.50**	2.43	2.13	**2.28**
13	233.33	310.00	**271.67**	2.23	2.27	**2.25**
14	277.00	281.67	**279.33**	2.30	1.70	**2.00**
15	210.33	245.00	**227.67**	2.40	2.20	**2.30**
16	235.00	303.33	**269.17**	2.33	2.37	**2.35**
17	255.00	263.00	**259.00**	2.07	2.07	**2.07**
18	228.33	281.33	**254.83**	2.53	2.40	**2.47**
19	235.00	303.33	**269.17**	2.33	2.37	**2.35**
20	265.67	241.67	**253.67**	2.43	2.27	**2.35**
21	230.00	208.33	**219.17**	2.50	2.63	**2.57**
22	235.00	278.33	**256.67**	2.27	2.20	**2.23**
23	225.00	268.33	**246.67**	2.80	2.57	**2.68**
24	237.33	230.00	**233.67**	2.67	2.33	**2.50**
25	203.33	246.67	**225.00**	2.17	2.27	**2.22**
26	225.00	216.67	**220.83**	2.47	2.43	**2.45**
27	271.67	330.00	**300.83**	2.30	2.10	**2.20**
28	231.67	305.00	**268.33**	2.20	2.17	**2.18**
29	220.00	275.00	**247.50**	2.30	2.23	**2.27**
30	221.00	271.67	**246.33**	2.70	2.20	**2.45**
'GT54-9'	325.00	310.00	**317.50**	2.87	2.77	**2.82**
'Ph8013'	295.00	287.67	**291.33**	2.27	2.47	**2.37**
Mean	**245.79**	**269.77**	**257.78**	**2.40**	**2.32**	**2.36**
LSD at 5%						
Genotype (G)	10.56	**15.50**	9.26	0.16	**0.30**	0.17
Crop-year (C)		**			*	
G×C		**13.1**			**0.24**	

first ratoon, the best mean number of stalks/fed (98.76 thousand stalks/fed) was recorded by genotype No.25, however, in the across crops, the highest mean number of stalks/fed (84.19 thousand stalks/fed) was recorded by the genotype No.19. Across crops; the highest genotype (No.19) exceeded the check varieties 'Ph8013' by 30.82 thousand stalks/fed and 'G.T.54-9' by 17.47 thousand stalks/fed. Similar results were obtained by Bissessur *et al. (*1999) and Manjunath *et al. (*2007), who found significant differences among genotypes and the interaction between genotypes and crops-year for number of stalks/fed.

Cane yield and Brix %

Mean listed in Table 4 indicated that cane yield (ton/fed) and Brix % varied significantly among evaluated genotypes in the plant cane, first ratoon and across crops. For cane yield (ton/fed**)** the genotype No.7 recorded the highest mean cane yield (ton/fed) in the plant cane (68.12 ton/fed), while in the first ratoon, the highest mean cane yield (67.37 ton/fed) was recorded by genotype No.30, however, across crops the highest mean cane yield (67.17 ton/fed) was recorded by the genotype No. 30. Across crops; the best genotype (No.30) exceeded the check varieties 'Ph8013' by 12.87 ton/fed and

Table 3 Mean performance of sugarcane genotypes for stalk weight (kg) and number of stalks/fed in plant cane, first ratoon and across crops during 2012 - 2014 seasons

Genotype	Stalk weight (kg)			Number of stalks/fed. X 10^3		
	Plant cane	First ratoon	Across crops	Plant cane	First ratoon	Across crops
1	0.77	0.89	**0.83**	40.76	51.81	**46.29**
2	1.42	0.95	**1.18**	37.14	68.00	**52.57**
3	0.89	1.21	**1.05**	47.24	48.52	**47.88**
4	0.64	0.59	**0.62**	51.24	53.71	**52.48**
5	1.26	0.48	**0.87**	46.29	48.57	**47.43**
6	0.83	0.72	**0.77**	52.19	84.86	**68.52**
7	2.19	1.42	**1.81**	40.19	42.86	**41.52**
8	0.78	0.70	**0.74**	50.09	52.38	**51.24**
9	0.64	0.85	**0.75**	61.72	64.95	**63.34**
10	1.20	0.81	**1.00**	54.67	76.19	**65.43**
11	1.23	1.05	**1.14**	40.00	53.90	**46.95**
12	1.01	0.56	**0.79**	58.86	88.38	**73.62**
13	0.80	0.99	**0.89**	41.14	49.90	**45.52**
14	0.69	0.72	**0.71**	45.14	49.33	**47.24**
15	0.97	1.00	**0.98**	43.05	52.00	**47.52**
16	0.58	0.54	**0.56**	76.10	86.00	**81.05**
17	0.66	0.76	**0.71**	40.19	40.95	**40.57**
18	1.24	0.89	**1.06**	52.48	67.43	**59.95**
19	0.58	0.53	**0.56**	72.76	95.62	**84.19**
20	0.92	0.85	**0.88**	51.05	52.95	**52.00**
21	1.15	1.24	**1.20**	46.48	48.00	**47.24**
22	0.91	0.64	**0.78**	29.71	31.24	**30.48**
23	1.42	1.12	**1.27**	38.86	53.91	**46.38**
24	1.18	0.53	**0.86**	58.86	64.19	**61.52**
25	0.73	0.46	**0.60**	59.05	98.76	**78.91**
26	0.89	0.77	**0.83**	45.52	76.00	**60.76**
27	0.81	0.64	**0.73**	74.86	77.14	**76.00**
28	0.65	0.51	**0.58**	53.52	54.66	**54.09**
29	1.02	1.02	**1.02**	42.48	54.10	**48.29**
30	0.98	1.00	**0.99**	74.67	77.71	**76.19**
'GT54-9'	1.19	0.84	**1.02**	57.52	75.91	**66.72**
'Ph8013'	1.06	0.98	**1.02**	49.71	57.02	**53.37**
Mean	**0.98**	**0.82**	**0.90**	**51.05**	**62.40**	**56.73**
LSD at 5%						
Genotype (G)	0.07	**0.05**	0.05	3.24	**4.16**	2.62
Crop-year (C)		**			**	
G×C		**0.07**			**3.70**	

'G.T.54-9' by 4.58 ton/fed. Similar results were obtained by Musa *et al*. (1997), Bissessur *et al. (*1999) and El-Taib (1999), who found significant differences among genotypes, however, crops-year ×genotype interaction was insignificant for cane yield (ton/fed).

For Brix reading, the genotype No.29 recorded the highest mean Brix percentage in the plant cane (21.50%), while, in the first ratoon, the highest mean Brix percentage (21.93%) was recorded by genotype No.29, however, across crops, the best mean Brix percentage (21.72%) was recorded by the genotype No.29. Across crops; the highest genotype (No.29) exceeded the check varieties 'Ph8013' by 2.97 % and 'G.T.54-9' by 1.52 %. Similar results were reported by Masri *et al.* (2014) and Manjunath *et al. (*2007), who found significant differences among genotypes and crops-year for Brix %.

Sucrose percentage and purity percentage

Mean listed in Table 5 indicated that sucrose percentage and purity percentage varied significantly among evaluated genotypes in the plant cane, first ratoon and across crops. For sucrose percentage, the genotype No.29 recorded the highest mean sucrose percentage in the plant cane (17.17%), while in the first ratoon, the highest mean sucrose percentage (17.13%) was recorded by genotype No.3. Moreover, across crops the highest mean sucrose percentage (16.59%) was recorded by the genotype No.3. Across crops; the best genotype (No.3) exceeded the check varieties 'Ph8013' by 2.11 % and 'G.T.54-9' by 1.45 %. Similar results were reported by Bissessur *et al. (*1999), Mohamed and El-Taib (2007) and Jamoza *et al*. (2014), who found significant differences among genotypes and the interaction between genotypes and crop-year for sucrose percentage.

For purity percentage, the genotype No.11 recorded the highest mean purity percentage in the plant cane (91.54%), while in the first ratoon, the highest mean purity percentage (92.04%) was recorded by genotype No.11; moreover, across crops, the highest mean purity percentage (91.79%) was recorded by the genotype No.11. Across crops; the best genotype (No.11) exceeded the check varieties 'Ph8013' by 14.55 % and 'G.T.54-9' by 16.82 %. Singh and Singh (2000) found significant differences among genotypes and the interaction between genotypes and crop-year for purity percentage.

Sugar recovery percentage and sugar yield

Mean listed in Table 6 indicated that sugar recovery percentage and sugar yield (ton/fed) varied significantly among evaluated genotypes in the plant cane, first ratoon and across crops. For sugar recovery%, the genotype No.27 recorded the highest mean sugar recovery percentage in the plant cane (15.91%), while, in the first ratoon, the highest mean

Table 4 Mean performance of sugarcane genotypes for cane yield (ton/fed) and Brix% in plant cane, first ratoon and across crops during 2012-2014 seasons

Genotype	Cane yield (ton/fed)			Brix%		
	Plant cane	First ratoon	Across crops	Plant cane	First ratoon	Across crops
1	31.09	46.14	**38.62**	17.00	18.00	**17.50**
2	52.42	64.16	**58.29**	18.67	19.50	**19.08**
3	41.88	58.53	**50.21**	19.76	20.17	**19.96**
4	32.71	31.69	**32.20**	16.17	16.93	**16.55**
5	58.40	23.12	**40.76**	14.83	15.83	**15.33**
6	43.13	60.65	**51.89**	18.67	18.90	**18.78**
7	68.12	60.70	**64.41**	13.17	14.50	**13.83**
8	39.11	36.92	**38.01**	17.17	18.17	**17.67**
9	39.54	55.56	**47.55**	17.00	17.50	**17.25**
10	65.42	61.56	**63.49**	18.33	18.67	**18.50**
11	49.03	56.42	**52.73**	17.00	17.40	**17.20**
12	59.21	49.21	**54.21**	18.50	19.33	**18.92**
13	32.86	49.35	**41.11**	18.00	18.50	**18.25**
14	31.07	35.57	**33.32**	13.67	16.00	**14.83**
15	41.88	51.83	**46.85**	20.17	20.67	**20.42**
16	44.46	46.63	**45.55**	21.00	21.50	**21.25**
17	26.60	31.03	**28.82**	16.17	16.65	**16.41**
18	65.10	60.33	**62.72**	17.17	17.83	**17.50**
19	42.50	50.55	**46.53**	21.33	21.67	**21.50**
20	46.92	44.86	**45.89**	14.83	15.67	**15.25**
21	53.57	59.57	**56.57**	20.83	21.17	**21.00**
22	27.03	19.97	**23.50**	15.50	18.00	**16.75**
23	54.97	60.31	**57.64**	20.50	21.00	**20.75**
24	61.68	34.32	**52.00**	16.50	18.00	**17.25**
25	43.32	45.35	**44.34**	19.00	19.47	**19.23**
26	40.81	58.92	**49.87**	15.50	16.83	**16.17**
27	60.64	49.24	**54.94**	20.67	21.33	**21.00**
28	34.79	27.86	**31.33**	20.67	21.50	**21.08**
29	43.20	54.99	**49.09**	21.50	21.93	**21.72**
30	66.97	67.37	**67.17**	17.50	18.33	**17.92**
'GT54-9'	63.00	62.18	**62.59**	19.90	20.50	**20.20**
'Ph8013'	52.84	55.77	**54.31**	18.17	19.33	**18.75**
Mean	**47.32**	**49.08**	**48.20**	**17.43**	**18.21**	**17.82**
LSD at 5%						
Genotype (G)	2.32	**3.85**	2.22	0.96	**0.99**	0.68
Crop-year (C)		**n. s.**			******	
G×C		**3.18**			**0.97**	

Table 5 Mean performance of sugar cane genotypes for sucrose% and purity% in plant cane, first ratoon and across crops during 2012 -2014 seasons

Genotype	Sucrose%			Purity%		
	Plant cane	First ratoon	Across crops	Plant cane	First ratoon	Across crops
1	14.21	15.08	**14.64**	83.59	83.77	**83.68**
2	14.75	15.70	**15.23**	79.01	80.52	**79.76**
3	16.05	17.13	**16.59**	81.21	84.92	**83.07**
4	14.19	14.93	**14.56**	87.84	88.26	**88.05**
5	10.52	12.20	**11.36**	71.02	77.09	**74.06**
6	15.72	16.23	**15.98**	84.25	85.89	**85.07**
7	10.34	11.67	**11.01**	78.73	80.55	**79.64**
8	15.20	15.92	**15.56**	88.63	87.66	**88.14**
9	12.97	13.85	**13.41**	76.42	79.54	**77.98**
10	14.81	15.56	**15.18**	80.77	83.45	**82.11**
11	15.56	16.01	**15.79**	91.54	92.04	**91.79**
12	15.43	16.04	**15.73**	83.45	83.02	**83.24**
13	14.57	15.35	**14.96**	80.97	82.99	**81.98**
14	11.31	12.41	**11.86**	82.85	77.63	**80.24**
15	15.72	16.13	**15.93**	77.95	78.02	**77.99**
16	13.82	13.29	**13.56**	65.82	61.80	**63.81**
17	11.45	8.86	**10.15**	70.77	53.25	**62.01**
18	14.39	11.13	**12.76**	83.84	62.43	**73.14**
19	13.98	13.53	**13.76**	65.57	62.50	**64.03**
20	12.13	9.40	**10.77**	82.21	60.17	**71.19**
21	16.58	15.31	**15.95**	79.63	72.36	**76.00**
22	12.45	11.81	**12.13**	80.39	65.72	**73.06**
23	14.69	14.48	**14.58**	71.69	68.94	**70.32**
24	13.82	11.28	**12.55**	83.77	62.69	**73.23**
25	11.34	10.25	**10.79**	59.68	52.70	**56.19**
26	13.93	12.76	**13.35**	89.97	75.79	**82.88**
27	16.98	15.59	**16.29**	82.18	73.13	**77.66**
28	14.38	12.22	**13.30**	69.61	56.84	**63.22**
29	17.17	14.84	**16.01**	79.88	67.67	**73.77**
30	11.76	12.37	**12.07**	67.26	67.42	**67.34**
‘GT54-9’	14.70	15.58	**15.14**	73.92	76.02	**74.97**
‘Ph8013’	14.10	14.85	**14.48**	77.62	76.85	**77.24**
Mean	**13.59**	**13.33**	**13.46**	**75.89**	**71.18**	**73.54**
LSD at 5%						
Genotype (G)	0.60	**0.84**	0.51	4.51	**6.38**	3.87
Crop-year (C)		**n. s.**			******	
G×C		**0.73**			**5.54**	

sugar recovery percentage (16.24%) was recorded by genotype No.3, moreover, across crops; the best mean sugar recovery percentage (15.60%) was recorded by the genotype No.3. Across crops; the highest genotype (No.3) exceeded the check varieties ‘Ph8013’ by 2.37 % and ‘T.54-9’ by 1.93 %. Similar results were reported by El-Taib (1999) and Tahir *et al.* (2014), who found significant differences among genotypes and the interaction between genotypes, however, insignificant differences existed between crop-year for sugar recovery percentage.

For sugar yield (ton/fed), the genotype No.27 recorded the highest mean sugar yield (ton/fed) in the plant cane (9.65 ton/fed), while in the first ratoon, the highest mean sugar yield (9.50 ton/fed) was recorded by genotype No.3, in addition for across crops; the highest mean sugar yield (9.02 ton/fed) was recorded by the genotype No.10. Across crops; the best genotype (No.10) exceeded the check variety ‘Ph8013’ by 1.83 ton/fed but was lower than the other check variety ‘G.T.54-9’ by 0.87 ton/fed. Castillo *et al.* (2007), Mohamed and El-Taib (2007) and Bell *et al.* (2008), found significant differences among genotypes and insignificant interaction between genotypes and crop-year for sugar yield (ton/fed).

CONCLUSION

It can be concluded that the highest sugar yield was recorded with clones, G2009-10 (9.02 ton/fed), G2009-27(8.25

Table 6 Mean performance of sugar cane genotypes for sugar recovery% and sugar yield (ton/fed) in plant cane, first ratoon and across crops during 2012-2014 seasons

Genotype	Sugar recovery%			Sugar yield (ton/fed)		
	Plant cane	First ratoon	Across crops	Plant cane	First ratoon	Across crops
1	13.39	14.23	**13.81**	4.17	6.57	**5.37**
2	13.61	14.59	**14.10**	7.13	9.37	**8.25**
3	14.96	16.24	**15.60**	6.27	9.50	**7.89**
4	13.62	14.34	**13.98**	4.46	4.54	**4.50**
5	9.27	11.13	**10.20**	5.41	2.58	**3.99**
6	14.86	15.45	**15.16**	6.41	9.37	**7.89**
7	9.52	10.84	**10.18**	8.38	6.58	**7.48**
8	14.63	15.27	**14.95**	5.72	5.63	**5.68**
9	11.79	12.79	**12.29**	4.66	7.09	**5.88**
10	13.78	14.65	**14.22**	9.01	9.03	**9.02**
11	15.14	15.61	**15.37**	7.42	8.81	**8.11**
12	14.53	15.07	**14.80**	8.61	7.42	**8.01**
13	13.57	14.43	**14.00**	4.46	7.13	**5.80**
14	10.63	11.36	**10.99**	3.30	4.04	**3.67**
15	14.43	14.80	**14.62**	6.04	7.67	**6.86**
16	11.73	10.89	**11.31**	5.22	5.07	**5.14**
17	10.07	6.58	**8.33**	2.68	2.06	**2.37**
18	13.57	9.18	**11.37**	8.84	5.48	**7.16**
19	11.83	11.15	**11.49**	5.03	5.64	**5.34**
20	11.34	7.58	**9.46**	5.32	3.40	**4.36**
21	15.34	13.61	**14.48**	8.22	8.11	**8.17**
22	11.56	10.00	**10.78**	3.13	2.00	**2.57**
23	12.99	12.57	**12.78**	7.14	7.58	**7.36**
24	13.04	9.32	**11.18**	9.10	3.21	**6.16**
25	9.10	7.55	**8.33**	3.94	3.42	**3.68**
26	13.47	11.57	**12.52**	5.50	6.82	**6.16**
27	15.91	13.92	**14.91**	9.65	6.86	**8.25**
28	12.55	9.51	**11.03**	4.36	2.65	**3.51**
29	15.91	12.77	**14.34**	6.87	7.00	**6.94**
30	10.09	10.63	**10.36**	7.35	8.23	**7.79**
'GT54-9'	13.18	14.15	**13.67**	8.17	8.13	**8.15**
'Ph8013'	12.91	13.54	**13.23**	6.82	7.56	**7.19**
Mean	**12.47**	**11.91**	**12.19**	**6.21**	**6.20**	**6.21**
LSD at 5%						
Genotype (G)	0.72	**1.12**	0.66	0.50	**0.76**	0.45
Crop-year (C)		**n.s.**			**n.s.**	
G×C		**0.94**			**0.64**	

ton/fed), G2009- 2(8.25 ton/fed), and G2009-21 (8.17 ton/fed), respectively, indicating that they have greater promise and can be evaluated in subsequent regional selection programs in different maturity levels.

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Management and weather based fore warning system for pokkah boeng disease in sugarcane caused by *Fusarium moniliforme.* Sheldon

N RAJA KUMAR*, V GOURI and T CHITKALA DEVI

Regional Agricultural Research Station, Anakapalle- 531 001, Andhra Pradesh, India.

ABSTRACT

Pokkah boeng caused by *Fusarium moniliforme.* Sheldon, is an important disease in sugarcane growing areas of Andhra Pradesh during monsoon period. An experiment was carried out at Regional Agricultural Research Station, Anakapalle during 2011-2012 to 2015-16 growing seasons to study the relation of weather factors with the incidence and spread of top rot in sugarcane crop. The study revealed that, percent disease index (PDI) was influenced by rainfall and relative humidity (RH) at 2 hours showing significant positive correlation, while evaporation showed significant negative correlation. Other weather parameters were insignificant with positive values for minimum temperature and morning RH and negative values for maximum temperature. The disease initiation coincided with summer showers and progressed linearly through the season and gradually reduced towards the end of the growing season depicting a sigmoidal disease curve. Receipt of rains coupled with relative humidity levels above 50% recorded at 2 hours favours the primary infection of the crop and progresses rapidly with increase in rainfall coupled with higher humidity levels. By employing step down linear regression models, based on preceding monthly averages, the incidence of top rot on sugarcane can be predicted with an accuracy of 85%. Sett treatment + foliar spray with Carbendazim -0.05% showed the highest percent germination and also low disease incidence of pokkah boeng disease (84.16 and 5.84) respectively.

Keywords: Correlation, Regression equation and management, Top rot, Weather forecasting.

Sugarcane is one of the important cash crop of India and plays a pivotal role in both agricultural and industrial economy of the country. India is one of the largest producers of sugar and is in close competition with Brazil for the top position. During 2014-15, India ranked second in the world (22 % in world's production) with an average production of 352.14 million tonnes of sugarcane in an area of about 5.01 million hectares. The state of Andhra Pradesh ranked seventh in sugarcane area of the country with an area of 0.139 m/ha (Sugar statistics 2016). To cater the crushing requirement of sugar factories operated in the country, India needs to produce more than 320 million tons of sugarcane.

Sugarcane crop is infected by different kinds of pathogens *viz.*, fungi, bacteria, viruses and phytoplasmas. Among the diseases of sugarcane, pokkah boeng is caused by the fungus (*Fusarium moniliforme)*. It may cause serious yield losses in commercial plantings. Many outbreaks of the disease have been reported so far, but they have caused little economic loss. *F. moniliforme* var. *subglutinans* reduces the quality of the harvested crop especially of the varieties with the high sugar yields and the loss is up to 40.8-64.5% of sugar production depending upon the variety. It has not been of major importance to Indian sugarcane industry till date but due to the change in the environmental factors and sudden cyclonic rains, this disease became a major one in almost all the sugarcane growing states of India especially Maharashtra, Gujarat, Madhya Pradesh, Karnataka and Andhra Pradesh in recent years (Viswanathan and Rao, 2011). Under the present changing climatic scenario, with favourable conditions conducive to disease prevalence, top rot may result in severe crop losses. Hence, the present study was conducted to know the epidemiology of the disease with special reference to vital weather variables on the top rot incidence and spread.

MATERIALS AND METHODS

This experiment was carried out during 2011-12 to 2015-16 at Regional Agricultural Research Station, Anakapalle to know the relation of environmental factors on incidence and spread of pokkah boeng disease in sugarcane under rainfed situations.

The sugarcane variety 'CoA 99082' (Sarada) susceptible to pokkah boeng was planted during the month of February by following all recommended package of practices for sugarcane. Monthly weather data *viz.*, number of rainy days, rainfall, minimum and maximum temperatures, relative humidity, wind velocity, bright sunshine hours (BSSH) and evaporation was recorded at automatic weather station, Regional Agricultural Research Station, Anakapalle. The experiment was carried out in three plots of 10 x 10 m^2 area each and the data on total number of canes and number of canes infected by the pokkah boeng disease was taken every time. The data on percent disease incidence (PDI) was calculated every month from planting to harvest. The data on disease incidence at fortnightly

*Corresponding author's E-mail: rajkumar1016@gmail.com

intervals was recorded up to the harvest of the crop and mean of the three plots was taken, and the weather parameters were correlated using XLSTAT ver.2013.5 software. For the management of pokkah boeng, a separate RBD experiment was carried out from 2011-12 to 2015-16 with 4 treatments and five replications. Data on germination percentage at 45 days after planting and percent disease incidence (PDI) was recorded and the data was analyzed by using AGRISTAT software.

RESULTS AND DISCUSSION

The mean of five years experimental data on the incidence of pokkah boeng and weather variables presented in Fig. 1 revealed that under rainfed conditions, the weather factors during the months of July to October favoured high disease incidence and disease spread (PDI 13.9 to 28.6%). During this period, a total of 803.07 mm rainfall was received in 38.69 rainy days coupled with RH-II in the range of 64.4 to 72.1% and low evaporation losses (3.1 to 4.0 mm), which resulted in higher disease incidence. The disease initiation occurred when the crop received its first showers of the season *i.e.* during April-May, wherein the average rainfall was in the range of 27.9 to 77.3 mm. Similar observations were made by several workers (Wang *et al*. 2017) in other crops, wherein rainfall played a crucial role in the disease incidence and further spread. During the month of August, a sudden increase in rainfall (231.64 mm) coupled with high RH-II (72.14%) resulted in the rapid buildup of the disease and the disease incidence reached to the maximum (PDI 27.38%) towards the maturity *i.e.* by September month (Table 1). Vishwakarma *et al.* (2013) reported that disease incidence levels of pokkah boeng were higher with

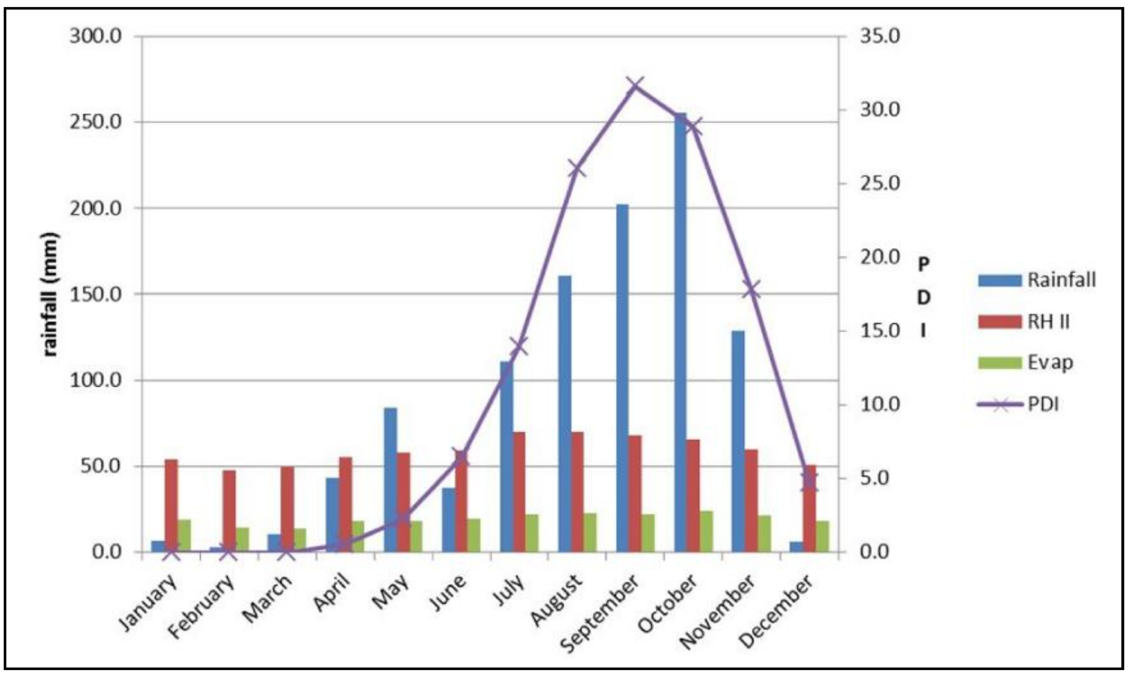

Fig. 1. Pokkah boeng disease progress during crop growth period (2011-2016).

Table 1   Average incidence levels of Top rot in relation to weather variables (2011-2016)

Month	Rainfall	No of rainy days	T_{Max}	T_{Min}	RH I	RH II	Wind velocity	BSSH	Evap	PDI
January	4.40	0.17	29.67	14.52	94.40	52.95	0.47	6.65	3.18	0.00
February	1.30	0.17	31.72	15.67	92.94	45.14	1.89	5.90	4.20	0.00
March	2.65	0.17	34.85	18.97	88.15	43.14	2.24	6.73	5.45	0.65
April	27.99	1.34	36.12	22.59	85.75	49.89	2.04	6.73	5.78	2.33
May	77.39	4.67	37.03	24.24	84.54	55.34	2.25	6.33	5.90	7.43
June	84.45	6.50	36.20	24.54	84.77	56.52	1.25	4.15	4.80	11.15
July	105.32	8.67	33.45	23.47	90.59	68.00	1.34	2.55	4.02	13.55
August	231.64	12.34	33.24	22.90	92.77	72.14	1.25	3.78	3.58	22.98
September	165.42	8.34	33.10	22.64	92.15	65.89	0.94	3.85	3.13	27.38
October	300.69	9.34	32.54	21.82	88.92	64.45	2.89	4.03	3.35	28.60
November	74.05	3.17	31.20	19.52	87.42	58.80	1.71	4.93	3.08	8.90
December	13.97	2.00	30.57	17.75	87.57	50.15	2.75	5.08	3.30	2.05

higher humidity values of 70-80%, which is in agreement with the present findings.

The rainfall distribution during experimental period might have favoured conidial germination, multiplication and disease development. In general, the environmental conditions were favourable for the outbreak of disease during the experimental period over the three years. Hence, a higher level of top rot or pokkah boeng was observed. The results obtained are in agreement with the findings of Vishwakarma *et al.* (2013) in sugarcane.

Correlation of PDI with weather parameters

The PDI obtained at different stages of crop growth were correlated with weather parameters prevailing during the crop growth period under the rainfed farming situation. The correlation coefficients presented in Table 2 revealed that during the experimental period, the maximum temperature was positively correlated with PDI and are not significant (r = 0.361), whereas minimum temperature was negatively correlated with r value of -0.273 and also not significant. Thus, the temperature was found to have no role in the disease incidence and spread with respect to the top rot or pokkah boeng disease of sugarcane. However, studies remain to be conducted to know the role of temperature on the incubation of the conidial inoculum of the pathogen with respect to the crop growth stage on inciting the disease and its further spread.

vital role in conidial dispersal leading to steady progress of the disease at the later stages (Table 1). A sudden increase in the disease was observed in the month of July (PDI 13.9%) as compared to the previous month (PDI 6.5%) which coincided with the most susceptible stage of the crop to the disease (Viswanathan and Padmanaban 2008) with high rainfall (110.9 mm), that in turn, might have resulted in rapid secondary infection under field conditions.

Linear regression equations for disease prediction

The data was subjected to step down regression by eliminating the non-significant factors and to identify significant factors for predicting the incidence of pokkah boeng using XLSTAT ver. 2013.5 software and the statistical parameters are given in Table 3. By employing step down linear regression equations obtained (Table 4) under the rainfed farming situation, in which usually the crop is grown at farmers level, the incidence of pokkah boeng can be predicted to an extent of 85% accuracy. The high R^2 values under regression models confirm the validity of the model in estimating the percent disease index. Further, very minimal differences were found between observed and predicted values of PDI (Fig. 2), when average, actual and predicted values were plotted using the linear regression equations developed in the present study.

Table 2 Correlation matrix of PDI levels of top rot with major weather variables

Variable	Rainfall	T_{Max}	T_{Min}	RH I	RH II	Evap	PDI
Rainfall	1	-0.101	0.465	-0.035	**0.835**	-0.512	**0.940**
T_{Max}	-0.101	1	**0.733**	**-0.745**	-0.013	**0.879**	-0.273
T_{Min}	0.465	**0.733**	1	**-0.742**	**0.658**	0.361	0.361
RH I	-0.035	**-0.745**	**-0.742**	1	-0.188	-0.550	0.064
RH II	**0.835**	-0.013	**0.658**	-0.188	1	-0.434	**0.843**
Evap	-0.512	**0.879**	0.361	-0.550	-0.434	1	**-0.674**

RH-I values were positively correlated with PDI (r = 0.064) but were not significant. RH-II observed to have more effect on the disease incidence, showing positive and significant correlation with the top rot incidence (r = 0.843). Evaporation was another weather variable which had a significant correlation with PDI of pokkah boeng but was negatively correlated (r = -0.674). The low evaporation led to conducive microclimate under field conditions along with increased humidity levels, that resulted in enhanced activity of the inoculum was leading to higher disease levels.

Rainfall was significantly and positively correlated with PDI under field conditions during the entire period of the crop growth. Several workers (Wang *et al.* 2017; Gud *et al.* 2007) reported favourable influence of rainfall on disease development in different crops. During the period of investigation, the rainfall data showed that sufficient amount of rainfall was received during the crop growth which helped in the disease incidence during the early stages and played a

Table 3 Summary for the significant variables affecting top rot disease incidence and spread

Variable	Mean	Standard deviation
a. Quantitative variables		
Rainfall	87.433	85.127
RH II	59.011	7.904
Evaporation	19.500	3.116
b. Dependant variable		
PDI	11.025	12.193

Table 4 Regression equations for top rot of sugarcane (with significant variables)

Multiple regression	Equation	R*	Adj $R^{2@}$
Linear	Average PDI = -17.504 + 0.108*Rainfall + 0.2152*RH II + 0.329*Evap	0.946	0.856

@ R : Coefficient of correlation

*Adj R^2 : Adjusted coefficient of determination

Table 5 Management of top rot of sugarcane during 2012-13 to 2015-16

	Treatments	Germination (%)	PDI
T1	Sett treatment- Overnight soaking with Carbendazim- 0.1% a.i.	83.56	13.14
T2	Foliar spray- Carbendazim -0.05% a.i. (3 sprays at 15 days interval from May 15th)	80.32	10.43
T3	Sett treatment (T1) + Foliar spray- Carbendazim-0.05% (T2)	84.16	5.84
T4	Control	68.52	31.86
	SE+	2.06	3.32
	CD at 5 %	NS	8.43
	C.V. %	6.21	13.54

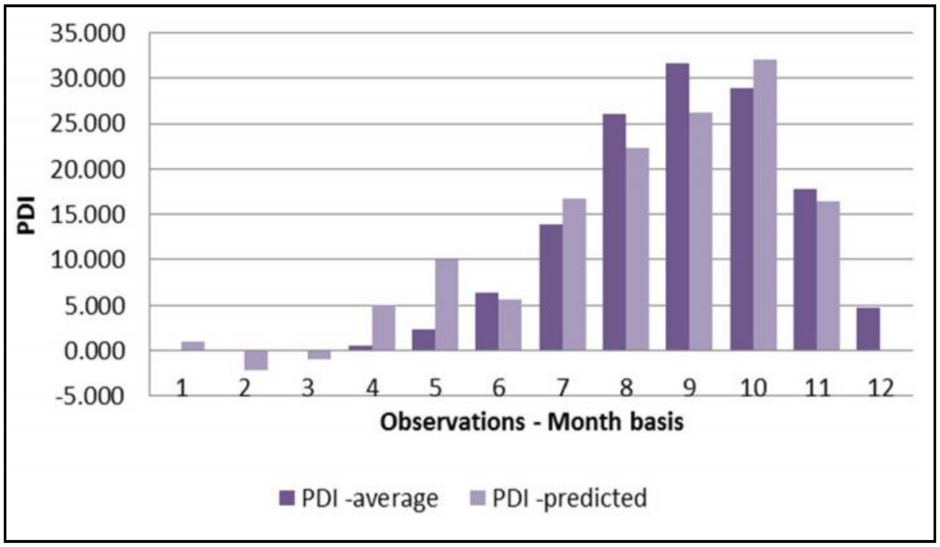

Fig. 2. Observed and predicted percent disease incidence of pokkah boeng.

Correlation of PDI with weather parameters

The PDI obtained at different stages of crop growth were correlated with weather parameters prevailed during the crop growth period under rainfed farming situation. The correlation coefficients presented in Table 2 revealed that during the experimental period, maximum temperature was positively correlated with PDI and was not significant (r = 0.361), whereas minimum temperature was negatively correlated with r value of -0.273 and also not significant. Thus, the temperature was observed to have no role in the disease incidence and spread with respect to the top rot disease of sugarcane. However, studies have to be conducted to know the role of temperature on the incubation of the conidial inoculum of the pathogen with respect to the crop growth stage on inciting the disease and further spread.

RH-I values were positively correlated with PDI (r=0.064) but were not significant. RH-II was observed to have more effect on the disease incidence, showing positive and significant correlation with the top rot incidence (r = 0.843). Evaporation is another weather variable which had significant correlation with PDI of top rot but was negatively correlated (r = -0.674). As the lower evaporation led to conducive micro climate under field conditions and increased humidity levels, the inoculum activity was enhanced leading to higher disease levels.

Rainfall was significantly and positively correlated with PDI under field conditions during entire period of the crop growth. Several workers (Gud *et al.* 2007 and Hiremath *et al.* (1990) reported favourable influence of rainfall on disease development in different crops. During the period of investigation, rainfall data showed that sufficient amount of rainfall was received during the crop growth and it helped in the disease incidence during the early stages and further played vital role in conidial dispersal leading to steady progress of the disease at the later stages (Table 1). A sudden increase in the disease was observed in the month of July (PDI 13.9) compared to the previous month (PDI 6.5) which coincided with the most susceptible stage of the crop to the disease (Viswanathan and Padmanaban 2008) with high rainfall (110.9 mm), might have resulted in rapid secondary infection under field conditions.

Management of pokkah boeng disease

Results presented in table 5 revealed that T3 treatment showed the highest percent germination and also low disease incidence of pokkah boeng disease (84.16 and 5.84) respectively compared to the other treatments.

CONCLUSION

Forecasting the incidence and spread of foliar diseases helps in adopting effective fungicidal spray schedule. The correlation and regression analysis clearly indicated that rainfall and RH-II are the major weather factors influencing the incidence and spread of pokkah boeng (top rot) disease. The Linear-regression models were found to be precise for predicting pokkah boeng (top rot) incidence and its further spread. Hence, these regression-based equations after validation can be utilized in Agro-Advisories for pokkah boeng (top rot) prediction of sugarcane.

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'CoLk 09204' (Ikshu-3)-a new midlate maturing high yielding sugarcane variety for North West Zone of subtropical India

SANJEEV KUMAR*, J SINGH, P K SINGH and D K PANDEY

ICAR-Indian Institute of Sugarcane Research, Lucknow-226002, U.P.

ABSTRACT

A new midlate maturing high yielding sugarcane variety 'CoLk 09204' (Ikshu-3) was developed from the progeny of the bi-parental cross 'CoLk 8102' x 'CoJ 64' and subsequently evaluated in clonal generations. 'CoLk 09204' was proposed and accepted as midlate maturing clone for multi-location testing in the North West Zone of All India Coordinated Research Project on Sugarcane during 2009. 'CoLk 09204' was tested in zonal varietal trials along with popular standard varieties *viz.,* 'CoS 767', 'CoS 8436' and 'CoPant 97222' for its performance regarding cane yield and its components, quality traits and resistance to major diseases and insect pests for three consecutive years 2012-13 to 2014-15. It has given excellent performance in the zonal varietal trials with commercial cane sugar and cane yield of 9.30 and 82.8 t/ha, respectively. The variety has shown an improvement of 19.83%, 13.11% and 9.96% for cane yield over the standard varieties 'CoS 8436', 'CoPant 97222' and 'CoS 767', respectively. It has also shown an improvement of 11.51%, 5.32%, and 5.20% for CCS yield over the standard varieties 'CoS 8436', 'CoS 767' and 'CoPant 97222', respectively. For sucrose% in juice at harvest (360 days), 'CoLk 09204' recorded an average value of 17.0 % for two plant and one ratoon crop across nine locations in the North West Zone which is comparable and *on par* to the best standard 'CoS 767' (17.1%). Ratoon performance of 'CoLk 09204' was assessed along with the popular standard varieties and it was found that this variety had very good ratooning potential. No disease was noticed under natural field condition in 'CoLk 09204' while it had shown resistant to moderately resistant reactions to *Cf* 08 and *Cf* 09 red rot pathotypes under artificial inoculation conditions. It had also shown least susceptible reaction to the borer complex. 'CoLk 09204' is a high yielding, tall growing variety and could be easily identified through its lush green cane top having large drooping leaves. Based on the superiority of the 'CoLk 09204' over standards in 2 plant + 1 ratoon crop for cane yield and quality traits over nine locations, it has been identified as new variety of sugarcane by the Varietal Identification Committee for its release. Later on, it has been notified through the Gazette of India No. S.O. 1379 (E) dated 17 March, 2018 and released for commercial cultivation in North West Zone comprising of Central and Western parts of Uttar Pradesh, Uttarakhand, Haryana, Punjab and Rajasthan.

Keywords: 'CoLk 09204', Variety, Midlate, Sugarcane

Sugarcane is one of the most important agro-industrial crop grown in India. It is cultivated over 5.0 million hectares area with the total production of 350 million tonnes. Sugarcane is grown in both tropical and subtropical India. In subtropical India, it is cultivated as cash crop mainly in Uttar Pradesh, Uttarakhand, Haryana, Punjab and Rajasthan of North West Zone. This zone is very important as for as sugarcane area and its production are concerned. It occupies over 50% area of the total sugarcane acreage in India. In recent years, sugarcane productivity and sugar recovery have improved with the adoption of new high sugar and high yielding varieties in this zone, particularly in Uttar Pradesh. Analyzing the varietal scenario in Uttar Pradesh, the proportion of early maturing varieties has been increased up to 60%. Harvesting of early maturing varieties in the late crushing season may negatively impact on sugar recovery and cane productivity. As per the ideal varietal proportion and harvesting schedule, it is recommended that early maturing varieties should be 30-35% and remaining area should be under high sugar and high yielding midlate maturing or main season varieties. Keeping in the view, a high yielding and high sugar midlate maturing variety 'CoLk 09204' of sugarcane has been released and notified for commercial cultivation in North West Zone.

Further, unavailability of suitable high sugar and high yielding midlate maturing sugarcane variety for North West Zone, a concerted research efforts for varietal improvement was initiated and carried out by ICAR-Indian Institute of Sugarcane Research, Lucknow. The results of carefully planned hybridization programme including selection of suitable parents and their utilization, followed by rigorous selection for high cane and sugar yield reflected in the form of improved varieties identified for commercial cultivation in the area. This paper is aimed to discuss newly released midlate maturing sugarcane variety 'CoLk 09204' for North West Zone as one of the end products of such concerted efforts along with its salient features.

MATERIALS AND METHODS

'CoLk 09204', a high yielding and high sugar midlate maturing sugarcane genotype was developed through

*Corresponding author's E-mail: sanjeev.kumar6@icar.gov.in

selection from the progenies of a bi-parental cross 'CoLk 8102' x 'CoJ 64' at ICAR- Indian Institute of Sugarcane Research, Lucknow. This particular cross was attempted at National Hybridization Garden, Coimbatore during the crossing season 2003. Fluff was sown in the glass house to raise the seedlings and thereafter it was transplanted in the field condition for its evaluation and selection. The genotype was selected from the original seedlings and tested under different clonal stages for quality and yield attributes. It was also screened for red rot reaction and finally evaluated for cane yield in pre zonal varietal trial under plant as well as ratoon crops. The clone was accepted for multi-location testing under zonal varietal trials of North West Zone of All India Coordinated Research Project on Sugarcane during 2009 and designated as 'CoLk 09204'. The clone was evaluated against popular standard varieties for its performance of yield and its attributes, quality parameters and resistance reaction to major diseases at nine locations for three consecutive years (2012-2015). Ramburan (2018) reported that strong variety x season interaction shall be exploited more aggressively in irrigated sugarcane selection programme.

The final trials i.e. Advance Varietal Trials comprising of five promising sugarcane clones, 'Co 09022', 'CoH 09264', 'CoLk 09204', 'CoPb 09214' and 'CoS 09232' along with three popular standard varieties 'CoS 767', 'CoPant 97222' and 'CoS 8436' were conducted for two plant and one ratoon crops at nine locations of the North West Zone. These experiments were laid out in randomized complete block design with three replications having plot size of eight rows of six meters and inter row spacing of 90 cm. Recommended agronomic package of practices were followed to raise the good and healthy crop stand during the crop seasons as per the technical programme. The observations on cane yield and its attributes like number of millable canes, single cane weight, stalk length and diameter etc and quality parameters like brix%, sucrose content in juice, purity%, CCS%, fibre content and extraction% were recorded as per schedule. Juice quality analysis was carried out at harvest stage in plant as well as ratoon crops as per standard procedures (Meade and Chen 1977). The commercial cane sugar (CCS) yield was estimated by multiplying the cane yield and CCS% and used as major criterion for ranking of the best performing clones. The test clones were also screened for resistance to major diseases and insect pests and rated accordingly. Statistically analyzed data from all the locations were presented during biennial workshop of AICRP(S) and published in the Principal Investigators' Reports (2014, 2015). Molecular profiling of 'CoLk 09204' was done with 07 SSR markers along with other some varieties including standards.

RESULTS AND DISCUSSION

Based on the mean performance over two plant and one ratoon crops at nine locations, 'CoLk 09204' was identified for its release and notification by the Varietal Identification Committee during 2017 and later on released and notified in 2018 vide Gazette Notification No. S.O. 1379 (E) dated March 27, 2018. Salient features of 'CoLk 09204' are being presented in Fig. 1, 2, 3 and as below.

Fig. 1 Crop view of 'CoLk 09204'

Fig. 2 Unexposed colour of internode

Fig. 3 Exposed colour of internode

Cane and sugar yields

'CoLk 09204', a high yielding midlate maturing variety recorded cane yield of 82.9 t/ha averaged over two plant and one ratoon crops at nine locations. It showed an improvement of 9.96%, 19.83% and 13.11% over popular standard varieties 'CoS 767', 'CoS 8436' and 'CoPant 97222', respectively. As far as commercial cane sugar (CCS) yield is concerned, it had produced 9.30 t/ha which was an improvement of 5.32%, 11.51% and 5.20% over best standards 'CoS 767', 'CoS 8436' and 'CoPant 97222', respectively (Table 1). Kumar *et al*. (2007) suggested that varieties found most stable with high CCS yield under given set of conditions having dynamic stability.

Yield components

Manifestation of cane yield mainly depends on its component traits like number of millable canes, single cane weight, cane length and its thickness etc. 'CoLk 09204' had produced 94.46 thousand millable canes per hectare averaged over crops and locations which was numerically *at par* with the best standard 'CoS 767'. The variety 'CoLk 09204' recorded higher single cane weight (0.92 kg) than the best standard 'CoPant 97222' (0.87 kg) for this trait. Low single cane weight in the popular cultivated varieties of sugarcane is one of the limiting factor for the higher cane productivity particularly in subtropical India. Higher single cane weight along with higher NMC in 'CoLk 09204' is an indication of its potential for high cane yield. Kumar *et al.* (2003) studied the direct and indirect effect of different traits on cane yield and revealed that the higher positive direct effect of cane weight was intensified further with marginal indirect effects via number of millable canes and single cane weight. Other important yield parameters like stalk length and diameter were also higher in 'CoLk 09204' as compared to the best popular standard 'CoS 767'.

Quality parameters

Various quality parameters, such as sucrose content in juice, CCS percent, pol% cane, fibre% and extraction percent were recorded at harvest stage and presented in Table 2. The variety 'CoLk 09204' recorded 17.0 percent sucrose in juice at harvest stage which was *at par* with the standard varieties 'CoS 767' (17. %), 'CoS 8436' (17.8%) and 'CoPant 97222' (17.5%). Similarly, 'CoLk 09204' recorded 11.5 % CCS at 12 months stage which was *at par* with the standard varieties 'CoS 767' (11.7%), 'CoS 8436' (12.3%) and 'CoPant 97222' (12.1%). Kumar *et al.* (2002) reported that 'CoLk 94184' had shown higher sucrose percent and CCS% at 10 months of crop stage. Pol in cane (13.2%) and fibre content (13.8%) of variety 'CoLk 09204' at harvest stage were found *at par* with the popular standard varieties. Juice extraction is one of the most important component during the cane crushing which impacts the total sugar recovery of any variety. 'CoLk 09204' had recorded 53.3 % juice extraction which was almost *at par* with popular standard varieties 'CoS 767' (52.4%), 'CoS 8436' (53.7%) and 'CoPant 97222' (54.0%).

Ratoonability

Ratoon performance of 'CoLk 09204' was assessed along with the popular standard varieties and it was found that this variety had very good ratooning potential. Perusal of data presented in Table 1 indicated that 'CoLk 09204' had recorded higher cane yield (71.2 t/ha) compared with the best standard 'CoPant 97222' (67.0 t/ha) in ratoon crop. Similarly, CCS yield was also higher in 'CoLk 09204' (7.90 t/ha) than the standard varieties 'CoS 767' (7.35 t/ha), 'CoS 8436' (7.45 t/ha) and 'CoPant 97222' (7.66 t/ha) in ratoon crop. Milligan *et al.* (1996) studied the inheritance of ratooning ability and its traits among crops in sugarcane.

Reaction to major diseases and insect pests

No disease was noticed under natural field conditions in 'CoLk 09204'. It was observed that 'CoLk 09204' had shown resistant (R) to moderately resistant (MR) reactions against red rot pathotype '*Cf* 08' and '*Cf* 09' under artificial inoculation by plug method during three consecutive years at six locations of North West Zone. Similarly, 'CoLk 09204' exhibited moderately resistant (MR) to (R) resistant reaction against these two pathotypes of red rot under nodal or cotton swab methods at different test locations (Mohanraj *et al.* 1997). In view of the non availability of effective systemic fungicides for controlling red rot under field conditions, breeding for red rot resistance remains the most practical, economical and effective option (Meeta *et al.* 2007 and Kaur *et al.* 2014). 'CoLk 09204' had shown moderately resistant reaction to wilt and smut diseases under natural field conditions. 'CoLk 09204' was also screened for assessing its tolerance to the major insect pests such as top borer, stalk borer and early shoot borer at different test locations. It was observed that 'CoLk 09204' exhibited least susceptible (LS) reaction to top borer, stalk borer and early shoot borer.

Distinguishing characteristics

'CoLk 09204' is a high yielding, tall growing variety and could be easily identified through its lush green cane top having large drooping leaves. 'CoLk 09204' had been characterized based on 27 morphological characters used in the DUS testing (Singh *et al.* 2017). These distinguishing morphological characters of 'CoLk 09204' are presented in the Table 3. In addition, 'CoLk 09204' had also been characterized through molecular profiling with 07 SSR markers along with other varieties including standards (Fig.4a, b, c, d, e, f and g).

Table 1 Performance of 'CoLk 09204' for cane and CCS yield in zonal varietal trials averaged over 2 plant + 1 ratoon at nine locations of North West Zone

Variety	Cane yield (t/ha)					CCS yield (t/ha)				
	Plant-I	Plant-II	Ratoon	Mean	Percent improvement over check	Plant-I	Plant-II	Ratoon	Mean	Percent improvement over check
'CoLk 09204'	89.2	87.9	71.2	82.8		9.89	10.12	7.90	9.30	
Standards										
'CoS 767'	80.7	79.9	65.4	75.3	9.96	9.58	9.55	7.35	8.83	5.32
'CoS 8436'	71.1	72.8	63.3	69.1	19.83	8.75	8.83	7.45	8.34	11.51
'CoPant 97222'	75.5	77.2	67.0	73.2	13.11	9.23	9.65	7.66	8.84	5.20

Table 2 Mean performance of 'CoLk 09204' for quality parameters at harvest stage in zonal varietal trials averaged over 2 plant + 1 ratoon at nine locations of North West Zone

Variety	Sucrose %	CCS %	Pol % cane	Fibre %	Extraction %
'CoLk 09204'	17.0	11.5	13.2	13.8	53.3
Standards					
'CoS 767'	17.1	11.7	13.4	14.1	52.4
'CoS 8436'	17.8	12.3	14.6	13.3	53.7
'CoPant 97222'	17.5	12.1	14.1	13.4	54.0

Table 3 Morphological characteristics (DUS) of sugarcane variety 'CoLk 09204'

Sl. No.	Character	State
1.	Plant growth habit	Semi-Erect
2.	Leaf Sheath: hairiness	Absent
3.	Leaf Sheath: Shape of ligule	Crescent
4.	Leaf Sheath: Shape of inner auricle	Deltoid
5.	Leaf Sheath: Colour of dewlap	Green
6.	Leaf Blade: Curvature	Arched
7.	Leaf Blade: Width	Medium
8.	Plant: Adherence of leaf sheath	Weak
9.	Internode: Colour (Not exposed to sun)	Green (RHS) 139 D
10.	Internode Colour: (Exposed to sun)	Purple (RHS) 77D
11.	Internode: Diameter	Medium
12.	Internode: Shape	Conoidal
13.	Internode: Zig zag alignment	Present
14.	Internode: Growth crack (Split)	Present
15.	Internode : Rind surface appearance	Smooth
16.	Internode: Waxiness	Medium
17.	Node: Shape of bud	Round
18.	Node: Size of bud (Measured from base of bud to the tip)	Medium
19.	Node: Bud groove	Absent
20.	Node: Bud cushion (Space between bud base and leaf scar)	Absent
21.	Node: bud tip in relation to growth ring	Below growth ring
22.	Node: Prominence of growth ring	Weak (not Swollen)
23.	Node: Width of root band (opposite to bud)	Broad
24.	Internode Cross section	Oval
25.	Internode: Pithiness	Present
26.	Plant: Number of millable canes (NMC) per stool	High
27.	Plant: Cane height	Medium

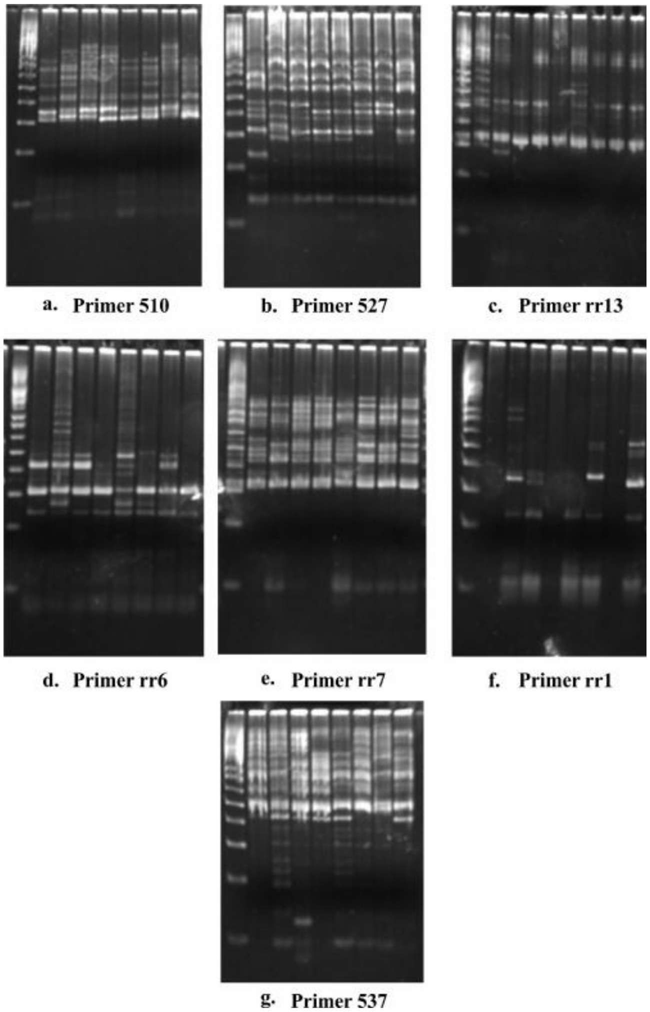

Fig. 4. (a to g): Molecular Profile of variety 'CoLk 09204' along with other varieties with 07 SSR Markers. Left to right: Ladder, 'CoJ 64', 'CoPant 84211', 'CoPb 09181', 'CoLk 09202', 'CoS 767', 'CoS 8436', 'CoPant 97222', 'CoLk 09204').

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Effect of aspirin (Acetyl Salicylic Acid) on sugarcane under moisture stress condition

S P SINGH*, PRIYANKA SINGH and A K TIWARI

U.P. Council of Sugarcane Research, Shahjahanpur-242 001, U.P., India

ABSTRACT

Drought is one of the devastating environmental stresses which limits the sugarcane production in sub-tropical as well as tropical India. The soil moisture reduction leads to imbalance of water potential in plant tissues which in turn results in the reduced crop growth, cane yield and sugar yield. It was found that salicylic acid treatment reduces the damaging effect of water deficiency on growth attributes. To study the performance of Aspirin (Acetyl salicylic acid), six sugarcane varieties *viz.*, 'CoS 95255', 'CoS 96268', 'CoSe 01235' (drought susceptible), 'CoS 97261', 'CoS 96275' and 'CoSe 01424' (drought tolerant) were selected. Results indicate that physiological and biochemical characters such as transpiration rate (TR), stomatal diffusive resistance (SDR), leaf water potential (LWP) and total chlorophyll varied significantly due to the application of 500 ppm of Aspirin. Lower rate of transpiration was observed under water stress condition which declined further after the foliar application of Aspirin. Higher stomatal diffusive resistance (SDR) was noticed under water stress condition which was found to be further enhanced by the spraying of Aspirin. Treated plants retained higher water content in the leaves (LWP). Two sprayings of 500 ppm Aspirin under water stress condition during the formative stage of the crop maintained higher total chlorophyll, leaf water potential, stomatal diffusive resistance with lower rate of transpiration, resulting in significantly higher shoot population, number of millable canes and cane yield.

Key words: Acetyl salicylic acid (Aspirin), Moisture stress, Leaf water potential, Transpiration rate, Stomatal diffusive resistance

Drought an abiotic stress is one of the serious environmental factor affecting plant growth, development and yield in both subtropical and tropical part of India. It induces various physiological and biochemical adaptation in plants. It has been estimated that up to 45% of the world agricultural lands are affected by drought (Bot *et al.* 2000). Water deficiency leads to the perturbation of most of the physiological and biochemical process and consequently reduces plant growth and yield (Boutraa 2010). Many authors have reported that water scarcity reduces the rate of photosynthesis in plant. Leaf water potential (LWP) and osmotic adjustment have been suggested as selection criteria for improving drought tolerance. Leaf water potential has been recognized as index for whole plant water status. Drought is a complex and captivating problem as it involves the plant soil and atmosphere. Abnormal water balance in plant tissues is reported to reduce the growth and yield of cane (Singh and Negi 1959; Singh and Ali 1973; Singh and Reddy 1976). Generally, the varieties possessing low frequency and smaller stomata were more tolerant to drought. In northern India particularly in Uttar Pradesh sugarcane plants are grown under extreme drought conditions caused by high temperature, low humidity and high soil moisture tress. Among three types of drought *i.e.;* soil, atmospheric and physiological, the soil one is most important as it causes major damage to crops.

Aspirin (acetyl salicylic acid), is being used for the treatment of human beings as an anti-pain, anti-inflammatory and fever suppressant drug for more than hundred years. Recently, agriculture scientists discovered that this chemical can induce resistance in plants to pathogens, environmental stresses and to some insects which in turn will enable the plant to grow more vigorously. Spraying of aqueous solution of aspirin on the garden vegetable beds may yield healthier and larger vegetables. Salicylic acid (SA) is a common plant hormone which produces phenolic compound, which is involved in the regulation of photosynthesis related protein expression and in plant defense against biographic pathogens (Miura and Tada 2014). It plays an important role in the regulation of plant growth, development, ripening, flowering and response to sustain biotic stress (Erdal *et al.* 2011; Rivas and Plasencia 2011; Hara *et al.* 2012). Salicylic acid was also found to play an important role in abiotic stress tolerance in plants (Raksin 1992; Pooja and Sharma 2010).

Water stress affects sugarcane crop severely in the form of reduction in growth rate including metabolic changes (Munns 2003). Intricate water supply to roots and comparatively high transpiration rate are two main causes of drought stress and these two conditions coincide under semi arid climates. The effect of water stress varies with the variety, degree and duration of stress and the growth stage of the plant. Salicylic acid has been shown to be an essential signal molecules involved in local defense reactions and plant shows resistance

*Corresponding author's E-mail: shivpalupcsr@gmail.com

response often at the time of pathogen attack by the affect of SA (Loake and Grant 2007). The ameliorative effect of SA on growth of crops under abiotic stress conditions may have been due to its effective role in nutrient uptake, water relation, stomatal regulation and photosynthesis (Khan *et al.* 2003; Arfan *et al.* 2007).

The growth parameters were significantly reduced under the water stress condition; however, foliar application of salicylic acid improves the growth parameters in stress affected plants. The plants under water stress exhibited a significant increase in the activities of nitrate reductase and carbonic anhydrase and electrolyte leakage proline content free amino acid and in pepcarbo-xylase activities. Dhaliwal *et al.* (1997) and Zhou *et al.* (1999) have indicated that SA also increases leaf area in sugarcane. Keeping these studies in view the idea behind the present work was to study the physiological and biochemical alteration attributes by SA in sugarcane plant under water stress condition.

MATERIALS AND METHODS

Planting of the sugarcane

A field experiment was conducted during 2009-10 and 2010-11 at the research farm of UP Council of Sugarcane Research, Shahjahanpur situated at 27.53^{0}N latitude and 79.54^{0}E longitude using six sugarcane varieties *viz*., ‘CoS 95255’, ‘CoS 96268’, ‘CoSe 01235’ (drought susceptible); ‘CoS 97261’, ‘CoS 96275’ and ‘CoSe 01424’ (drought tolerant). Two budded setts were planted, replicated thrice in strip plot design during spring planting season. Crop was raised with normal package and practices.

Maintenance of moisture levels and application of Aspirin

Normal moisture (50% ASM) and deficient moisture (20% ASM) levels were maintained by giving 5 and 2 irrigations, respectively, before the onset of monsoon. Two normal irrigations were given at formative phase to both normal and deficient plots. Normal plots were given 3 more irrigations to maintain 50% available soil moisture, whereas the deficient plots did not receive any further irrigation till the onset of monsoon. Two spraying of 500 ppm of Aspirin (acetylic salicylic acid) and water as control was applied twice in the mid of April and May on both normal and deficient plots.

Observations on physiological and biochemical attributes

Observations on physiological and biochemical parameters were taken after the completion of irrigation and spraying of acetyl salicylic acid. Germination percent was observed at 45DAP. Tillers were counted in the month of June and observation on number of millable canes (NMC) was carried out in the month of October. Crop was harvested in the month of March at 12 month of crop age and yield was calculated. Juice quality parameters were estimated using standard laboratory methods (Meade and Chen 1977).

Stomatal diffusive resistance (SDR) and transpiration rate (TR) on abaxial leaf surface at the mid portion of first fully expanded leaf was measured in normal and moisture deficient plants at the formative phase of the crop between 7 to 9 AM with the help of Li-16000 steady state porometer (LI-COR Inc Lincoln, Nebraska (USA) and by using narrow leaf apparatus (1cm^2) simultaneously. Leaf water potential was measured by “Plant water status console model 3005”, (Soil moisture equipment corporation, USA). Total chlorophyll content was measured using the standard method. The fresh leaves were grounded in the mortar and pestle containing 80% acetone. The optical density (OD) of the solution was evaluated at 662 and 642 nm (Chlorophyll a and b) using spectrophotometer (Shimadzu UV- 1700UK). The data were analyzed statistically and mean value was compared.

RESULTS AND DISCUSSION

Effect of Aspirin spray on yield attributes

The study revealed that the overall response of varieties to drought stress resulted in a significant reduction in growth and yield. Foliar spray of SA exhibited significant improvement in the growth attributes as compared to untreated SA plants. Significant reduction in shoot population, number of millable canes (NMC) and cane yield was observed under deficient moisture condition where only two pre monsoon irrigations were applied. Shoot population was found higher in SA treated plot than in control. However, among the varieties ‘CoSe 01424’, ‘CoS 96275’ and ‘CoS 95255’ gave significantly higher shoots, NMC and cane yield under water stress condition which was still higher in aspirin treated (500 ppm) crop. All the varieties gave higher yield under SA receiving plots than in control (Table 1 & 2). The deficiency of soil moisture led to imbalance of water potential in plant tissues which resulted in the reduced crop growth, cane yield and sugar yield (Meena *et al.* 2013). The effect of SA on growth of crop plants under abiotic stress condition may be due to enhanced nutrient uptake, water relation stomatal regulations and photo synthesis. Water stress is characterized by wilting, closure of stomata and decreasing cell enlargement and growth due to reduction of water content, turgor and total water potential. The stem length and number of leaf per plant were reduced by drought stress (Reddy *et al.* 2003; Sundaravalli *et al.* 2005). SA treated plants exhibited an increase in tolerance to water stress. This increase in water stress tolerance was reflected in the measured growth criteria, number of tillers, millable canes and yield were increased as compared with plants facing water stress without SA application.

Effect of Aspirin spray on physiological and biochemical parameters

Drought stress reduced the total chlorophyll content to a significant extent in water deficient plants in all the varieties. The total chlorophyll was found to be numerically higher in moisture stressed plant with aspirin application than the control one. All the genotypes expressed higher total chlorophyll both

Table 1 Effect of acetyl salicylic acid (Aspirin) on physiological and biochemical characters of sugarcane crop under moisture stress condition

Variety	Deficient (D)/ Normal (N)	Total chlorophyll (mg/g fresh leaf)		Transpiration rate (µg/cm^2/s^{-1})		SDR (cm^2/S^{-1})		LWP (- bar)	
		Water spray	Aspirin 500ppm	Water spray	Aspirin 500ppm	Water spray	Aspirin 500ppm	Water spray	Aspirin 500ppm
'CoSe 01424'	D	1.21	1.26	8.05	7.82	3.07	4.06	9.61	9.20
	N	1.68	1.72	9.42	9.41	1.32	1.36	8.78	8.77
'CoS 97261'	D	1.27	1.32	7.77	7.61	3.23	3.98	9.70	9.29
	N	1.57	1.82	9.70	9.70	1.21	2.21	8.33	8.34
'CoS 96275'	D	1.36	1.41	7.51	7.36	2.27	4.38	9.66	9.29
	N	1.56	1.76	9.81	9.80	1.42	1.42	8.66	8.69
'CoSe 01235'	D	1.17	1.25	7.56	7.16	2.87	3.05	6.68	8.28
	N	1.58	1.58	9.71	9.71	1.26	1.27	7.92	7.93
'CoS 95255'	D	1.22	1.24	7.18	6.91	3.09	3.82	9.51	9.24
	N	1.60	1.72	8.89	8.81	1.37	1.39	8.63	8.65
'CoS 96268'	D	1.18	1.26	7.29	6.94	2.69	3.86	9.25	9.00
	N	1.40	1.51	9.05	9.03	1.45	1.45	8.27	8.25
	Mean D	1.23	1.29	7.56	7.30	2.87	3.69	9.06	9.05
	Mean N	1.60	1.69	9.43	9.41	1.34	1.35	8.42	8.43
	Total mean	1.47	1.49	8.49	8.36	2.10	2.52	8.92	8.74
	SE/CD (Variety)	0.02/0.06		0.19/ NS		0.068/0.171		0.07/0.18	
	SE/CD (Treatment)	0.03/0.08		0.32/0.70		0.07/1.51		0.05/0.18	
	SE/CD (Interaction)	0.026/NS		0.22/ NS		0.22/ NS		0.46/ NS	

Table 2 Effect of acetyl salicylic acid (Aspirin) on growth, yield and quality of sugarcane crop under moisture stress condition

Variety	Deficient (D)/ Normal (N)	Shoots (000/ha)		Millable canes (000/ha)		Sucrose (%)		Cane yield (t/ha)	
		Water spray	Aspirin 500ppm	Water spray	Aspirin 500ppm	Water spray	Aspirin 500ppm	Water spray	Aspirin 500ppm
'CoSe 01424'	D	153.4	163.0	121.4	131.3	16.18	16.15	87.2	88.2
	N	185.7	188.9	135.7	136.9	16.16	16.17	93.8	93.9
'CoS 97261'	D	140.7	146.6	113.5	130.9	16.52	16.52	76.8	77.3
	N	176.7	181.5	138.9	139.7	16.39	16.32	80.6	81.7
'CoS 96275'	D	149.2	153.4	130.9	145.2	16.46	16.43	75.8	76.9
	N	187.8	191.5	143.6	142.8	16.49	16.49	78.9	79.3
'CoSe 01235'	D	142.3	146.0	111.1	113.9	17.21	17.09	71.3	71.8
	N	189.9	193.1	135.7	133.3	17.15	17.29	80.1	81.8
'CoS 95255'	D	150.8	152.4	113.5	119.0	16.95	16.98	76.4	77.1
	N	190.4	193.1	132.5	133.3	16.68	16.84	78.9	78.1
'CoS 96268'	D	142.3	144.4	108.7	116.7	17.14	17.15	71.3	71.9
	N	189.4	191.0	126.2	127.0	16.96	17.03	79.3	80.4
	Mean D	146.4	150.9	116.5	126.1	16.74	16.72	76.4	77.2
	Mean N	186.6	189.8	135.4	137.2	16.63	16.69	81.9	82.5
	Total mean	151.8	170.4	126.0	129.2	16.69	16.71	79.2	79.9
	SE/CD (Variety)	1.3/3.2		4.2/ NS		0.001/0.003		0.3/3.0	
	SE/CD (Treatment)	1.6/3.6		8.7/19.0		0.05/ NS		1.0/ NS	
	SE/CD (Interaction)	2.7/NS		2.5/ NS		0.05/0.59		1.8/3.1	

under normal and deficient conditions when aspirin was applied. Maintaining higher chlorophyll in leaves during formative phase of crop due to this chemical seems to be a type of protective mechanism in coping with drought (Table 1). Transpiration rate (TR), stomatal diffusive resistance (SDR) and leaf water potential (LWP) varied significantly due to application of aspirin (500 ppm). Transpiration rate decreased, stomatal diffusive resistance and leaf water potential were increased under water stress condition. Johari *et al.* (2005) and Sharma *et al.* (2009) also observed that drought tolerant varieties exhibited higher total chlorophyll content, leaf water potential and stomatal diffusive resistance along with minimum rate of transpiration under deficient moisture stress condition at formative phase of the crop.

Sucrose percent in juice was not affected significantly due to application of aspirin. Varieties 'CoS 96268', 'CoSe 01235' and 'CoS 95255', however, showed significantly higher sucrose percent in juice as compared to other varieties tested. The sucrose percent was found maximum in the variety 'CoS 96268' under water stress condition.

CONCLUSION

The adverse effects of water stress lead to high mortality of tillers, reduction in growth, cane yield and its contributing traits. Based on the study, it is therefore concluded that the foliar application of aspirin improved the growth parameters in stress affected plants.

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Genetic variability and correlation of foliar characters, HR-brix and juice quality attributes of sugarcane genotypes in ratoon

RADHA JAIN*, ANSHU SINGH and SANGEETA SRIVASTAVA

ICAR-Indian Institute of Sugarcane Research, Lucknow-226002 (U.P.)

ABSTRACT

Twenty one varieties of sugarcane (*Saccharum* sp. hybrid) were ratooned to study genetic variability for different foliar characters and HR-Brix at early stage of ripening. Marked variation was observed among foliar characters *viz*., leaf length, width, area, specific leaf weight, leaf sheath moisture content, chlorophyll a and b contents. The extent of variation ranged between 2.61 to 5.60 g dwt, 3.45 to 6.35 cm, 1.00 to 2.55 mg/g fwt and 0.29 to 0.80 mg/g fwt in leaf dry weight, leaf width, chlorophyll a and b contents, respectively among different varieties which in turn resulted in variation in sugar yields. HR-Brix value varied widely in different portions of cane; it ranged between 15.53 to 21.33 °Brix, 14.66 to 22.06 °Brix and 7.53 to 17.67 °Brix in bottom, middle and top portions, respectively. On overall mean basis, variety 'Co 87263' exhibited highest HR-Brix value (20.42 °Brix), while, lowest Brix was found in variety 'Co 88216' (13.24 °Brix) in the month of October. At harvesting, in the month of December, Brix value was in the range of 21.5 °Brix ('CoS 95255') to 19.2 °Brix ('CoS 91269'), sucrose% juice was in the range of 19% ('CoPant 84211'), 18.7% ('CoS 95255') and lowest 16.1% in variety 'CoS 91269'. Juice purity value was high in varieties 'CoPant 84211' (91.3 %), 'CoPant 90223' (87.1%) and 'CoS 95255' (87%) and lowest in variety 'CoSe 92423' (80.5%). Regression correlation indicated positive correlation among HR-Brix value of whole canes and chlorophyll a, b contents and leaf area while negative correlation with leaf sheath moisture and specific leaf weight at early stage of ripening and positive correlation with juice quality attributes *viz*., Brix, sucrose (%) juice and purity at harvesting.

Key words: Sugarcane, Ratoon, HR-Brix, Leaf attributes, Sucrose content

Maturity is one of the major factors that influence cane yield. Harvesting at appropriate age *i.e.,* peak maturity is necessary to realize maximum yield with possible least field losses (Muchow *et al.* 1998). Brix in standing cane in the field using hand refractometer is the common maturity testing practice for preliminary screening of large number of genotypes for high sucrose content and it has direct relationship with sugar content in cane (Qudsieh *et al.* 2001). Foliar characters have strong relationship with the rate of photosynthesis, cane productivity and sugar translocation (Inman-Bamber 2004). Present investigation was aimed to study the genetic variation and correlation of foliar characters and HR- brix in different parts of millable canes in the month of October and juice quality parameters at harvesting of first ratoon of sugarcane.

MATERIALS AND METHODS

Ratoon of twenty one varieties of sugarcane (*Saccharum* sp. hybrid) was initiated from plant crop in the month of February at the farm of Indian Institute of Sugarcane Research, Lucknow in a randomized block design with three replications. Foliar characters namely; leaf weight, leaf sheath moisture, leaf length, width and area, and specific leaf weight were investigated in the month of October *i.e.,* at 8 month crop stage.

Chlorophyll content was determined in fresh leaves by the method of Arnon (1949). 50 mg fresh leaf material was homogenized in 80% acetone and centrifuged for 10 minutes. The supernatant was collected and absorbance was read at 663 and 645 nm, spectrophotometrically. Chlorophyll contents were calculated using the formula given below, and the amounts were calculated as mg/g fresh weight of leaf:

(1) Chlorophyll a (mg/g fwt) = $((12.7 \times A_{663}) - (2.69 \times A_{645})) \times 0.2$

(2) Chlorophyll b (mg/g fwt) = $((22.9 \times A_{645})-(4.68 \times A_{663})) \times 0.2$

HR-Brix of different portions (top, middle and bottom) of millable canes was determined at early stage of ripening (in the month of October) using Hand Refractometer. After harvesting of ratoon, °Brix, sucrose (%) juice and juice purity were determined at 10 month crop stage (in the month of December). The data obtained from three replications was statistically analyzed using WASP 2.0 Software.

RESULTS AND DISCUSSION

Marked variation was observed among different varieties for foliar characters *viz*., leaf length, width, area, leaf fresh weight and dry weight, leaf moisture, specific leaf weight, leaf sheath moisture, chlorophyll a and b contents. Leaf length ranged between 101 ('Co 88029') to 150 cm ('CoPant 84212'), width from 3.45 ('UP 22') to 6.35 cm ('Co 88029'), leaf area from 256 ('CoJ 64') to 449 cm^2 ('CoS 88230'), leaf fresh weight from 7.19 ('CoS 767') to 16.91g ('CoPant 90223'), dry weight from 2.61 ('CoS 767') to 5.60g ('CoPant 90223'), leaf moisture from

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

61.9 (‘Co 88029’) to 73.37% (‘Co 88216’) and leaf sheath moisture ranged from 66 (‘CoPant 84211’) to 79.64 % (‘CoS 8436’), respectively. Sheath moisture content decreases at senescence as green leaves dry and decrease in number and is inversely related to harvest age (Inman-Bamber 2004). Chlorophyll a content ranged from 1.00 (‘CoPant 84212’) to 2.55 mg/g fresh weight (‘CoPant 90223’) and chlorophyll b from 0.29 (‘CoPant 84212’) to 0.80 mg/g fresh weight (‘CoPant 90223’). Specific leaf weight ranged between 0.66 (‘Co 88216’) to 1.016 g dry weight per 100 cm^2 (‘CoS 8436’) (Table 1 and 2). Variety ‘CoPant 90223’ showed highest chlorophyll a and b contents and, fresh and dry weight of leaf. Chlorophyll content and leaf weight exhibited positive correlation (Table 5).

Sequential accumulation of soluble solid was observed from base to top on different parts of stalks of millable canes. HR-Brix value determined in the month of October varied widely in different portions; it ranged between 15.53 to 21.33 °Brix, 14.66 to 22.06 °Brix and 7.53 to 17.67 °Brix in bottom, middle and top portions, respectively (Table 3). Harvest age enhanced brix content in bottom portion followed by the middle and top portions (Qudsieh *et al.* 2001; Wagih *et al.* 2004; Siswoyoa *et al.* 2007). Brix ratio of bottom to top (B/T) portions was in the range of 0.97 to 2.28 (Table 3). Sugarcane matures when top/bottom brix ratio approaches unity (Hadush *et al.* 2014). Extent of variation among different varieties was 1.37, 1.5 and 2.35 fold for HR- brix in bottom, middle and top part of cane respectively. Level of variation was found highest in top portion (2.35 fold) and least in bottom portion (1.35 fold) among different varieties. The variety ‘CoS 767’ exhibited least variation in Brix value among different portions of cane, while highest variation among different portions of cane was observed in the variety ‘UP 22’. The variety ‘Co 87263’ exhibited highest Brix value (20.42 °Brix) while it was the lowest in variety ‘Co 88216’ (13.24 °Brix). Regression correlation determined among Brix value in the month of October and different foliar characters indicated positive correlation with chlorophyll a, b contents and leaf area and negative correlation with leaf sheath moisture and specific leaf weight (Table 5).

Various juice quality parameters determined at harvesting indicated wide variation among different varieties. Brix value was in the range of 21.5 (‘CoS 95255’) to 19.2 °Brix (‘CoS 91269’); sucrose% juice was in the range of 19% (‘CoPant 84211’), 18.7% (‘CoS 95255’) and lowest 16.1% in variety ‘CoS 91269’. Juice purity value was high in varieties like, ‘CoPant 84211’ (91.3 %), ‘CoPant 90223’ (87.1%) and in ‘CoS 95255’ (87%) and low in variety ‘CoSe 92423’ (80.5%) (Table 4). Juice data at harvesting *viz*., degree Brix, sucrose percent juice and juice purity showed positive correlation with HR-Brix of October month (Table 5). However, in over-aged ratoon cane, the sucrose content is reduced due to heavy lodging and

Table 1 Chlorophyll content, leaf sheath moisture and SLW of sugarcane varieties in ratoon crop.

Variety	Chlorophyll (mg/g fwt)			Leaf sheath	SLW*(g dry
	Chl a	Chl b	Chl a/b ratio	Moisture (%)	wt/100cm^2)
‘CoLk 8102’	2.23	0.71	3.14	74.31	0.75
‘Co 88029’	1.87	0.58	3.22	75.09	0.79
‘CoS 91269’	1.88	0.58	3.24	74.82	0.74
‘CoSe 92423’	2.33	0.73	3.19	66.79	0.75
‘CoS 95255’	2.15	0.69	3.12	71.22	0.69
‘CoPant 90223’	2.55	0.80	3.19	73.57	0.74
‘CoPant 84211’	1.65	0.51	3.24	66.07	0.94
‘CoJ 64’	1.45	0.42	3.45	71.70	0.78
‘Co 87263’	2.19	0.66	3.32	72.42	0.75
‘CoS 687’	2.26	0.68	3.32	67.75	0.78
‘CoS 8436’	1.36	0.40	3.40	79.64	1.02
‘CoJ 84192’	1.77	0.54	3.28	70.96	1.00
‘CoLk 8001’	2.07	0.62	3.34	68.93	0.72
‘Co 1148’	1.03	0.30	3.43	79.15	0.72
‘CoPant 90222’	1.59	0.49	3.24	71.94	0.75
‘UP 39’	1.55	0.44	3.52	66.35	0.79
‘Co 88216’	2.17	0.66	3.29	74.71	0.66
‘UP 22’	1.79	0.54	3.31	71.79	0.82
‘CoS 767’	1.53	0.43	3.56	71.46	0.79
‘CoS 88230’	1.35	0.39	3.46	71.82	0.96
‘CoPant 84212’	1.00	0.29	3.45	73.10	0.73
Mean	1.80	0.55	3.32	72.08	0.76
Range	1.00-2.55	0.29-0.80	3.12-3.56	66.07-79.64	0.66-1.02
Highest	‘CoPant 90223’	‘CoPant 90223’	‘CoS 95255’	‘CoPant 84211’	‘CoS 8436’
Lowest	‘CoPant 84212’	‘CoPant 84212’	‘CoS 767’	‘CoJ 84192’	‘Co 88216’
CV (%)	23.88	26.38	3.74	5.07	12.63

* Specific leaf weight

Table 2 Leaf fresh and dry weight, moisture content and leaf area of sugarcane varieties in ratoon crop

Variety	Leaf length (cm)	Leaf Width (cm)	Leaf area (cm^2)	Leaf Fresh wt (g)	Leaf dry wt (g)	Leaf Moisture (%)
'CoLk 8102'	125	4.70	369	16.64	5.37	67.73
'Co 88029'	101	6.35	402	13.22	5.04	61.90
'CoS 91269'	136	3.60	307	11.78	4.16	64.72
'CoSe 92423'	138	4.90	425	14.63	4.83	67.03
'CoS 95255'	128	3.85	309	13.85	4.51	67.43
'CoPant 90223'	132	4.75	395	16.91	5.60	66.87
'CoPant 84211'	132	4.95	411	14.55	5.25	63.91
'CoJ 64'	107	3.80	256	9.21	3.26	64.91
'Co 87263'	143	3.75	338	10.80	3.77	65.06
'CoS 687'	129	4.95	401	12.24	4.27	65.12
'CoS 8436'	113	4.96	280	13.31	3.70	72.18
'CoJ 84192'	126	4.25	336	9.88	3.51	64.52
'CoLk 8001'	142	4.10	336	11.69	4.31	63.09
'Co 1148'	136	4.00	343	10.58	3.28	68.96
'CoPant 90222'	130	3.90	318	12.39	4.16	66.41
'UP 39'	142	4.40	393	15.45	5.55	64.09
'Co 88216'	120	3.85	291	11.62	3.09	73.37
'UP 22'	121	3.45	263	12.78	3.93	69.24
'CoS 767'	118	3.50	260	7.19	2.61	63.69
'CoS 88230'	146	4.90	449	14.40	5.07	64.78
'CoPant 84212'	150	3.75	353	14.01	4.41	68.48
Mean	129	4.32	344	12.72	4.27	66.36
Range	101-150	3.45-6.35	256-449	7.19-16.91	2.61-5.60	61.90-73.37
Highest	'CoPant 84212'	'Co 88029'	'CoS 88230'	'CoPant 90223'	'CoS 767'	'Co 88029'
Lowest	'Co 88029'	'UP 22'	'CoJ 64'	'CoS 767'	'CoPant 90223'	'Co 88216'
CV (%)	9.90	16.36	16.69	18.97	20.04	4.38

Table 3 Brix value of sugarcane varieties in ratoon crop in the month of October

Variety	^{o}Brix				Brix Ratio Base/Top
	Base	Middle	Top	Whole cane	
'CoLk 8102'	19.46	17.40	14.00	16.95	1.39
'Co 88029'	16.73	15.66	16.20	16.20	1.03
'CoS 91269'	16.80	17.86	16.20	16.95	1.04
'CoSe 92423'	18.86	17.26	11.80	15.97	1.60
'CoS 95255'	21.33	20.00	14.00	18.44	1.52
'CoPant 90223'	19.80	18.06	11.73	16.53	1.69
'CoPant 84211'	19.53	17.13	16.13	17.60	1.21
'CoJ 64'	19.26	18.13	15.00	17.46	1.28
'Co 87263'	21.20	22.06	18.00	20.42	1.17
'CoS 687'	18.46	17.86	15.33	17.22	1.20
'CoS 8436'	18.73	14.66	8.66	14.02	1.82
'CoJ 84192'	17.13	17.13	15.16	16.47	1.13
'CoLk 8001'	18.60	17.26	13.60	16.49	1.11
'Co 1148'	17.40	16.93	15.65	16.66	1.36
'CoPant 90222'	21.30	20.60	15.67	19.19	1.36
'UP 39'	18.20	16.27	14.13	16.20	1.29
'Co 88216'	15.53	15.00	9.20	13.24	1.69
'UP 22'	17.20	15.07	7.53	13.27	2.28
'CoS 767'	17.13	17.53	17.67	17.44	0.97
'CoS 88230'	17.20	15.30	12.47	14.99	1.37
'CoPant 84212'	17.20	16.07	12.07	15.11	1.42
Mean	18.43	17.30	13.82	16.52	1.38
Range	15.53-21.33	14.66-22.06'	7.53-18.00	13.24-20.42	0.97-2.28
Highest	'Co 88216	'CoS 8436'	'Co 87263'	'Co 87263'	'UP 22'
Lowest	'CoS 95255'	'Co 87263'	'UP 22'	'Co 88216'	'CoS 767'
CV (%)	8.79	10.78	20.63	10.68	22.56

Table 4 Juice quality attributes of sugarcane varieties in ratoon crop at harvesting

Variety	°Brix	Sucrose % juice	Juice purity (%)
'CoLk 8102'	20.5	16.9	82.4
'Co 88029'*	-	-	-
'CoS 91269'	19.2	16.1	83.8
'CoSe 92423'	20.0	16.5	80.5
'CoS 95255'	21.5	18.7	87.0
'CoPant 90223'	20.9	18.2	87.1
'CoPant 84211'	20.8	19.0	91.3
'CoJ 64'	20.8	17.5	84.1
'Co 87263'	21.2	17.6	83.0
'CoS 687'	20.7	17.8	86.0
'CoS 8436'	21.2	17.5	82.5
'CoJ 84192'	20.5	16.6	81.0
'CoLk 8001'	19.8	16.6	83.8
'Co 1148'	20.7	17.7	85.5
'CoPant 90222'	21.2	17.8	84.0
'UP 39'	20.5	17.2	83.9
'Co 88216'	20.7	17.6	85.0
'UP 22'	19.6	16.3	83.2
'CoS 767'	20.0	16.9	84.5
'CoS 88230'	20.2	17.5	86.6
'CoPant 84212'	20.1	16.6	82.6
Mean	20.5	17.3	84.4
Range	19.6-21.5	16.1-19.0	80.5-91.3
Highest	'CoS 95255'	'CoPant 84211'	'CoPant 84211'
Lowest	'UP 22'	'CoS 91269'	'CoSe 92423'
CV (%)	23.10	23.37	23.10

*Data could not be recorded

Table 5 Regression correlation among foliar characters, Brix value and juice quality attributes of sugarcane ratoon

Parameters	Foliar characters						HR-Brix in October					Juice Data at harvest		
	Chl a	Chl b	Chl a/b ratio	LSM*	SLW*	Leaf area	Base	Middle	Top	Mean Brix	Ratio B/T	Brix	Sucrose %	Purity
Foliar characters														
Chl a	1													
Chl b	0.995	1												
Chl a/b ratio	-0.706	-0.772	1											
LSM	-0.290	-0.260	0.033	1										
SLW	-0.343	-0.345	0.212	-0.013	1									
Leaf area	0.193	0.206	-0.204	-0.387	0.140	1								
Brix in October														
Bottom	0.297	0.323	-0.384	-0.226	-0.106	0.056	1							
Middle	0.332	0.340	-0.310	-0.201	-0.361	-0.073	0.781	1						
Top	-0.039	-0.045	0.049	-0.197	-0.107	0.137	0.262	0.628	1					
Mean Brix	0.187	0.194	-0.200	-0.246	-0.217	0.065	0.722	0.929	0.839	1				
Ratio B/T	0.082	0.100	-0.162	0.205	0.027	-0.206	0.011	-0.352	-0.889	-0.599	1			
Juice Data at harvest														
Brix	-0.028	-0.042	0.150	-0.170	0.016	-0.226	0.319	0.252	-0.176	0.092	0.263	1		
Sucrose%	-0.021	-0.032	0.132	-0.198	0.017	-0.183	0.338	0.256	-0.154	0.111	0.251	0.993	1	
Purity	-0.038	-0.053	0.165	-0.210	0.013	-0.194	0.260	0.207	-0.166	0.063	0.242	0.988	0.992	1

*LSM-Leaf sheath moisture; SLW- Specific leaf weight remobilization to supply the newly growing shoots (Qudsieh *et al.* 2001).

Results unravelled genetic variation and correlation of foliar characters as well as in Brix values at early stage of ripening among different varieties of sugarcane in ratoon crop. The bottom part of cane exhibited highest value of HR-Brix in the month of October, whereas, the top portion had the lowest HR-Brix in general. Brix value in the month of October indicated positive correlation with chlorophyll a, b contents and leaf area, but negative correlation with leaf sheath moisture and specific leaf weight.

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