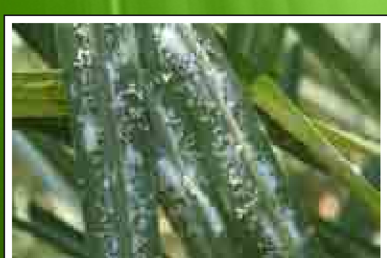
ISSN 0970-3233 Volume 32, No. 1 June 2017

Indian Journal of Sugarcane Technology






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

The Association of Sugarcane Technologists of India

EXECUTIVE COUNCIL

EDITORIAL BOARD

INDIAN JOURNAL OF SUGARCANE TECHNOLOGY

Frequency of Publication : Half Yearly (June & December)

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

INDIAN JOURNAL OF SUGARCANE TECHNOLOGY

ISSN 0970-3233 Issue: Volume 32 No.1 June 2017

CONTENTS

Indian Journal of Sugarcane Technology **32(01)**: 1-6, June 2017

Resource conservation technologies for input use efficiency and sustainable yield of sugarcane

T K SRIVASTAVA* and R L YADAV

ICAR-Indian Institute of Sugarcane Research, Lucknow-226 002, Uttar Pradesh

ABSTRACT

Sugar industry in India is the second largest agro-based industry in rural areas. Availability of sufficient sugarcane to sugar mills is pre-requisite for their efficient functioning. About 50 million farmers including their dependents and large number of agricultural labourers constituting 7.5 per cent of rural population are involved in sugarcane production which is utilized in 538 sugar mills with installed sugar production capacity of 32.93 million tonnes in 18 states. However, operating at 86 % of the installed capacity, Indian sugar mills could produce 28.31 million tonnes of sugar during 2014-15. There exists a discernible cyclic trend of sugar production in India with occurrence of 'boom and bust' phases at an interval of every five years. For ensuring sustainable sugar production in the country for the benefits of sugarcane farmers, sugar mills and consumers, it is desirable that sugarcane production be sustained at higher level which might be achieved by conserving organic carbon content and fertility of the soil with enhanced input use efficiency. To achieve these objectives, Indian Institute of Sugarcane Research, Lucknow has developed low cost eco-friendly agro-technologies. These agro-technologies include green manuring, trash mulching and crop residue recycling. For enhancing input use efficiency the Institute has also developed ring-pit planting method and double row planting geometry. All these technologies have been elaborated in this communication.

Key words: Sugarcane, resource conservation, organic carbon, input-use efficiency, sustainable

INTRODUCTION

Sugarcane occupies a pivotal position in agricultural economy of our country. The industry it sustains is the second largest agro-industry of India, coming next to the textiles. As an instrument of agrarian reforms and economic emancipation, sugarcane is perhaps second to none. This is so because, it is a labour intensive crop and provides livelihood to millions through an organized industry that carries with it in rural India. In fact, 50 million sugarcane growers, their dependents and large mass of agricultural labourers are involved in sugarcane cultivation including its harvesting and other ancillary activities, constituting 7.5% of the rural population. Besides, about 0.5 million skilled and semi-skilled workers, mostly from rural areas, are employed in sugar industry. The sugar industry contributes substantially to central and state exchequers annually and pays approximately 70000 crores to sugarcane growers as price of the raw material. Thus, the sugar industry in India has been a focal point for socio-economic development of rural areas by mobilizing rural resources, generating employment and higher income, transport and communication facilities. Many sugar factories have also established schools, colleges, medical centres, and hospitals for the benefit of rural population. Some of the sugar factories have also diversified into by-products based industries and have invested and put up distilleries, organic chemical plants, paper and board factories, and electricity co-generation plants. The industry generates its own replenishable biomass and uses it as fuel without depending on fossil fuel. Thus, the contributions of sugar industry to agricultural economy of the country are enormous.

About 12.8% of the national sugarcane production provides the grist for cottage *gur* industry and small scale *khandsari*. Though about 76% of it feeds the installed capacity of 32.9 million tonnes of white sugar industry, the national annual production of white sugar could reach 28.31 million tonnes in 2014-15 crop season. Thus, from a sugar importing country few decades ago, India emerged as an important sugar exporting country with sizeable foreign exchange earnings. However, due to failure of monsoon rains during previous years in important sugarcane growing states like UP, Maharashtra and Karnataka sugarcane production stagnated around 360 million tonnes, sugarcane productivity to 70 t ha^{-1} and sugar production to 28.31 million tonnes in 2014-15 crop season. However, rising domestic consumption (25 million tonnes annually) and decline in global sugar production for consecutive three years leave little scope for complacency on this front. Specter of cyclic dip in sugarcane and sugar production in India after every 3-5 good years still remains a nightmare both for sugarcane growers and millers. As availability of sufficient quantity of good quality sugarcane in the mills is important pre-requisite for the factory to be economically viable, it is necessary that suitable agro-

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

techniques be developed to ensure availability of sufficient cane to sugar mills. As biological entity, sugarcane, among cultivated plants, is one of the physiologically most efficient converters of incident solar energy into sugar. During the peak growth period, it can produce around half a tonne dry matter per ha per day; rarely so in other crops (Yadav 1981a).

It also scores well over other domesticated species in energy-return, for every calorie of energy invested in sugarcane cultivation, about five calorie-energy is harvested in its usable form *i.e.* in terms of sugar. Thus, sugarcane is physiologically the most active flora of immense economic value.

Notwithstanding with such a marvelous physiological efficiency, sugarcane productivity in India is merely a fraction of this potential. Could it be due to lack of genetic variability? Or could it be due to cultural bottlenecks that can primarily be overcome? What are these constraints that limit the sugarcane production especially in India?

Constraints to sugarcane production

Realization of the fullest potential of sugarcane crop is the function of adequate and appropriate crop husbandry, since sugarcane is the most exhaustive and exacting crop. A crop yielding 100 tonnes cane ha $^{-1}$ removes 208 kg N, 53 kg P and 280 kg K from soil. The soils of Indo-Gangetic plain region in sub-tropical India, where 60 % sugarcane of the country is cultivated are porous in texture and deficient in organic carbon and total N contents (Yadav *et al*. 2000 a; Yadav *et al*. 2000 b; Yadav *et al*. 1998; Yadav 1998; Ladha *et al*. 2003). On these soils when sugarcane is grown, it requires application of large quantities of fertilizer N.

The sugarcane crop also requires large amount of water. Its water requirement varies from 1100 mm to 2000 mm depending on cane cultivar (Yadav and Prasad 1988). In sub-tropical India that hosts 65 % of sugarcane acreage, the crop water requirement has been estimated to be 20 Mega litres/ha/ year (Shrivastava *et al*. 2011). To meet this water requirement, sugarcane is irrigated frequently and when frequent irrigations are applied, most of the applied nitrogen leaches down along with irrigation water in the coarse textured soils of the Indo-Gangetic plain region (Yadav *et al*. 1997). May be because of this, N use efficiency of the system is only about 50 per cent (Dwivedi *et al*. 2003).

Dimension of the possibilities

Immense possibilities are, however open to manipulate sugarcane cultivation for yield maximization by sustaining soil fertility, and enhancing input use efficiency. Soil fertility and nutrient supplying capacity of the soil can be maintained on a long term basis only by replenishing *i.e.* by addition through external inputs for the nutrients removed by the crop and those lost through physical, chemical and biological processes. In addition to replenishing plant nutrients, the application of organic matter is also crucial for maintaining fertility of these soils. Therefore, attention needs to be diverted for conserving organic carbon content of the soil as organic carbon in soil is important for enhancing soil microbial activities, for mobilizing availability of soil nutrients thereby enhancing their use efficiency. Soil organic matter is known to serve as soil conditioner, nutrient source, substrate for microbial activity, preserver of the environment and major determinant for sustaining and increasing agricultural productivity (Schnitzer 1991). Organic matter is also essential for maintaining moisture content of the soil. Organic carbon content of the soil may be conserved by including legume crops in the cropping system. Legumes, besides providing nitrogen in soil by biological nitrogen fixation, may also provide additional income to farmers in form of grain yield. In the same pretext, the loss of vegetative product of sugarcane crop *i.e.* cane trash can also be avoided. Recycling techniques of the use of such waste material may be perfected. Green manuring is another cheap source of nitrogen which may be used in sugarcane farms, alternatively, planting techniques be evolved for enhancing nutrient and water use efficiencies.

Realm of possibilities appearing at the first glance are merely a wishful thinking. However, it is heartening that these trends are duly corroborated by the results of our technological experimentation aiming at destroying the ceiling of yield potential of sugarcane.

In a developing country like India, availability of monetary inputs such as N fertilizers and sophisticated farm-husbandry *etc*. is considerably restricted. But availability and engagement of labour force *vis-à-vis* employment opportunity for landless is of great consequence. Therefore, agro-technological devices based on sound experimentation were developed and relegated to eliminate the possible yield barrier and enhancing input use efficiencies thus stabilizing the national sugarcane production. Needless to say, that these technologies were, consummated by low cost, which even the small and marginal farmers can readily afford.

Based on our experimental findings, cheap and effective agro-technology be distinguished for attaining the following desired objectives in sugarcane cultivation in India.

1. Conserving soil organic carbon content

1.1 Recycling organic farm waste

Incorporation of farm wastes (chopped trash, rice straw and legume husk) into the soil before sugarcane planting marginally increased soil organic carbon and nitrogen content but caused no significant changes in the available phosphorus and potassium contents (Yadav and Prasad 1992). Maximum benefits however, were produced by the incorporation of legume husk. The results of this experiment confirm those of Yadav *et al*. (1987) who found that organic carbon content of different soils was increased when these were incubated with cane trash with urea. Similar results were obtained by Akinyemi and Adiwale (1984) who found that additional doses of nitrogen accelerated the decomposition process of organic wastes thus increased the organic carbon content of the soil. The increase in organic carbon content of the soil might also be caused by the humification of cane trash and other farm wastes (Sinha *et al.* 1977).

Besides, increasing the organic carbon content, the initial decomposition of farm wastes immobilizes soil nitrogen because of the high carbon: nitrogen ratio of the wastes. This transformed nitrogen is slowly released as decomposition advances and immediately used by the sugarcane crop, so that none is lost by leaching. Because of their slow decomposition, farm waste materials serve as a better agent for solubilizing and chelating nutrients, which can then be utilized by a long duration crop such as sugarcane as they are made available. As a result of such gradual process, organic waste materials have residual effects which benefit the crop and help sustain yields on a long term basis (Yadav and Prasad 1992). The enzymes and vitamins released during the decomposition of waste materials may also improve crop yields (Yadav 1985). In a sugarcane multi ratooning system, continuous addition of farmyard manure or biogas slurry at 10 t/ha caused at par cane yield up to 4^{th} ratoon crop and significant ratoon yield enhancement over that with recommended dose of fertilizers (150, 60, 60 kg NPK) thereafter till 10^{th} ratoon crop. Besides, conspicuous soil health improvement was evident in terms of soil bulk density reduction (from 1.41 to 1.23 g/cc), enhanced infiltration rate (3.6 to 5.2 mm/hr), increased soil organic carbon content (0.39 to up to 0.86%), soil microbial biomass carbon and nitrogen (Srivastava *et al.* 2014). A carbon sequestration potential of 3.27 t/ha/year has also been worked out for continuous farmyard manure addition in sugarcane plant-ratoon system under sub-tropical conditions (Suman *et al*. 2009).

1.2 Green manuring

While evaluating green manuring experiments on sugarcane in north Indian sugarcane growing belt, Yadav (1985) held that at Shahjahanpur (UP) and Jalandhar (Punjab) about 50% of benefit of green manuring could be obtained in the form of increased sugarcane yield even when the above ground portion of the green manure crop was removed. There was no straight forward relation between the amounts of nitrogen and organic carbon buried by the green manure crop and the increase in the yield of the subsequent cane crop. The manurial value of the sunnhemp (*Crotalaria juncea*) green manure crop was slightly reduced even when the stems were utilized for extraction of fibre and only the remaining parts were buried as green manure. There was only a nominal decrease in the manurial value of the crop when seeds were also taken. The manurial value of sunnhemp roots together with ashes of the above ground portion was not significantly less than that of green manuring with the whole plant.

Green manuring with sunnhemp left little or no residual effect on the soil as measured by the amount of organic carbon and nitrogen in soil after harvest of the crop following it. The results of these experiments have suggested that leguminous crop grown during the monsoon-fallow period, either for fodder or for seed, may be equally effective as green manuring for raising the yield of the subsequent sugarcane crop. The possible reason for the limited effectiveness of the above ground portion of the green manure in sugarcane cultivation has been attributed to the interval of 5 months (September to February) between the turning-in of sun hemp green plants and the planting of the subsequent sugarcane crop. This seems to be obvious because in the hot climate of north India decomposable organic matter mineralizes very rapidly. A 5-month interval between the ploughing-in of green manure and planting of the following sugarcane crop allows the mobile nitrate nitrogen to be leached out from the root zone. To shorten the time period between turning-in of green manure crop and planting of following sugarcane crop Yadav and Prasad (1997) shifted sugarcane planting from February (spring) to October (autumn) at Lucknow, and studied the effect of *Sesbania* green manuring on crop yields. In their experiments conducted at Lucknow, sugarcane yields were significantly greater following *Sesbania* green manuring than following rice because of large N uptake of the crop. N uptake of the crop was significantly affected by organic carbon content of the soil.

1.3 Crop residue management

Sugarcane produces a large quantity of biomass and leaves a considerable amount of root residues after harvest which upon decomposition enrich soil fertility (1995). Singh and Agarwal (1985) observed 3.9 t/ha root biomass from a sugarcane crop yielding 80 t/ha. Holliday (1956) reported turnover of 50 kg each of P and K per hectare in soil by the under ground parts of sugarcane plants.

Interest in such nutrient rich residues has recently been renewed in India due to an increase in price of fertilizers. Yadav and Varma (1995) therefore, measured amount of root residues turned over in soil under rice-sugarcane-ratoon and cowpea (*Vigna unguiculata*)-sugarcane-ratoon crop rotations at Lucknow and studied their effect of soil organic carbon content. They found that rice produced significantly greater root biomass (1.5 t/ha) than cowpea (0.7 t/ha), but overall the cowpea –sugarcane- ratoon crop rotation added little more residues (7.9 t/ha) to the soil compared to rice-sugarcane-ratoon rotation (7.5 t/ha). Organic matter (OM) and total N in the soil not only increased more after cowpea (OM=0.78 %, N=0.048 %) compared with rice (OM=0.66%, N=0.024%) but also remained at higher level throughout the crop sequence.

1.4 Legumes in crop rotation

There is extensive evidence to indicate that legumes when included in a cropping sequence increase soil organic carbon and nitrogen contents and the yield of crops grown either in association or succession (Yadav 1981; Yadav 1982; Singh *et al.* 2005).

In sugarcane farming these benefits can be derived in two ways:

(a) By growing legumes as a preceding crop: Pigeon-pea grown as inter-crop with maize in the previous season increased

soil N due to substantial root nodulation. However, as intercrop, it failed to increase yield of maize at any level of N. But autumn planted sugarcane crop after pigeon-pea gave 43 % more yield than that planted after maize. These benefits were derived because of increase in soil organic carbon and total N contents (Yadav 1984).

(b) By growing legumes as intercrops: Inter-cropping of moong (*Vigna radiata*) and urd (*Vigna mungo*) as *zaid* crop in spring planted sugarcane enriched soil fertility and reduced nitrate nitrogen leaching beyond the potential root zone of the crop (Yadav 1982).

2. Enhancing input use efficiency

2.1 Mulching:

Vegetation cover can affect the soil in several ways. It can prevent or lessen soil erosion, ensure greater absorption of rainfall, reduce temperature changes and accordingly, modify biological activities including changes in availability of nutrients, particularly nitrogen and phosphorus. In most soils and climates, seasonal changes occur in nitrate content under bare fallow, which are modified by mulching or by shade (Yadav 1985). Nitrate content of an un-mulched soil was markedly greater than that of mulched soil, whether the soil was under crop or not. It was pointed out that nitrate formation under mulch was not completely inhibited, but merely reduced. Factors responsible for beneficial effect of mulch are increased soil water content, lowered soil temperature and reduced insulation. The relative importance of all these three factors could not be determined from the experiments as they were inter-dependent. The presence of crop would also result in shading of the ground, removal of water and consumption of nitrate.

In a carefully conducted irrigated trial with two levels of irrigation, 25 and 50 per cent available soil moisture, three levels of fertilizer nitrogen 50, 100 and 150 kg/ha with and without trash mulching at Lucknow, the effectiveness of trash mulch was demonstrated in improving irrigation water use efficiency (Yadav 1985) as a result of which either economy in water might be affected or yield potential could be enhanced which is not possible in absence of mulch. Thus, mulching not only improves the cane yield under water stress conditions, it also increases water use efficiency in irrigated conditions. Under mulching favourable temperature enhanced the microbial activities which ultimately resulted into mineralization of nutrients in the soil, particularly as nitrate nitrogen. Sugarcane trash, often treated as waste upon cane harvest, when used as mulch was found to enhance the availability of nutrients to ratoon crop (Shahi *et al*. 2003) resulting in apparent increase in relative growth rate, net assimilation rate, leaf area and dry matter partitioning to cane stalk. .

When trash was retained as mulch in successive ratoon crops at Lucknow, it increased N uptake and recovery of applied N by the crop by improving soil organic carbon content and decreasing soil bulk density. The concentration of nitrate-N in upper soil layers also increased due to mulching (Yadav *et al*. 1994).

2.2 Planting technique:

The ring pit system of sugarcane planting was developed for yield maximization (Singh *et al*., 1984). In this technique, seed setts are adjusted in circular pit of 75/90 cm diameter and 45 cm depth and pits are arranged in a square geometry in the field. A shoot population density of 162 thousand millable canes/ha and yield of 184 t/ha have been harvested in this method of sugarcane planting. This technique is also useful for enhancing nutrient and water use efficiency of sugarcane as for producing one tonne cane, the crop required only 2.34 kg N and 0.34 ha-cm water in ring-pit method compared to 8.48 kg N and 0.99 ha-cm water in conventional flat method of sugarcane planting. This might be possible because in ring-pit method nutrients and water are applied locally *i.e.* in the pits itself where roots are concentrated, rather than spreading into entire field as in conventional (Yadav 2004).

2.3 Planting geometry

Planting geometry refers to the shape of the land area which it takes after the establishment of plants in it. When the area per plant is constant, the shape of the ground area assignable to each plant is something like square with narrow rows and rectangle with wider rows (Yadav 1991).

Experimental results obtained under sufficient moisture and constant seed rate per plot or per row in sub-tropical sugarcane growing belt indicate that when inter-row distance decreases, the stalk number and the total cane weight per unit area increase while the number of tillers and the individual stalk weight decrease. This therefore suggests that the capacity of sugarcane to compensate for tiller production is limited by the shape of the ground area occupied by the plant.

Variation in crop geometry as single rows; and double and triple pairs have resulted into increased initial shoot population density from single to double and then triple rows in that order. We also found reduced losses of nitrate nitrogen through leaching in double row planting geometry thus increasing recovery of applied N by 15.8 per cent over conventional single row planting. Consequently, the yield response per kg applied N was 369 kg cane from double row planting (Yadav *et al*. 1997).

2.4 Slow release N fertilizers and nitrification inhibitors

Certain products like *gamma BHC*, *telodrin*, *N-serve* and a few others have been found to increase the efficiency of fertilizer N due to their nitrification inhibitory character when applied in soil at the time of planting. These should be used extensively to enhance N use efficiency in sugarcane (Yadav 1985). Comparison of new N carriers like urea super granules (USG), neem-cake coated urea (NCU) and dicyandiamide-treated urea (DCD) and the traditional source of N, prilled urea (PU) to supply 150 kg N/ha to sugarcane revealed that differences in yield resulting from use of the new carriers were not significant (Yadav *et al*. 1990). Uptake and recovery of N were significantly greater using USG, NCU, and DCD than using PU probably because of reduction in losses of N through volatilization and leaching when new carriers of N were used (Ram *et al*. 1988). The direct effect of nitrogen was 184 kg cane/kg N applied to ratoon crop but residual and cumulative effects of N applied to the plant crop on yield and quality of ratoon crop were small. Adequate direct application of N is therefore suggested for increasing yields of ratoon crop.

CONCLUSION

Sugarcane is an input intensive and management responsive crop and efficient and judicious input management is pivotal to ascertain remunerative cane yield. Sustained enhancement of soil health including soil organic carbon enrichment contributes substantially to the productivity of plant-ratoon production system. Practices like addition of bio-manures, recycling of crop residues, use of cane trash as mulch, green manuring and intercropping of leguminous crops add to the soil fertility improvement. Such practices have also been found to add to the improvement of soil physical, physico-chemical and microbiological properties. Further, enhanced input use efficiency through adoption of appropriate planting technique, planting geometry and slow release nitrogenous fertilizers effectively reduces the cost of cultivation and brings about additional profit to the growers.

REFERENCES

Akinyemi D and Adewale A. 1984. Effect of incubation temperature and different sources of N and P on decomposition of saw dust in soil. *Biological Wastes,* **11**: 293-306.

Dwivedi B S, Shukla A K, Singh V K and Yadav R L. 2003. Improving efficiency of fertilizer N and P in rice-wheat system by inclusion of forage cowpea in summer. *Field Crops Research,* **80**:167-93.

Holliday D J. 1956. The manuring of sugarcane No. 2, Centre, d'elude de 1' azote, Geneva.

Ladha J K, Dawe D, Pathak H, Padre, A T, Yadav R L, Singh B, Singh Y, Yadav C R and Hobbs P R. 2003. How intensive are yield declines in long term rice-wheat experiment in Asia. *Field Crops Research,* **81**: 159-80.

Ram M, Chatterjee B N, Yadav R L and Singh D V. 1988. Minimizing volatilization and leaching losses of nitrogen by different nitrogen carriers in Japanese mint. *J. Agric. Sci.*, **110**: 415-8.

Schnitzer M. 1991. Soil organic matter – the next 75 years. *Soil Science,* **151**: 41-48.

Shahi H N, Srivastava T K, Ramakant R and Suman A. 2003. Soil behaviour and growth and productivity of sugarcane ratoon as influenced by trash management and preceding intercrops. *Indian Journal of Agronomy*, **48**(4):271-3.

Shrivastava A K, Srivastava A K and Solomon S. 2011. Sustaining sugarcane productivity under depleting water resources. *Current Science,* **101**:748-54.

Singh K, Yadav R L, Singh B, Hora B S, Singh R V and Singh R A. 1984. Ring method of planting sugarcane-A new technique. *Biological Memoirs,* **9**:161-6.

Singh M and Agrawal M P. 1985. Nitrogen transformation during sugarcane root decomposition. *J. Indian Soc. Soil Sci*., **33**: 676-8.

Singh V K, Dwivedi B S, Shukla A K, Chauhan Y S and Yadav R L. 2005. Diversification of rice with pigeonpea in rice-wheat cropping system on a typic ustochrept: Effect on soil fertility, yield and nutrient use efficiency. *Field Crops Research*, **92**: 85-105.

Sinha M K, Sinha D P and Sinha H. 1977. Organic matter transformations in soils. V. Kinetics of carbon and nitrogen mineralization in soils amended with different organic materials. *Plant and Soil,* **46**: 579-90.

Srivastava T K, Singh K P and Singh P. 2014. Bio manured multi-ratooning enhances sugarcane plant-ratoon system productivity. *Indian Farming,* **64**(8):12-6.

Suman A, Singh K P, Singh Pushpa and Yadav R L. 2009. Carbon input, loss and storage in sub-tropical inceptisol under multi-ratooning sugarcane. *Soil & Tillage Research,* **104**: 221-6.

Yadav D V, Singh T and Srivastava A K. 1987. Recycling of nutrients in trash with N for higher cane yield, *Biological Wastes,* **20**:133-41.

Yadav R L. 1981 a. Agro-technology for enhancing sugarcane production at sustaining it at higher level with low production cost. *Sci. Acad. Medals for Young Scientists Lectures,* pp. 7-14.

Yadav R L. 1981b. Inter cropping pigeon pea to conserve fertilizer nitrogen in maize and produce residual effect on sugarcane. *Experimental Agriculture,* **17**: 311-7.

Yadav R L. 1982. Minimizing nitrate nitrogen leaching by parallel multiple cropping in long duration row crops, *Experimental Agriculture,* **18**:37-42.

Yadav R L, Dwivedi B S and Pandey P S. 2000 a. Rice-wheat cropping system: assessment of sustainability under green manuring and chemical fertilizer inputs. *Field Crops Research,* **65**:15-30.

Yadav R L, Dwivedi B S, Prasad K, Tomar O K, Surpali N J and Pandey P S. 2000 b. Yield trends and changes in soil organic C and available NPK in long term rice-wheat system under integrated use of manures and fertilizer. *Field Crops Research,* **68**:219-46.

Yadav R L, Yadav D S, Singh M and Kumar A. 1998. Long term effect of inorganic fertilizer inputs on crop productivity in a rice-wheat cropping system. *Nutrient cycling in agro-ecosystems,* **51**:193-200.

Yadav R L.1998. Factor productivity trend in a rice-wheat cropping system under long term use of chemical fertilizers. *Experimental Agriculture,* **34**:1-18.

Yadav R L, and Prasad S R. 1988. Moisture use characteristics of sugarcane genotypes under different available soil moisture regimes in alluvial entisols. *J. Agric. Sci.* **110**: 5-11.

Yadav R L, Singh R V, Singh R and Srivastava V K. 1997. Effect of planting geometry and fertilizer N rates on nitrate leaching, nitrogen use efficiency and sugarcane yield. *Tropical Agric*ulture, **74**:115-20.

Yadav R L and Prasad S R. 1992. Conserving the organic matter content of the soil to sustain sugarcane yield. *Experimental Agriculture,* **28**:57-62.

Yadav R L. 1985. Enhancing recoveries of fertilizer N applied to sugarcane, *Biological Memoirs,* **11**: 135-42.

Yadav R L and Prasad S R. 1997. Maximising sugarcane yield by increasing plant population density, minimizing NO_3-N leaching and improving soil organic matter in different crop rotations. *J. Agronomy & Crop Science,* **178**: 117-23.

Yadav R L and Varma R P. 1995. Crop residue management to conserve soil organic matter content in sugarcane based crop rotations, *Bioresource Technology,* **51**:241-5.

Yadav R L. 1984. Soil fertility in relation to crop yields of sugarcane based cropping systems in north-central India. *J. Agronomy & Crop Science,* **153**:328-33.

Yadav R L, Prasad S R, Singh, R and Srivastava V K. 1994. Recycling sugarcane trash to conserve soil organic carbon for sustaining yields of successive ratoon crops. *Bioresource Technology,* **49**:231-5.

Yadav R L. 2004. Enhancing efficiency of fertilizer N use in sugarcane by ring pit method of planting. *Sugar Tech,* **6**:169-71.

Yadav R L. 1991. High population density management in sugarcane. *Proc. Indian Natn. Sci. Acad*., **57**:175-82.

Yadav R L, Kumar R and Varma R S. 1990. Effect of nitrogen applied through new carriers on yield and quality of sugarcane. *J. Agric. Sci.*, **114**:125-30.

Indian Journal of Sugarcane Technology **32(01)**: 7-12, June 2017

Design and development of a forced air drier for drying of jaggery

A K SINGH*, J SINGH, D KUMAR, R D SINGH, S I ANWAR, S SINGH and R GUPTA

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

ABSTRACT

A 100 kg capacity, batch type drier, was designed and developed for forced air drying of jaggery. Designed drier consisted of an air blower for supply of forced air, a heating device for heating of supplied air and a drying chamber for housing of jaggery to be dried. A thermostat was provided to regulate the temperature of supplied air. Thermo-hygrometers were provided for recording the temperature and relative humidity of the air entering into and leaving from the drying chamber. The performance of the drier was evaluated for drying of 25.4 mm size cubic shape jaggery during 6 hours of drying and two tempering periods of one hour duration each at the end of second and fourth hour. During 6 hours of intermittent drying, the moisture content (d.b.) of jaggery reduced from 14.55 to 9.41% (12.7 to 8.6 % on wet basis). During the entire period of drying, rate of drying was under falling drying rate periods. The heat utilisation factor decreased from 0.57 to 0.29 with the increase in drying time. The cost of jaggery drying was ₹ 1.70 kg^{-1}.

Key words: Sugarcane, Sweetener, Jaggery, Drier, Moisture content, Blower, Thermostat.

Jaggery is a natural, traditional sweetener made by the concentration of sugarcane juice and is known all over the world in different local names. It is a traditional unrefined non-centrifugal sugar consumed in Asia, Africa, Latin America and the Caribbean. It contains all the minerals and vitamins of sugarcane juice and known as the healthiest form of sugar. India is the largest producer and consumer of jaggery. Out of total world production, more than 70% is produced in India (Jagannadharao *et al.* 2007). Out of the 300 million tonnes of sugarcane produced, 53% is processed into white sugar, 36% into jaggery and *khandsari*, 3% for chewing as cane juice, and 8% as seed cane (Singh *et al.* 2011).The jaggery and *khandsari* industry provides employment to over 2.5 million people in rural areas (Nath *et al.* 2015).

Moisture content of jaggery plays an important role in its storage, packaging, handling and transportation. Jaggery with high moisture deteriorates faster and unfit for consumption (Ramya *et al.* 2010). Jaggery with high moisture content is more prone to fungal infestation and inversion of sucrose, making it difficult to store with large stack height as the compressive strength of jaggery reduced at higher moisture content.

Jaggery has poor keeping quality due to its hygroscopic nature. This is probably because of its non-sucrose constituents like glucose, fructose, proteins *etc.* which absorb moisture from the surrounding atmosphere and create congenial condition for microbial colonisation and subsequent increase of sucrose. This resulted in the formation of alcohols and organic acids as end products of decomposition (Baboo and Singh 1986).

Freshly prepared jaggery having the moisture content in the range of 13-15 % takes considerable time for drying, under natural conditions. Conventionally jaggery is dried naturally and it takes 7-10 days to reach moisture content of 8-9 % depending upon weather conditions. Work on natural drying of jaggery for its storage in Uttar Pradesh has been reported (Baboo and Das 1985). Natural drying takes a long period for reducing the moisture content for packaging/storage of jaggery. Smaller size jaggery blocks dried faster and showed good keeping quality under all treatments of jaggery drying *viz.*, shade drying, sun drying and artificial drying using forced air circulation tray drier (Singh 1998).Thermal modelling for the greenhouse drying of jaggery under forced convection mode were done to predict the jaggery temperature, the greenhouse air temperature and the moisture evaporation.The parametric study was also performed to find the effects of various parameters namely number of air changes h^{-1}, relative humidity and mass of the jaggery (Kumar and Tiwari 2006). Attempt was also made to predict the rate of moisture evaporation by natural and forced convection for jaggery under controlled environment. To reduce the drying time, drying with a warmer air under natural and forced conditions is essential (Prakash *et al.* 2015). In view of the above, the present study was undertaken to design and develop a forced air drier for drying of jaggery and evaluate its performance.

MATERIALS AND METHODS

Design of the drier

Drier was designed for drying of 100 kg of jaggery in 6 hours (8 hours when 2 hours of tempering is also included) per batch. The designed drier was batch type equipment. It was based on the principle of moisture removal by passing

*Corresponding author's E-mail: aksingh8375@gmail.com

over forced hot air over the jaggery samples. It consisted of a drying chamber for housing the jaggery for each batch of jaggery drying, a blower for supply of forced air and a heating device with a thermostat for heating and regulating the temperature of forced air entering into drying chamber (Fig 1).

Design of drying chamber

Drying chamber was designed for the capacity of 100 kg of jaggery per batch of drying (Fig 2). It consisted of a drying, plenum and exhaust chambers. Different dimensions of rectangular drying chamber (615 mm x 500 mm x 815 mm) were worked out to accommodate 100 kg of jaggery, evenly distributed in seven sliding trays.

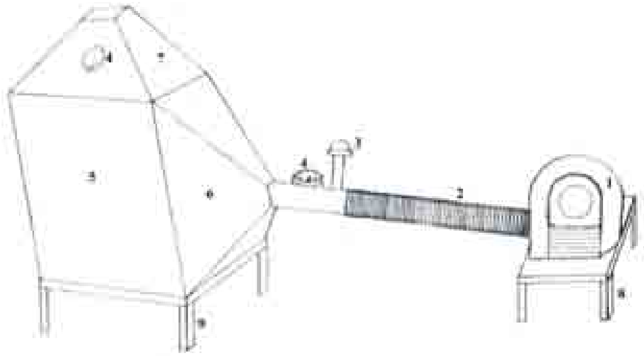


Fig 1. Schematic view of designed drier. 1. Air blower coupled with electric motor, 2. Fin type heater, 3. Thermostat, 4. Thermo-hygrometer, 5. Drying chamber, 6. Plenum chamber, 7. Exhaust chamber, 8. Air blower stand, 9. Drying chamber stand

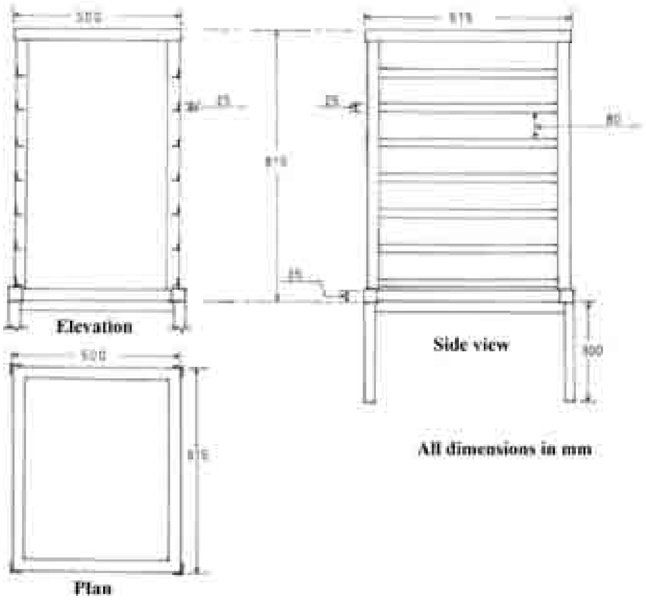


Fig 2. Dimensional details of drying chamber

Selection of air blower

Air blower was selected to match the required flow rate of supplied air for drying of jaggery. The drying time per batch was assumed as 6 hours. The temperature of heated air passed through the drying chamber was kept at 45°C because jaggery lost its shape beyond this temperature (Singh and Singh 1998). Required flow rate of air at 45°C for drying of 100 kg of jaggery from initial moisture content (w.b.) of 13% (14.94% on d.b.) to final moisture content of 8% on wet basis (8.70% on d.b.), was analysed as below;

Weight of moisture present in the fresh jaggery (per batch) = 13kg

Weight of moisture to be removed = (87/100)*(14.94-8.70) = 5.43 kg

Average ambient temperature ranged from 25 to 35°C and relative humidity 50 to 70% during preparation of jaggery. For computing the air flow rate of blower, for removal of moisture from jaggery, atmospheric air temperature and relative humidity (RH) were assumed in such a way that air flow rate should be sufficient enough for adverse temperature and RH conditions *viz.* lower temperature and higher RH. Therefore, lower temperature of 25°C and higher relative humidity of 70% was assumed.

Air at 25°C and RH of 70% has humidity ratio of 0.014 kg/kg of dry air and has specific volume of 0.863 m^3/kg of dry air (from the psychrometric chart).

At initial condition, weight of dry air (volume- V m^3) supplied in 6 hours = V/0.863 kg

Assuming the temperature of exhaust air as 40°C, for analysing the moisture gained by the air exiting from the exhaust chamber.

Humidity ratio at the exit condition of air = 0.024 kg/kg of dry air

Thus, increase in humidity ratio = 0.024-0.014 = 0.010 kg/kg of dry air

Therefore, total moisture gained by exit air = V/ (0.863*0.010) kg

Since, total moisture gained by exit air = total moisture lost by jaggery

Therefore, V/ (0.863*0.010) = 5.43

So, V = 5.43*0.863/0.010 = 468.60 m^3 in 6 hours

Assuming system efficiency = 30%

Thus, the required flow rate of air = 468.60/ (0.30*6*60*60) = 0.07 m^3/s

The selected air blower should have a minimum of 0.07m^3/s air flow rate. Assuming that in future this drier could be used for drying of other commodities for round the year use, an air blower with higher air flow rate of 0.09 m^3/s was selected.

Selection of heater

The heater was selected for heating of atmospheric air to 45°C. The size of heater (kW) was selected to heat the supplied air from 25°C (at relative humidity of 70%) to 45°C at a flow rate of 0.09 m^3/s. The analysis was done as per mathematical equations and procedure explained by Lal and Datta (1971);

For air, M = 28.97 and R = 848 kilo mole/ °K

Hence, P*V = 29.3*W*T

So, W = P*V/ (29.3*T)

Air flow rate of air (V) = 0.09m^3/s

Atmospheric pressure (P) = 10330 kg/m^2

Temperature of air to be raised up to 45 ^{0}C (273+45 = 318^{o}K) by the heater

Hence, weight of air (W) to be supplied= 10330*0.09/ (29.3*318) = 0.09 kg/s

Now, enthalpy of an air vapour mixture is equal to the enthalpy of the dry air plus the enthalpy of water vapour;

$H = H_a + W_h * H_w$

Where,

H = Total enthalpy of air vapour mixture is kcal/kg dry air

H_a = Enthalpy of dry air referred to zero degree temperature = 0.24*t, where t is dry bulb temperature of the air and 0.24 is the average specific heat of dry air

W_h = Humidity ratio

H_w = Enthalpy of water vapour per kg = 597.3+0.45*t, where 597.3 is the heat content in kcal of 1 kg of water vapour at 0 ^{0}C and 0.45 is average specific heat of water vapour

Therefore,

Heat required to raise the temperature of air for each kg of dry air by t ^{0}C

= 0.24*t + (597.3+0.45*t)* W_h kcal

From the psychrometric chart, humidity ratio at atmospheric air condition (temperature = 25 ^{0}C and relative humidity = 70%) is 0.014 kg water vapour per kg of dry air

Therefore,

Enthalpy of atmospheric air = 0.24*25+ (597.3+0.45*25)*0.014= 14.52 kcal/kg of air

Enthalpy of heated air= 0.24*45+ (597.3+0.45*45)*0.014 = 19.45 kcal/kg of dry air

Hence, increase in enthalpy = 19.45-14.52= 4.93 kcal/kg of dry air = 20.60 kJ/kg of dry air

Therefore, heat required to raise the atmospheric air to 45 ^{0}C at a flow rate (weight of air) of 0.09 kg/s = 20.60*0.09 kJ/s [1] = 1.85 kJ/s = 1.85 kW

Hence, a 2 kW heater was selected for heating the supplied air.

Fabrication of the drier

Different components of the drier were fabricated and assembled in the workshop of Agricultural Engineering Division of ICAR-Indian Institute of Sugarcane Research, Lucknow, India. The material for frame of rectangular drying chamber was MS angle of 35 mm x 35 mm x 5 mm and for side walls 18 g GI sheet in order to sustain the static and dynamic stresses exerted at the walls and floors of the drying chamber, without failure. For fabrication of inlet plenum chamber, 16 g MS sheet was used. MS sheet was used to facilitate welding of flange joints. The exhaust chamber was fabricated by using 18 g GI sheet. Provisions were made for sliding in and out of the trays loaded with jaggery from drying chamber through the opposite side of the plenum chamber. The rectangular trays have holes of 5 mm square size, made of MS wire of 1.5 mm diameter. The frame of wire mesh was fabricated using 5 mm thick wooden ply. The height of face through which trays to be slid in was kept at 82 mm whereas, height of the opposite face was kept at 35 mm. This was to reduce the space between the trays at the closing end of the chamber, to prevent easy escape of forced air. A rectangular MS sheet shutter was fabricated for closing the chamber. The chamber was closed by sliding down the shutter during drying. For opening of the chamber, the shutter was pulled up. A stand was fabricated with MS angle of 40mm x 40mm x 5mm for supporting the drying chamber. Stand was grouted in the ground for reducing vibrations during drying operation.

An air blower consisting of axial flow type fan coupled with an electric motor of 0.373 kW (0.5 hp) was used. The air flow rate of blower was 0.09 m^3/s. A stand with 40mm x 40mm x 5mm of MS angle was fabricated for supporting the air blower. The stand was grouted in the ground for reducing vibrations during drying operation. A wooden board was fitted with the support stand of air blower for fitting the electrical sockets.

A 2 kW, fin type, heater was used for heating of supplied air. The heater was housed linearly in a 1080 mm long MS pipe of 100 mm internal diameter. In order to reduce the loss of heat from the surface of the MS pipe, an asbestos rope of 12 mm diameter was wrapped over the MS pipe surface along its entire length. One end of the pipe was connected to the outlet of the blower using flange joint. In order to avoid the leakage through the flange joint, rubber packing was provided. The other end of the pipe was connected to the inlet structure of the drying chamber using flange joint. Thermostat was fitted with the heater by inserting a MS pipe of 30 mm diameter at the inlet of the chamber. The contactor of the thermostat was fitted at the wooden board attached with the blower stand.

Thermo-hygrometers were provided at the inlet and outlet of the drying chamber for recording the temperature and relative humidity of air entering and leaving the drying chamber. The developed drier is shown in Fig 3.

Fig 3. Developed drier for drying of jaggery

Performance evaluation

The performance of the drier was evaluated at ICAR-Indian Institute of Sugarcane Research, Lucknow, India in the month of March, 2016. All the seven trays were loaded with fresh jaggery cubes (25.4mm x25.4mm x 25.4mm) and slid into the drying chamber. The chamber was closed with the help of the sliding shutter. During drying air blower and heater was switched on. Air blower forced the air and heater heated the forced air prior to its entering in to the drying chamber. The temperature was regulated with the help of thermostat provided for the purpose. The moisture content (wet basis) of fresh jaggery was estimated. The weight of fresh jaggery loaded in the trays and weight of jaggery, after drying, were recorded. The difference in the weight of fresh and dried jaggery gave the weight of moisture removed during drying. The moisture content of dried jaggery was estimated with the help of the following mathematical relationship;

$m.c._{w.b.} = W_{w1}/W_1$

where,

W_{w1} = weight of moisture in fresh jaggery = W_1-W_2

W_1 = weight of fresh jaggery sample

W_2 = weight of dried jaggery sample

Moisture content on wet basis was converted into moisture content on dry basis by using following relationship;

$m.c._{d.b.} = m.c._{w.b.}/(1-m.c._{w.b.})$

Where,

$m.c._{d.b.}$ = moisture content on dry basis

$m.c._{w.b.}$ = moisture content on wet basis

Heat utilization factor (HUF) of the drier without considering the radiation losses from the drier was analysed by using following mathematical relationship as suggested by Lal and Datta (1971); HUF= air temp (d.b.) decrease during drying/air temp (d.b.) increase during heating

$= (T_2-T_3)/(T_2-T_1)$

Where,

T_1 = d.b. temperature of air before heating

T_2 = d.b. temperature of air after heating

T_3 = d.b. temperature of exhaust air leaving the drying chamber

Jaggery was dried for six hours intermittently by providing tempering time in between the drying. Two tempering periods of one hour duration each were provided at after second and fourth hour of drying. Cumulative time for drying was eight hours with six hours of drying and two hours of tempering time.

Cost of drying of jaggery was analysed by adding the fixed and variable cost of the drier and prime mower and labour cost as per the procedure adopted by Singh and Singh (2016). The parameters used in the analysis of cost components were either based on the actual performance data of the drier or as Bureau of Indian Standards (Anon 1979). As full time engagement of labour was not needed during drying, the cost of labour was analyzed by considering the actual labour involved during loading and unloading of jaggery in the drying chamber. During remaining time labour was engaged in other activities of jaggery making.

RESULTS AND DISCUSSION

Performance of the drier

Performance of different components of drier, *viz.* air blower, heating device, and thermostat, were satisfactory. No breakdowns were observed during the trials. Heating unit worked well and heated the forced air for the desired temperature range of 40 to 50°C. The temperature of the forced supplied air reached to 45°C within 10 minutes of start. Thermostat also worked well and regulated the temperature of supplied air at pre-set temperature of 45°C by engaging and disengaging the contactor. Static pressure in the plenum chamber was 10950 kg/m^2 (107.382 kPa).

Drying rate

The moisture content (dry basis) of jaggery was reduced from 14.55 to 9.41% after 6 hours of intermittent drying. Two tempering of one hour duration each were provided at after two hours of drying interval *i.e.*, second and fourth hour of drying. During the entire drying period the rate of drying was under falling drying rate periods. Rate of drying (reduction in moisture content on dry basis, % per h) decreased with the increase in the drying time. During initial first hour, rate of drying was 1.81% per h which reduced to 1.26, 0.86, 0.49, 0.48 and 0.24% per h during second, third, fourth, fifth and sixth hour of drying, respectively (Table 2). Similar trend of reduction of drying rate was also reported by Hien *et al.* (1999) for drying of rice.

Heat utilisation factor

Drier was designed for low heat utilization factor because with sustained exposure of heated air, jaggery softened and tends to deform.The heat utilisation factor of jaggery was 0.57, 0.50, 0.43, 0.36, 0.36 and 0.29 after 1, 2, 3, 4, 5 and 6 hours of drying, respectively (Table 2). The heat utilisation factor decreased with the increase in drying time because initially heat was used for heating the jaggery and thereafter, a considerable amount of heat was lost with the exhaust air. This may be the reason for falling of heat utilisation factor of jaggery with the progress of time. Similar results were reported by Kaleemullah and Kaliappan (2007) in case of drying of chilly in a rotary type chilly drier.

Cost of drying

The fixed cost of jaggery drying was ₹ 0.60 kg^{-1}and the variable cost was ₹ 1.10 kg^{-1}. The total cost of drying of jaggery was ₹ 1.70 kg^{-1}.

CONCLUSION

A batch type, forced air drier, was designed and developed for drying of jaggery. All components of the drier worked well

Table 1 Technical specification of the developed drier

S. No.	Particular	Detail
1.	Drying chamber	MS square pipe 50 mm x 50 mm x 5 mm
	Length	615 mm
	Width	500 mm
	Height	815 mm
	Material	Frame made of MS angle 35 mm x 35 mm x 5 mm and material for wall and floor 18 g GI sheet
	Number of sliding trays	7 rectangular trays having uniform perforations of 5 mm square holes made of MS wire of 1.5 mm dia
	Plenum chamber	16 g MS sheet
	Exhaust chamber	18 g GI sheet
	Stand	Material MS angle (40 mm x 40 mm x 5 mm)
	Size	Rectangular 630 mm x 520 mm
	Height of stand	300 mm
2.	Heater	Fin type
	Source of power	2 kW electrical heater
	Length	1000 mm
3.	Air blower	
	Type of fan	Axial flow
	Source of power	Single phase electrical motor 0.373 kW (0.50 hp)
	Air flow rate	0.09 m^3-s^{-1}
	Stand	Material MS angle (40 mm x 40 mm x 5 mm)
	Size of stand	Rectangular 360 mm x 330 mm
	Height of stand	660 mm

Table 2 Drying rate and heat utilisation factor of the drier during drying of jaggery

Average temp of atmospheric air (T1) : 35^{0}C

Temperature of heated air entering the drying chamber (T2): 45 ^{0}C

Time, h	m.c. (w.b.), %	m.c. (d.b.), %	Rate of drying (Reduction in m.c.(d.b.), %-h^{-1}	Temp. of exhaust air (T3), ^{0}C	Heat utilisation factor (HUF), decimal
0	12.7	14.55	-	-	-
1	11.3	12.74	1.81	37	0.57
2	10.3	11.48	1.26	38	0.50
3	9.6	10.62	0.86	39	0.43
4	9.2	10.13	0.49	40	0.36
5	8.8	9.65	0.48	40	0.36
6	8.6	9.41	0.24	41	0.29

during testing for drying of 25.4 mm cubic shape jaggery. During six hours of drying (cumulative time of eight hours by including tempering time of two hours) moisture content (dry basis) of jaggery was reduced from 14.55 to 9.41%. During the entire drying period the rate of drying was under falling drying rate periods. The heat utilisation factor decreased from 0.57 to 0.29 with the increase in drying time from one to six hours. The cost of drying of jaggery was ₹ 1.70/ kg.

REFERENCES

Anon. 1979. Guide for estimating cost of farm machinery operation (IS: 9164-1979). New Delhi: Indian Standard Institution.

Baboo B and Das F C. 1985. Feasibility of natural drying of *gur* for its storage in Uttar Pradesh. *J Institution of Engineers (India),* **66**: 5-8.

Baboo B and Singh K. 1986. Jaggery storage research in India (1935-1984) - A review. *J Institution of Engineers (India),* 66: 76-80.

Hien P H, Ban LV, Hung B N, Thong D S and Gummert M. 1999. Development and distribution of low-cost dryer in Vietnam. *Agricultural Mechanization in Asia, Africa and Latin America* **30**(2):47-53.

Jagannadharao PVK, Dasand M and Das S K. 2007. Jaggery-A traditional Indian sweetener. *Indian Journal of Traditional Knowledge,***6**: 95-102.

Kaleemullah S and Kaliappan R. 2007. Design, development and evaluation of a rotary type chilly drier. *Agricultural Mechanization in Asia, Africa and Latin America,* **38**(3): 73-8.

Kumar A and Tiwari G N. 2006. Thermal modeling and parametric study of a forced convection greenhouse drying system for jaggery: an experimental validation. *International J Agricultural Research,* **1**(3): 265-79.

Lal R and Datta A C. 1971. Agricultural engineering through worked examples. Allahabad: *Saroj Prakashan*.

Nath A, Dutta D, Kumar P, Singh J P. 2015. Review on recent advances in value addition of jaggery based products. *J Food Process Technol.,* **6**: 440. doi:10.4172/2157-7110.1000440.

Prakash O, Kumar A, Kaviti A K and Kumar P V. 2015. Prediction of the rate of moisture evaporation from jaggery in greenhouse drying using the fuzzy logic. *Heat Transfer Research,* **46**(10): 923–35.

Ramya H N, Gowda M C, Jayamala G B, Krishnamma P N and Shreedevi M S. 2010. Effect of ambient atmospheric conditions on change in physico- chemical properties of stored jaggery. *International Journal of Applied Agricultural Research,* **5**(1): 9-18.

Singh A K and Singh P R. 2017. Development of a tractor operated sugarcane cutter planter for mechanization of sugarcane planting in deep furrows, *Sugar Tech,* **19**: 416-23. doi:10.1007/s12355-016-0471-9.

Singh J. 1998. Effects of drying methods on storage of jaggery. Coordinator's Report, Fourth Workshop of AICRP on Processing, Handling and Storage of Jaggery (*Gur*) and *Khandsari*, *Tech Report No. IISR/JK Cell*/97/ **3**: 18-9.

Singh J and Singh A K. 1998. Investigation on mechanical drying of jaggery. Paper presented at 33rd Annual Convention of Indian Society of Agricultural Engineers held at Central Institute of Agricultural Engineering, Bhopal, pp 21-23.

Singh J, Singh R D, Anwar S I and Solomon S. 2011. Alternative sweeteners production from sugarcane in India: Lump Sugar (jaggery). *Sugar Tech,* **13**: 366-371.

Indian Journal of Sugarcane Technology **32(01)**: 13-19, June 2017

Temperature and relative humidity effects on sugarcane flowering under natural conditions in Egypt

EID M MEHAREB*, EL-ARABY S R SALEM and MOHAMED A GHONEMA

Sugar Crops Research Institute, Agricultural Research Center (ARC), Cairo, Egypt

ABSTRACT

This study consisted of two experiments that were carried out at El-Sabahia Research Station, Sugar Crops Research Institute (ARC), Egypt, during 2013-2015 (plant cane) and 2015-2016 (ratoon crop) seasons to investigate behaviour of selected germplasm (40 genotypes from different origins) under natural flowering conditions to make synchronization of flowering for crossing. Results of individual and combined analysis of variance over two seasons, plant cane and first ratoon revealed significant differences among genotypes for durations of pre-flag leaf stage, flag leaf stage and emergence stage, and percent of total flowered plants. The genotypes × inductive cycles interaction was significant for all studied characters. The forty sugar cane genotypes under study were classified into four groups. The first group included fourteen genotypes *viz.* 'EI 8-129', 'M 35-157', 'PS 80-1424', 'K 81113', 'L 61-49', 'AN 56-79', 'SP 79-2233', 'G 2009-11', 'G 2009-10', 'G 2009-22', 'G 2009-86', 'G 2004-27', 'G 2008-64' and '88/5-27' that flowered in plant cane and first ratoon seasons. The second group consisted of ten genotypes *viz*. 'Java, 'SP 72-5181', 'G 84-68', 'G 84-47', 'G 74-96', 'G 2008-59', 'G 2006-3', 'G 2007-61', 'GT 54-9' and 'G 2008-20', that flowered only under plant cane. The third group included two genotypes *viz*. 'EI 242-16' and 'G 2006-36' that flowered only under first ratoon. The fourth group included fourteen genotypes *viz*. 'Co 775', 'G2003-47', 'US 59-161', 'ROC 10', 'EI 58-28', 'EI 8-10', 'F 161', 'L 62-96', 'G 2000-5', 'G 99-80, 'SP 80-3250', 'SP 80-1842', 'G 2003-49' and 'Mex 2001-80' that did not show any response in either plant cane or first ratoon. Thus, the forty evaluated sugarcane genotypes varied considerably among themselves in their response to flowering under plant cane and first ratoon. Further, flowering for genotypes in plant cane was higher than first ratoon because percentage of daily humidity for plant cane (2014) was higher than first ratoon (2015) during flowering stages and the number of days for flowering under the optimum temperature (18-31 °C) during three months (induction and initiation stage) in plant cane were also higher than the first ratoon. All these factors were the reasons why flowering in plant cant was higher than the first ratoon, so a better understanding of effects of temperature and relative humidity on sugarcane flowering is important to study the behaviour and to make synchronization of flowering between the genotypes for crossing in future.

Key words: *Saccharum* spp., Sugarcane genotypes, Plant cane, First ratoon, Synchronization, Flowering

INTRODUCTION

The development of new varieties of sugarcane from controlled crosses has established a successful long term breeding programme to introduce improved varieties. However, lack of flowering until 1970´S made it completely impossible to have any breeding programme. Flowering was a success by manipulation of nutritional and tissue moisture status of the plant. Moisture also affects sugarcane flowering (Clement and Awada 1964, Pereira *et al.* 1983). The enough moisture is very important and critical for induction of flowering, flowering initiation and flower emergence (Moore and Nuss 1987). Low moisture during the initiation period reduces tasseling (Berding 1995).The photoperiod and temperature are major factors to control transition from vegetative to reproductive growth in grasses and legumes (Aamlid *et al.* 1999). Managed initiation in flowering of sugarcane in a tropical environment has been advanced considerably by developing an understanding of the environmental variables affecting the flowering process and the management needs of the plants in which flowering is initiated, and/also by developing an avoidance strategy to circumvent the high temperature events that impact the initiation efficacy under prevailing ambient conditions (Berding and Moore 1996, 2001; Berding *et al* 2004, 2007). Besides natural flowering, panicle growth is sensitive to temperature as the panicle emergence is delayed at temperatures below 21°C (Clements and Awada 1965; Nuss and Brett 1977). Coleman (1968) reported that day's minimum ≤ 18.3°C and maximum ≥ 32°C temperatures are important during the flowering initiation period. Nuss (1979) reported the best night temperature for flowering to be around 23°C. Restrepo and Ranjel (1984) reported that lower temperatures at night was the only cause of failure of sugarcane flowering.

The reduction in flowering ability of clones in the traditional breeding plots could be due to high temperature prevailing prior to and during the floral initiation period and deficient rainfall (Shanmugavadivu and Gururaja Rao 2009). Both night and daytime temperatures are important factors in promoting

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

the physiological change from vegetative to reproductive phase in sugarcane (LaBorde *et al.* 2014). Average daily maximum temperatures during the vegetative, pre-initiation, and boot stages had a significant effect on tasseling percentage for the overall artificial photoperiod regimes examined in their study and critical temperatures identified during the pre-initiation stage and boot stage were >32.1 °C and >33.1 °C respectively. Maximum temperatures are frequently associated with cloudless skies, lack of rainfall, and low humidity, all of which might lead to water deficiency and drought stress, both of which are known to inhibit flowering (Moore and Berding 2014). Sugarcane plants differ in flowering from plant cane to first ratoon (Mohamed *et al.* 2016). The objectives of the present work were to study the behaviour of selected germplasm in sugarcane selection program at Mattana, Luxor, Egypt under natural flowering and to identify genotypes with synchronized flowering for crossing.

MATERIALS AND METHODS

Two experiments were conducted at El-Sabahia Research Station (31° 12 N), Alexandria, Egypt, during 2013/2014/2015 season (plant crop) and 2015/2016 season (first ratoon crop).

The experimental procedures

Thirty-seven sugarcane genotypes from different origins and three commercial checks 'GT 54-9', 'G 84-47' and 'G 2003-47' were used (Table 1). In the middle of August, 2013 three-budded cuttings of each genotype were planted in 3 ridge plots with plot size 15 m². The experimental design was Randomized Complete Block with two replications. After flowering season, plant-cane of all plots were cut on June 14, 2015 and allowed to grow the ratoon till June 14, 2016.

The following measurements were recorded at three stages as described by Mehareb (2006):

1. *Duration of Pre-flag leaf stage:* This stage was calculated as number of days from planting date until stopping formation of new leaves and beginning of the flag leaf formation and emergence.
2. *Duration of flag leaf stage:* calculated as number of days from the beginning of flag leaf formation to as soon as the emergence of the inflorescence form flag leaf sheath occurred.
3. *Duration of emergence stage:* calculated from the starting of emergence of the inflorescence from flag leaf until its full extension completed.

Percent of total flowered plants: number of flowered plants/ number of plants per plot × 100.

Statistical analysis

Analysis of variance for each season as well as a combined analysis for both seasons were conducted according to Snedecor and Cochran (1967). The durations of pre-flag leaf stage, flag leaf stage and emergence stages and the percentage values for total flowered stalks, were transformed to the corresponding angle values in degrees ARC-Sin according to Evwin *et al.* (1966). Means were compared using LSD at 5% level of probability according to Waller and Duncan (1969).

Table 1 Source country of sugarcane genotypes studied

S. No.	Genotype	Source Country	S. No.	Genotype	Source Country
1	'Co 775'	India	21	'SP 72-5181'	Brazil
2	'Koeng Java'	Indonesia	22	'G 84-68'	Egypt
3	'G2003-47'	Egypt	23	'G 84-47'	Egypt
4	'EI 8-129'	Salvador	24	'SP 79-2233'	Brazil
5	'US 59-161'	South Florida	25	'G 74-96'	Egypt
6	'M35-157'	Mauritius	26	'G 2003-49'	Egypt
7	'ROC 10'	Taiwan	27	'G 2009-11'	Egypt
8	'EI 58-28'	Salvador	28	'Mex 2001-80	Mexico
9	'EI 8-10'	Salvador	29	'G 2009-10'	Egypt
10	'EI 242-16'	Salvador	30	'G 2009-22'	Egypt
11	'PS 80-1424'	Sri Lanka	31	'G 2009-86'	Egypt
12	'F 161'	Taiwan	32	'G 2006-36'	Egypt
13	'K 81113'	Thailand	33	'G 2008-59'	Egypt
14	'L 62-96'	Louisiana	34	'G 2006-3'	Egypt
15	'L 61-49'	Louisiana	35	'G 2004-27'	Egypt
16	'G 2000-5'	Egypt	36	'G 2007-61'	Egypt
17	'G 99-80'	Egypt	37	'GT 54-9'	Egypt
18	'SP 80-3250'	Brazil	38	'G 2008-20'	Egypt
19	'NA 56-79'	Argentina	39	'G 2008-64'	Egypt
20	'SP 80-1842'	Brazil	40	'88/5-27'	Egypt

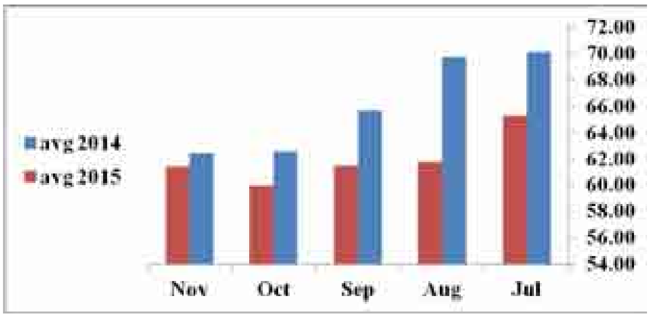


Fig. 1 The average daily humidity for five months from July to November for plant cane (2014) and first ratoon (2015)

Table 2 Number of days for flowering under optimum temperature (18-31°C) during three months from July to September in 2014 and 2015

Month	Number of days	
	2014	2015
July	25	22
August	14	2
September	24	9
Total	63	33

RESULTS AND DISCUSSION

Effect the humidity on sugarcane flowering

The average daily humidity for five months from July to November for plant cane (2014) and first ratoon (2015) are shown in figure 1. Daily humidity for plant cane was higher than first ratoon in all five months, so sugarcane flowering in plant cane (2014/2015) was higher than sugarcane flowering in first ratoon (2015/2016). These results were in agreement with those obtained by Clement and Awada (1964), Pereira *et al.* (1983) and, Moore and Berding (2014), who reported that moisture has more effect on sugarcane flowering. Enough moisture is critical for induction, initiation, time of flowering emergence and seed set (Moore and Nuss 1987). Low moisture during the initiation period reduces sugarcane flowering (Berding 1995).

Effect the temperature on sugarcane flowering

The number of days for flowering under the optimum temperature (18-31 °C) during three months (induction and initiation stage) from July to September in plant cane and first ratoon are given in Table 2. The number of these days in plant cane (63 days) were higher than first ratoon (33 days), so, flowering for genotypes in plant cane was higher than first ratoon. These results were in agreement with those obtained by Berding and Moore (1996, 2001); Berding *et al.* (2004, 2007), Moore and Berding (2014). They showed effect of high temperature on sugarcane flowering.

Individual and combined analysis of variance (Tables 3 and 4) over the two seasons (plant cane and first ratoon) revealed significant differences among genotypes for all measured characters. The difference between plant cane and first ratoon was significant for all characters. The genotype × year interaction was significant for all studied characters.

Duration of pre-flag leaf stage

Data presented in table 5 indicated that within the genotypes that flowered under plant cane and first ratoon, the duration of pre-flag leaf stage varied from 382 days for genotype 'G 2009-22' to 496 days for genotype 'NA 56-79', while in genotypes that flowered under first ratoon, the duration of

Table 3 Analysis of variance for the studied traits under plant cane and first ratoon

S.O.V.	df	Pre flag		Flag	
		Plant cane	First ratoon	Plant cane	First ratoon
Replication	1	644.11	49.613	68.45	0.8
Genotypes	39	99725.27**	57708.256**	158.963**	103.441**
Error	39	17.34	8.151	3.117	2.005
		Emergence		% Flowered plant	
		Plant cane	First ratoon	Plant cane	First ratoon
Replication	1	16.2	11.25	112.813	29.258
Genotypes	39	47.717**	58.358**	786.082**	794.385**
Error	39	0.995	0.788	3.838	1.604

Table 4 Combined analysis of variance over two seasons (plant cane and first ratoon) for the studied traits

S.O.V.	d.f	Pre flag	Flag	Emergence	% Flowered plant
Year	1	729810.23	483.03	40.00	666.75
Error	2	346.86	34.63	13.73	71.04
Genotypes	39	106742.43**	164.58**	70.90**	1442.81**
Y x G	39	50691.10**	97.82**	35.18**	137.66**
Error	78	12.75	2.56	0.89	2.72

pre-flag leaf stage ranged between 239 days for 'G 2009-22' to 440 days for 'SP 79-223l'.

Duration of flag leaf stage

This stage represents the development and elongation of the panicle from the end of pre-flag leaf stage to the time till panicle emergence from the flag leaf sheath occurred. Data in table 5 showed that in plant cane, the lowest duration of flag leaf stage was recorded by the genotype 'M 35-157' (6.5 days), while the highest duration was recorded by the genotype 'G 2008-20' (29.5 days). With respect to genotypes that flowered in first ratoon, this duration ranged from 7 days for four genotypes; 'PS 80-1424', 'L61-49', 'EI 242-16' and 'G 2006-36' to 26.5 days for the genotype 'G 2009-86'.

Duration of emergence stage

Emergence stage includes the full upward thrust off the inflorescence from the time it just emerges until the full extension of tassel is realized. Data in table 6 showed that within the genotypes that flowered in plant cane, duration of

Table 5 Duration of pre-flag leaf stage and flag leaf stage in plant cane and first ratoon

Genotype	Duration of pre-flag leaf stage		Duration of flag leaf stage	
	Plant cane	First ratoon	Plant cane	First ratoon
'EI 8-129'	400.00	240.00	15.00	15.00
'M35-157'	451.00	310.00	6.50	15.00
'PS 80-1424'	422.00	302.00	29.00	7.00
'K 81113'	493.00	363.00	10.50	12.00
'L 61-49'	495.00	395.00	10.00	7.00
'AN 56-79'	496.00	344.00	9.50	11.00
'SP 79-2233'	414.50	440.00	27.50	9.00
'G 2009-11'	435.00	349.50	16.00	21.00
'G 2009-10'	402.00	260.50	13.00	13.00
'G 2009-22'	382.00	239.00	13.00	13.00
'G 2009-86'	415.00	263.00	7.50	26.50
'G 2004-27'	430.00	336.00	12.00	8.50
'G 2008-64'	383.00	255.50	12.00	16.00
'88/5-27'	464.00	384.00	10.00	16.00
'SP 72-5181'	490.00	-	10.00	-
'G 84-68'	422.00	-	27.50	-
'G 84-47'	465.00	-	20.00	-
'G 74-96'	480.00	-	12.00	-
'G 2008-59'	435.00	-	10.00	-
'G 2006-3'	485.00	-	11.00	-
'G 2007-61'	460.00	-	13.00	-
'GT 54-9'	474.00	-	7.50	-
'G 2008-20'	424.00	-	29.50	-
'Koeng Java'	495.00	-	11.00	-
'EI 242-16'	-	433.00	-	7.00
'G 2006-36'	-	395.00	-	7.00
'G 2003-49'	-	-	-	-
'Mex 2001-80'	-	-	-	-
'Co 775'	-	-	-	-
'G2003-47'	-	-	-	-
'US 59-161'	-	-	-	-
'ROC 10'	-	-	-	-
'EI 58-28'	-	-	-	-
'EI 8-10'	-	-	-	-
'F 161'	-	-	-	-
'L 62-96'	-	-	-	-
'G 2000-5'	-	-	-	-
'G 99-80'	-	-	-	-
'SP 80-3250'	-	-	-	-
'SP 80-1842'	-	-	-	-
'LSD 0.05'	1.880	1.291	0.790	0.640
'LSD 0.05' (G X Y)	4.2	1.88		

this stage varied from 5 days for the genotype 'Koeng Java' to 18 days for the genotype 'G 2008-20', while among the genotypes that flowered under first ratoon, the duration of emergence stage fared from 7 days for three genotypes, *viz.,* 'SP 79-2233', 'G 2009-11' and 'EI 242-16' to 19.5 days for promising variety 'G 2004-27'.

Percentage of total flowered plants

The percentage (%) of total flowered plants in plant cane ranged from 12% (for 'SP 72-5181' and 'G 2008-20') to 65% (for 'G 2009-22'), while, % of total flowered plants in first ratoon varied from 11.40% (for promising variety 'G 2004-27') to 61.5% (for genotype 'NA 56-79') (Table 6).

Within the genotype that flowered in both plant cane and first ratoon, all emergence stages were present in fourteen genotypes, *viz.,* 'EI 8-129', 'M35-157', 'PS 80-1424', 'K 81113', 'L 61-49', 'NA 56-79', 'SP 79-2233', 'G 2009-11', 'G 2009-10', 'G 2009-22', 'G 2009-86', 'G 2004-27', 'G 2008-64' and '88/5-27'.

Results indicated that, the duration of pre-flag leaf stage is much longer than the other flowering stages as it included the

Table 6 Duration of emergence stage and percentage of total flowered plants in plant cane and first ratoon

Genotype	Duration of emergence stage		% of total flowered plants	
	Plant cane	First ratoon	Plant cane	First ratoon
'EI 8-129'	7.00	8.50	35.00	29.50
'M35-157'	8.00	14.00	60.00	56.25
'PS 80-1424'	6.00	13.00	44.00	43.35
'K 81113'	7.00	8.00	25.00	33.40
'L 61-49'	6.50	10.00	19.00	20.00
'AN 56-79'	6.00	8.00	45.00	61.50
'SP 79-2233'	14.00	7.00	26.00	29.25
'G 2009-11'	6.00	7.00	50.00	43.00
'G 2009-10'	7.50	10.00	41.00	35.64
'G 2009-22'	7.00	8.50	65.00	52.45
'G 2009-86'	15.00	7.50	40.00	38.25
'G 2004-27'	9.50	19.50	15.00	11.40
'G 2008-64'	7.50	11.00	49.50	47.40
'88/5-27'	7.00	12.00	40.50	33.35
'SP 72-5181'	8.00	-	12.00	-
'G 84-68'	14.00	-	25.50	-
'G 84-47'	6.50	-	14.00	-
'G 74-96'	8.00	-	20.50	-
'G 2008-59'	6.00	-	42.00	-
'G 2006-3'	6.50	-	23.00	-
'G 2007-61'	7.00	-	13.00	-
'GT 54-9'	8.00	-	13.00	-
'G 2008-20'	18.00	-	12.00	-
'Koeng Java'	5.00	-	12.50	-
'EI 242-16'	-	7.00	-	22.25
'G 2006-36'	-	10.00	-	22.20
'G 2003-49'	-	-	-	-
'Mex 2001-80'	-	-	-	-
'Co 775'	-	-	-	-
'G2003-47'	-	-	-	-
'US 59-161'	-	-	-	-
'ROC 10'	-	-	-	-
'EI 58-28'	-	-	-	-
'EI 8-10'	-	-	-	-
'F 161'	-	-	-	-
'L 62-96'	-	-	-	-
'G 2000-5'	-	-	-	-
'G 99-80'	-	-	-	-
'SP 80-3250'	-	-	-	-
'SP 80-1842'	-	-	-	-
'LSD 0.05'	0.450	0.402	0.880	0.573
'LSD 0.05' (G X Y)	1.11	1.94		

time needed for the accumulation of stimulus to divert the meristem from leaf production to reproductive stage, following that, there is a fairly long period in which no structural change appears but during which the tip of inflorescence undertakes the change from the bilateral arrangement to a spiral arrangement. The breeding stocks must be examined to define such response for better utilization of these materials in crossing programmes.

season) during flowering stages as well as the number of days for flowering under the optimum temperature (18-31°C) during three months (induction and initiation stage) in plant cane were also higher than first ratoon. So a better understanding of effect of temperature and relative humidity on sugarcane flowering is important to study the behaviour of flowering genotypes and make synchronization of flowering for crossing between these genotypes in future.

Table 7 Classification of the tested genotypes according to their flowering response under plant cane and first ratoon

S. No.	No flowering	Flowering in Plant cane	Flowering in first ratoon	Flowering in both seasons
1	'Co 775'	1-'Koeng Java'	'EI 242-16'	'EI 8-129'
2	'G2003-47'	2-'SP 72-5181'	'G 2006-36'	'M35-157'
3	'US 59-161'	3-'G 84-68'		'PS 80-1424'
4	'ROC 10'	4-'G 84-47'		'K 81113'
5	'EI 58-28'	5-'G 74-96'		'L 61-49'
6	'EI 8-10'	6-'G 2008-59'		'NA 56-79'
7	'F 161'	7-'G 2006-3'		'SP 79-2233'
8	'L 62-96'	8-'G 2007-61'		'G 2009-11'
9	'G 2000-5'	9-'GT 54-9'		'G 2009-10'
10	'G 99-80'	10-'G 2008-20'		'G 2009-22'
11	'SP 80-3250'			'G 2009-86'
12	'SP 80-1842'			'G 2004-27'
13	'G 2003-49'			'G 2008-64'
14	'Mex 2001-80'			'88/5-27'

The overall flowering behavior of forty sugarcane genotypes in plant cane and first ratoon is presented in Table 7. Results indicated that based on their flowering behavior, these forty sugarcane genotypes could be classified into four groups. The first group included fourteen genotypes *viz.* 'EI 8-129', 'M 35-157', 'PS 80-1424', 'K 81113', 'L 61-49', 'AN 56-79', 'SP 79-2233', 'G 2009-11', 'G 2009-10', 'G 2009-22', 'G 2009-86', 'G 2004-27', 'G 2008-64' and '88/5-27' that flowered in plant cane and first ratoon seasons. The second group consisted of ten genotypes *viz.* 'Java, 'SP 72-5181', 'G 84-68', 'G 84-47', 'G 74-96', 'G 2008-59', 'G 2006-3', 'G 2007-61', 'GT 54-9' and 'G 2008-20', that flowered only under plant cane. The third group included two genotypes *viz.* 'EI 242-16' and 'G 2006-36' that flowered only under first ratoon. The fourth group included fourteen genotypes *viz.* 'Co 775', 'G2003-47', 'US 59-161', 'ROC 10', 'EI 58-28', 'EI 8-10', 'F 161', 'L 62-96', 'G 2000-5', 'G 99-80, 'SP 80-3250', 'SP 80-1842', 'G 2003-49' and 'Mex 2001-80' that did not show any response in either plant cane or first ratoon. Therefore, the forty evaluated sugarcane genotypes varied considerably among themselves in their response to flowering in plant cane and first ratoon.

CONCLUSION

Number of genotypes that flowered in plant cane were higher than first ratoon because percentage of daily humidity for plant cane (2014 season) was higher than first ratoon (2015

REFERENCES

Aamlid T S, O M Heide, B R Christie and McGraw R L. 1999. Reproductive development and the establishment of potential seed yield in grasses and legumes. In: Fairey D T and. Hampton J G. (ed.), Forage Seed Production 1. Temperate Species. *CAB International*, New York, NY, pp. 17-44.

Berding N. 1995. Improving flowering through breeding: Progress and prospects. *Proc. Queensland Sugar Technol. Assoc.*, **17**: 162-71.

Berding N, Moore P H. 1996. Towards optimized induction of flowering in sugarcane. In: Wilson J R, Hogarth D M, Campbell J A and Garside A L. (ed), Sugarcane: Research towards efficient and sustainable production, *CSIRO Division of Tropical Crops and Pastures, Brisbane*, pp. 44-6

Berding N, Moore P H. 2001. Advancing from opportunistic sexual recombination in sugarcane: Lessons from tropical photoperiodic research. *Proceedings International Society of Sugar Cane Technologists*, **24**: 482–87.

Berding N, Dunne V, Swain R S, Owens W G. 2004. Tropical, managed initiation of sugarcane flowering: Optimization of non-photoperiodic variables. *Proceedings of the Australian Society of Sugar Cane Technologists,* **26:** 1-13, (CD-ROM)

Berding N, Pendrigh R S and Dunne V. 2007. Can flowering in sugarcane be optimized by use of differential declinations for the initiation and development phases? *Proceedings of the International Society of Sugar Cane Technologists,* **26**: 699-711.

Clements H F and Awada M. 1964. Factors affecting the flowering of sugarcane. *Ind J Sugarcane Res and Dev,* **8**(2): 140-59.

Clements H F and Awada M. 1965. Experiments on the artificial induction of flowering in sugarcane. *Proceedings of the International Society of Sugar Cane Technologists*, **12**: 795-812.

Coleman R E. 1968. Physiology of flowering in sugarcane. *Proceedings of the International Society of Sugar Cane Technologists*, **13**: 992–1000.

Evwin L L, Warren H L and Andrews G C. 1966. "Field plot technique" transformation of experimental data. *Burgess pub. Comp America,* pp. 338-49.

LaBorde C, Kimbeng C, Gravois K and Bischoff K. 2014. Temperature effects on sugarcane tassel production under artificial photoperiod regimes. *Journal of American Society of Sugar Cane Technologists,* **34**: 33-43.

Mehareb E M. 2006. Response of some sugarcane genotypes to artificial and natural flower induction. Dissertation submitted to the Graduate Faculty of Agriculture, Cairo University in partial fulfillment of the requirements for the degree of Master of Science.

Mohamed B D, Mahmoud E A, El-Hennawi H H and Mehareb E M. 2016. Sugarcane flowering in relation to nitrogen fertilization and ratoon. *Direct Research Journal of Agriculture and Food Science,* **4**(7):155-60.

Moore P H and Berding N. 2013. Flowering. In: Moore P H and Botha F C. (ed.), Sugarcane: Physiology, Biochemistry, and Functional Biology, *John Wiley & Sons Ltd, Chichester, UK*. doi: 10.1002/9781118771280.ch15

Moore P H and Nuss K J. 1987. Flowering and flower synchronization. In: Heinz D J. (eds.) Sugarcane improvement through breeding. *Elsevier Press, Amsterdam, The Netherlands*, pp. 273-311.

Nuss K J, Brett P G C. 1977. Artificial induction of flowering in a sugarcane breeding programme. *Proc. South. Afr. Genet. Soc*., **6**: 54-64.

Nuss K J. 1979. Factors influencing the number of seedlings obtained from sugarcane crosses. *Proc. South Afr. Sugar Technologist Association,* **53**: 167-69.

Pereira A R, Barbieri V and Villanova N A. 1983. Climatic conditioning of flower induction in sugarcane. *Agric. Meteorol.* **29**:103-10.

Restrepo F S and Ranjel J H. 1984. Induction and synchronization of sugarcane flowering in the Cauca Valley. *Acta-agronomica*, **34**(2): 20-5.

Shanmugavadivu R and Gururaja Rao P N. 2009. A comparison of flowering behaviour of sugarcane clones in two different locations. *Sugar Tech*., **11**(4): 401-4.

Snedecor G V and Cochran W G. 1967. Statistical methods. 6th ed., *Iowa State Univ. Press, Ames Iowa*, USA.

Waller R A and Duncan D B. 1969. A Bayes rule for the symmetric multiple comparisons problem. *J. Amer. Stat. Asso.,* **64**(328): 1484-1503.

Indian Journal of Sugarcane Technology **32(01)**: 20-24, June 2017

Evaluation of elite sugarcane clones/varieties against red rot disease (*Colletotrichum falcatum*) under differential water regimes

HARMANDEEP SINGH, G S SANGHERA*, V TYAGI and R P SINGH

PAU, Regional Research Station, Kapurthala-144601, Punjab, India

ABSTRACT

Thirty elite sugarcane clones/varieties were screened against prevalent red rot pathotypes (*Cf* 08 and *Cf* 09) under artificial inoculation using plug method under normal (E_1) and water stress (E_2) environments. Data revealed that disease score among the clones was higher in E_1 as compared to E_2 for both the pathotypes. It ranged from 3.7 to 8.7 in E_1 and from 3.5 to 8.5 in E_2 environment for *Cf* 08 pathotype while for *Cf* 09 the disease score ranged from 3.4 to 8.9 under normal (E_1) and from 3.5 to 8.7 under water stress (E_2) environments showing variable degree of resistance. Present study concludes that 5 of 30 varieties/clones screened for red rot disease resistance against the pathotypes *Cf* 08 and *Cf* 09 *viz.* 'Co 0238', 'CoS 8436', 'Co 0118', 'CoPb 92' and 'CoPb 93' and 8 elite clones namely 'ISH 07', 'ISH 135', 'CoPb 14211', 'CoPb 14212', 'CoPb 13182', 'CoPb 11214', 'CoPb 12211, 'CoPb 12212' were categorized as moderately resistant to red rot under both normal (E_1) and water stress (E_2) environments. The varieties/clones found moderately resistant (MR) under water stress (E_2) environment can be used for future evaluation across locations for red rot resistance under limited water conditions.

Key words: Sugarcane, red rot, plug method, water stress

INTRODUCTION

Sugarcane (*Saccharum* spp. hybrid complex) is the most important cash crop of India which is produced for making sugar, jaggery and khandsari. It is grown in over 110 countries and about 50 per cent of world sugarcane production occurs in Brazil and India (FAO 2016). India has emerged as the largest producer of sugar in the world. Sugar industry is the second largest agro processing industry in the country with significant contribution to the income, employment and tax revenue of the rural area (Priya *et al.* 2015). It is cultivated in most of the states of India (tropical and sub-tropical regions of the country) with total area coverage of 5.03 million hectare (M ha). In India, the states of Uttar Pradesh (38.57 %), Maharashtra (17.76 %) and Karnataka (12.20 %) lead the nation in sugarcane production (Anonymous 2014). However, in Punjab it is cultivated in 94 thousand hectare area with an average cane yield of 73.4 tons per hectare. Various biotic factors are accountable for low yield of sugarcane and diseases are a major cause of concern. About hundred diseases of sugarcane have been reported in different parts of the world. In India, among the various diseases, red rot caused by *Colletotrichum falcatum* is one of the earliest recorded diseases and has been aptly called the cancer of sugarcane (Agnihotri 1990). Red rot is causing considerable losses both in yield and juice quality especially in subtropical India resulting in significant losses to both cane growers and sugar factories (Gill *et al.* 2012). The red rot infection can cause complete depletion of sucrose in the cane (Agnihotri *et al.* 1992) and around 90 per cent reduction in juice extraction with 50 per cent red rot incidence (Ahmed *et al.* 1986). A number of elite varieties have been wiped out and cultivation of promising varieties like 'CoJ 64', 'CoJ 82', 'CoJ 84' and 'CoJ 86' in Punjab had to be discontinued by farmers from time to time due to their high susceptibility to this disease. 'CoJ 64', which had been the most popular variety of sugarcane in recent past, due of its highest sugar recovery, was among those varieties which succumbed to red rot disease. The disease which was earlier confined to sugarcane growing areas of Northern India and parts of North-Western India and Andhra Pradesh for several decades, has now started diffusing to parts of southern India, especially in the east coast zone, knocking down many improved sugarcane cultivars, the most notable being 'CoC 671' (Natarajan *et al.* 1998). Pathogen *Colletotrichum falcatum* responsible for this disease is highly variable in nature; hence, it causes the frequent breakdown of resistant sugarcane varieties due to its ongoing evolution (Kaur *et al.* 2014, Sharma and Tamta 2015). In spite of the best efforts of sugarcane improvement scientists, red rot is still posing challenges and threats in stabilizing cane and sugar production. Through the concerted efforts of breeders and pathologists, the disease has been contained to a manageable level and thus, the frequency and magnitude of red rot epidemic has been reduced to a great extent in recent decade (Duttamajumder 2008). As a result, breeding for red rot resistance has emerged as a significant aspect of present day varietal development and evolution. The red rot pathogen being a facultative parasite, keeps on mutating in nature

*Corresponding author's E-mail: sangheragulzar@pau.edu

resulting in formation of new races responsible for the breakdown of hitherto resistant varieties under field conditions (Kaur *et al.* 2014). 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 Sanghera *et al.* 2017). The continued efforts are being made to generate elite material possessing tolerance to the various isolates of red rot coupled with best agronomic performance from the hybridization of specifically chosen parents (Sanghera *et al.* 2016). Present study was conducted to assess the manifestation of red rot disease under different water regimes to isolate clones/varieties for rainfed cultivation with inbuilt resistance to red rot disease.

MATERIALS AND METHODS

The experimental plant material consisted of 30 diverse varieties/elite clones comprising of nine commercial varieties, seventeen local selections and four ISH clones as listed in Table 1. All the material was planted at PAU, Regional Research Station, Kapurthala in a randomized block design (RBD) with a plot size of 2R×6m×0.90m with two replications in normal (E_1) and water stress (E_2) environments. Normal package of practices was followed except irrigation that was suspended for 18-21 days in water stress (E_2) environment at tillering and grand growth stages. For evaluation of sugarcane varieties/clones against red rot disease the pathological cultures of pathotypes *Cf* 08 (from 'CoJ 84') and *Cf 09* (from 'CoS 767') were freshly revived by sub culturing in laboratory and used for inoculation in sugarcane plants under field conditions using plug method. Both the pathotypes (*Cf* 08 and *Cf* 09) were multiplied on oat meal agar medium in Petri dishes at 25±1ºC. Fresh sporulating 7-10 days old cultures were used for inoculations. The spores were washed with sterile distilled water and homogenized by shaking and spore suspensions with concentration of 2 X 10^4 conidia ml^{-1} were maintained. Using single bud setts, experimental plant materials were planted in the field area. Ten canes per treatment were selected and inoculated by a suspension of two pathotypes by artificial inoculation under field conditions using plug method (Srinivasan and Bhatt 1961). The inoculations were done in the third internode from the base of the standing canes with the help of hypodermic syringe by injecting 1.0 ml of spore suspension (2X10^4 conidia ml^{-1}). The core was then replaced and the openings were sealed with modeling clay. For disease screening, the condition of the top was recorded and the canes splitted longitudinally and observations were recorded on the number of internodes transgressed by the pathogen. Disease score was recorded at 60 days after inoculation for pathogenicity parameters (Table 2) and disease reaction following 0-9 scale (Table 3) as per Srinivasan and Bhatt (1961). The clones were categorized as resistant (R), moderately resistant (MR), moderately susceptible (MS), susceptible (S) and highly susceptible (HS) accordingly.

RESULTS AND DISCUSSION

The biotic and abiotic stresses lead to a gradual reduction in cane yield, sucrose per cent in juice and enhanced reducing sugars (Singh and Reddy 1980) in sugarcane crop. Red rot, the most dreadful disease of sugarcane causes great loss to growers as well as sugarcane industry. Moreover, most of the newly released cultivars to replace the susceptible ones succumb to the pathogen almost as soon as they become popular due to the frequent emergence of new variants of the pathogen (Gupta *et al.* 2010). Management of the disease by the use of disease-free seed canes for planting is impractical due to the difficulty in diagnosing the dormant infections of the fungus in seed canes under field conditions (Viswanathan and Samiyappan 2002). 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.*

Table 1 List of elite clones/varieties used in the study

S. No.	Clone/variety	Source	S. No.	Clone/variety	Source
1	'Co 0238'	RRS, Kapurthala	16	'KV 2012- 1'	-do-
2	'CoJ 88'	-do-	17	'KV 2012- 2'	-do-
3	'CoS 8436'	-do-	18	'KV 2012- 3'	-do-
4	'CoPb 91'	-do-	19	'KV 2012- 4'	-do-
5	'Co 011'	-do-	20	'KV 2012- 5'	-do-
6	'CoJ 85'	-do-	21	'CoPb 13181'	RRS, Faridkot
7	'CoJ 64'	-do-	22	'CoPb 13182'	-do-
8	'CoPb 92'	-do-	23	'CoPb 13183'	-do-
9	'CoPb 11214'	-do-	24	'CoPb 10181'	-do-
10	'CoPb 14212'	-do-	25	'CoPb 12181'	-do-
11	'CoPb 14211'	-do-	26	'CoPb 12182'	-do-
12	'CoPb 12212'	-do-	27	'ISH 148'	SBI, Coimbatore
13	'L 818/07'	-do-	28	'ISH 07'	-do-
14	'CoPb 11211'	-do-	29	'ISH 135'	-do-
15	'CoPb 93'	-do-	30	'ISH 159'	-do-

Table 2 Pathogenecity parameters used for screening of sugarcane against red rot disease

Symptoms	Numerical scale	Severity of symptoms
Conditions of tops	0	Green.
	1	Yellow or drying.
Nodal transgression	0	No lesion spread. Lesion restricted to the inoculated node.
	1	Lesion transgression of one node above the inoculated node.
	2	Lesion transgression of 2 nodes above the inoculated node.
	3	Lesion transgression of more than 2 nodes above the inoculated node.
Lesion width	0	No lesion spread.
	1	Lesion spread to about 25% of the width of the stalk.
	2	Lesion spread to about half the cane width.
	3	Lesion spread to more than half the width of the cane.
White spots	0	No white spots.
	1	Sparse presence of white spots.
	2	Moderate to profuse presence of white spots.

Table 3 Screening of sugarcane varieties against red rot and their reaction (0-9 scale)

Sr. No	Score on 0-9 scale	Reaction category
1	0.0-2.0	Resistant (R)
2	2.1-4.0	Moderately resistance (MR)
3	4.1-6.0	Moderately susceptible (MS)
4	6.1-8.0	Susceptible (S)
5	8.1-9.0	Highly susceptible (HS)

2007 and Kaur *et al.* 2014). The continued efforts are being made to generate elite material possessing tolerance to the various isolates of red rot coupled with best agronomic performance from the hybridization of specifically chosen parents. In the present study 30 varieties/ clones were screened against *Cf* 08 (isolated from 'CoJ 84') and *Cf* 09 (isolated from 'CoS 767') isolates of red rot pathogen using artificial inoculation by plug method under normal (E_1) and water stress (E_2) environments and the reaction of these genotypes was scored against both the red rot pathogen as per Srinivasan and Bhatt (1961) and results obtained are presented in the Table 4. The tested genotypes showed differential reaction against both the pathotypes ranging from moderately resistant (< 4.0) to highly susceptible (>7.0) indicating genetic variability for disease resistance in the research material used in study. Reaction to *Cf* 08 red rot pathotype under artificial inoculation by plug method revealed that varieties/clones like 'Co 0238', 'CoS 8436', 'Co 0118', 'CoPb 92', 'CoPb 93', 'ISH 07', 'ISH 135', 'ISH 159', 'KV 2012-1', 'KV 2012-3', 'KV 2012-5', 'CoPb 14211', 'CoPb 14212', 'CoPb 13182', 'CoPb 12211', 'CoPb 12212' and 'CoPb 10181' were found to be moderately resistant (MR) having disease score between 2.1-4.0 under both normal (E_1) as well as water stress (E_2) environments. Bharathi *et al.* (2012) screened fifty five early and mid late sugarcane cultivars for their resistance to red rot pathogen out of which twenty six were found moderately resistant to red rot. Clones like 'CoPb 12181' and 'CoPb 12182' were susceptible (S) to *Cf* 08 under normal (E_1) environment while they were moderately susceptible (MS) to this pathotype under water stress (E_2) environment. The highly susceptible (HS) reaction was exhibited by the clone 'CoPb 13183' (score 8.7 and 8.5, respectively) to *Cf* 08 under both the environments followed by 'CoJ 64' and 'CoJ 85'. The clone 'ISH 148' was found to be highly susceptible (HS) (score 8.4) under normal E_1 environment while under water stress (E_2) conditions, it exhibited moderately resistant (MR) reaction (score 4.0) against *Cf* 08. Variety 'CoJ 88' was found to be susceptible (S) (score 6.4 and 6.3, respectively) under both normal (E_1) and water stress (E_2) environment which indicates that pathogen is highly variable and resistance of cultivars breakdown frequently. Artificial inoculation of irradiated sugarcane subclones done by Kaur *et al.* 2016 against two red rot pathotypes *Cf* 08 and *Cf* 09 using plug method has revealed moderate level of resistance for different mutagenic treatments.

Similarly, varieties like 'Co 0238', 'CoS 8436', 'Co 0118', 'CoPb 92' and 'CoPb 93' and clones like 'ISH 07', 'ISH 135', 'CoPb 14211', 'CoPb 14212', 'CoPb 13182', 'CoPb 11214', 'CoPb 12211', 'CoPb 12212' and 'CoPb 10181' showed a varied disease score from 2.1 to 4.0 and exhibited moderately resistant (MR) reaction against *Cf* 09 red rot pathotype under normal (E_1) as well as water stress (E_2) environments. Gill *et al.* (2012) also screened 23 sugarcane genotypes belonging to twenty three diverse cross combinations under irrigated conditions for their reaction against red rot pathotypes *Cf* 08 and *Cf* 03 and found a total of 13 genotypes belonging to eleven cross combinations as moderately resistant reaction to both the pathotypes. Varieties 'CoJ 85' and 'CoJ 64' were found highly susceptible (HS) to *Cf* 09 pathotype under both the environments. Clone 'KV2012-3' found to be moderately susceptible (MS) having disease score 4.3 to this pathotype under normal (E_1) environment while this clone exhibited moderately resistant (MR) reaction (score 3.7) under water stress (E_2) environment. Similarly, clone 'ISH 148' exhibited high susceptibility (HS) having score of 8.4 to *Cf* 09 pathotype under normal (E_1) environment but exhibited moderately resistant score of 3.9 under water stress (E_2) environment. It

Table 4 Reaction and score of 30 sugarcane clones/varieties against *Cf* 08 and *Cf* 09 pathotypes of red rot under normal (E_1) and water stress (E_2) environments

Genotypes	*Cf* 08				*CF* 09			
	Normal (E_1)		Water stress (E_2)		Normal (E_1)		Water stress (E_2)	
	Score	Reaction	Score	Reaction	Score	Reaction	Score	Reaction
'CoPb 10181'	3.7	MR	3.6	MR	3.8	MR	3.8	MR
'CoPb 11214'	4.2	MS	3.9	MR	3.7	MR	3.9	MR
'CoPb 12181'	6.6	S	5.9	MS	6.2	S	5.8	MS
'CoPb 12182'	6.9	S	6.0	MS	6.8	S	6.7	S
'CoPb 12211'	3.7	MR	3.7	MR	3.7	MR	3.9	MR
'CoPb 12212'	3.7	MR	3.7	MR	3.5	MR	3.7	MR
'CoPb 13181'	5.5	MS	5.7	MS	5.6	MS	5.7	MS
'CoPb 13182'	3.6	MR	3.8	MR	3.8	MR	3.7	MR
'CoPb 13183'	8.7	HS	8.5	HS	8.9	HS	8.7	HS
'CoPb 14211'	3.6	MR	3.7	MR	3.7	MR	3.8	MR
'CoPb 14212'	3.8	MR	3.8	MR	3.7	MR	3.5	MR
'CoPb 92'	3.8	MR	3.7	MR	3.8	MR	3.6	MR
'CoPb 93'	3.8	MR	3.6	MR	3.4	MR	3.6	MR
'ISH 07'	3.7	MR	3.5	MR	3.9	MR	3.7	MR
'ISH 135'	3.7	MR	3.6	MR	3.7	MR	3.6	MR
'ISH 148'	8.4	HS	4.0	MR	8.4	HS	3.9	MR
'ISH 159'	3.8	MR	3.8	MR	6.1	S	5.8	MS
'L 818/07'	3.7	MR	3.6	MR	3.8	MR	3.5	MR
'KV 2012-1'	3.8	MR	3.8	MR	3.7	MR	3.7	MR
'KV 2012-2'	4.3	MS	3.7	MR	4.4	MS	3.8	MS
'KV 2012-3'	3.8	MR	3.8	MR	4.3	MS	3.7	MR
'KV 2012-4'	4.7	MS	4.7	MS	4.8	MS	4.5	MS
'KV 2012-5'	3.9	MR	3.6	MR	3.7	MR	3.6	MR
'Co 238'	3.7	MR	3.6	MR	3.9	MR	3.6	MR
'CoJ 88'	6.4	S	6.3	S	3.8	MR	3.7	MR
'CoS 8436'	3.7	MR	3.7	MR	3.7	MR	3.8	MR
'CoPb 91'	4.5	MS	4.5	MS	4.6	MS	4.3	MS
'Co 0118'	3.9	MR	3.5	MR	3.5	MR	3.6	MR
'CoJ 85'	8.4	HS	8.3	HS	8.6	HS	8.3	HS
'CoJ 64'	8.5	HS	8.3	HS	8.4	HS	8.2	HS

was observed in the present study that there was less incidence of red rot among genotypes planted under water stress (E_2) environment than in those genotypes that were planted under normal (E_1) environment that may be attributed to more favourable conditions under irrigated conditions, so there is decline in the severity under water stress (E_2) conditions. Results reported by Yin and Hoy (1997) were contradictory to present study, who revealed that red rot severity can be increased by the occurrence of drought conditions during the initial growth processes of vegetatively propagated sugarcane stalks. Similarly, Olufolaji (1989) also demonstrated increase in red rot incidence when standing cane was exposed to drought stress. The results under present study conclude that varieties *viz.* 'Co 0238',' CoS 8436', 'Co 0118', 'CoPb 92' and 'CoPb 93' and 8 elite clones namely 'ISH 07', 'ISH 135', 'CoPb 14211', 'CoPb 14212', 'CoPb 13182', 'CoPb 11214', 'CoPb 12211', 'CoPb 12212' were categorized as moderately resistant to *Cf* 08 and *Cf* 09 pathotypes of red rot under both normal (E_1) and water stress (E_2) environments and can be used in future red rot breeding programmes. Further, two clones *viz.*, 'ISH 148' and 'KV 2012-3' were categorized as moderately resistant under water stress (E_2) environment, so these clones can be used in future evaluation for red rot resistance under limited water conditions over locations.

REFERENCES

Agnihotri V P, Madan V K and Lal R. 1992. Proliferation of *Colletotrichum falcatum* in sugarcane genotypes and changes in sucrose content of affected tissues. *Indian Sugar,* **42**: 103-5.

Agnihotri V P. 1990. Diseases of sugarcane and sugarbeet. *Oxford and IBH Publishing Co. Pvt. Ltd.*, New Delhi.

Ahmed M, Ali R and Fasihi S. 1986. Effect of different infection levels of red rot of sugarcane on cane weight and juice quality. *J Agri Res.,* **24**: 129-31.

Anonymous 2014. *Agriculture statistics at a glance*. Directorate of Economics and Statistics. Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, P 124-6.

Bharathi V and Sudhakar R. 2012. Assessment of resistance to red rot (*colletotrichum falcatum* Went) disease by different methods of inoculation in sugarcane germplasm. *International Journal of Bio-resource and Stress Management,* **3**: 255-8.

Duttamajumder S K. 2008. Red rot of sugarcane. *Indian Institute of Sugarcane Research*, Lucknow, India, P 132.

Food and Agriculture Organization of the United Nations. http://faostat.fao.org/ (Source: Retrieved 2016-02-11).

Gill R S, Kumar B, Thind K S and Kumar N. 2012. Potential of sugarcane genotypes against red rot in north-west zone and under Punjab conditions. *Pl Dis Res.,* **27**:175-8.

Gupta V, Raghuvanshi S, Gupta A, Saini N, Gaur A, Khan M S, Gupta R S, Singh J, Duttamajumder S K, Srivastava S, Suman A, Jitendra P, Khurana, Kapur R and Tyagi A K. 2010. The water-deficit stress and red rot related genes in sugarcane. *Funct Integr Genomics,* **10**: 207–14

Kaur M, Thind K S, Sanghera G S, Kumar R and Kashyap L. 2016. Gamma rays induced variability for economic traits, quality and red rot resistance in sugarcane (*Saccharum* spp.) *International Journal of Science, Environment and Technology,* **5**: 355-65.

Kaur R, Kumar B, Vikal Y and Sanghera G S. 2014. Genetic diversity among *Colletotrichum falcatum* isolates causing red rot of sugarcane in subtropical region of India. *Not Sci Bio.,* **6**:308-15.

Meeta M, Kumar B, Gill R S and Thind K S. 2007. Identification of red rot resistant clones of sugarcane at settling stage III under Punjab conditions. *Pl Dis Res.,* **22**: 93-4.

Natarajan U S, Ramana Rao T C, Balasundaram N, Palanichamy K and Tripathi B K. 1998. Red rot resistance in sugarcane-a critique. *Sugar Cane,* **1**: 11-4.

Olufolaji D B. 1989. The effect of water stress on red rot in sugar cane. *Sugar Cane*, Autumn 1989 Supplement: 16.

Priya S R K, Vajpayi P K and Suresh P K. 2015. Stochastic models for sugarcane yield forecasting. *Indian J. Sugarcane Technol.,* **30**: 1-5.

Sanghera G S, Kashyap L, Kumar R, Singh O, Singh R P, Tyagi V, Thind K S and Kumar B. 2016. CoPb 08217- A Promising Mid Maturing Variety of Sugarcane for Punjab. *Jour Pl Sci Res.,* **32** (2): 165-71.

Sanghera G S, Singh R P, Tyagi V and Thind K S. 2017. Recent genomic approaches for sugarcane improvement: opportunities and challenges. *Quality and Quantum Improvement in Field Crops,* Chapter **6**: 109-52.

Sharma R and Tamta S. 2015. A review on red rot: The "Cancer" of sugarcane. *J Pl Pathol Microbiol* S1: 003 doi:10.4172/2157-7471.S1-003.

Singh S and Reddy M S. 1980. Growth, yield and juice quality performance of sugarcane varieties under different soil moisture regimes in relation to drought resistance. *Proc. ISSCT,* **27**:541-55.

Srinivasan K V and Bhatt N R. 1961. Red rot of sugarcane - criteria for grading resistance. *J Ind Bot Soc.,* **11**: 566-77.

Viswanathan R and Samiyappan R. 2002. Role of oxidative enzymes in the plant growth promoting rhizobacteria (PGPR) mediated induced systemic resistance against *Colletotrichum falcatum* in sugarcane. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz,* **109**: 88-100.

Yin Z and Hoy J W. 1997. Effect of stalk desiccation on sugarcane red rot. *Plant Dis.,* **81**: 1247-50.

Indian Journal of Sugarcane Technology **32(01)**: 25-30, June 2017

Sustainability of sugarcane based dairy farming in different regions of Uttar Pradesh

KAMTA PRASAD[1*], G SANKHALA[2], K KANT[2], NIKETHA L[2] and RAJESH KUMAR[1]

[1] *ICAR-Indian Institute of Sugarcane Research, P.O. Dilkusha, Lucknow-226 002, U.P., India*
[2] *ICAR-National Dairy Research Institute, Karnal-132001, Haryana, India*

ABSTRACT

Among various crop based dairy farming systems, sugarcane based dairy farming offers an excellent opportunity as sugarcane *per se* contributes a lot to dairy enterprise in the form of fodder, fuel, litter and housing material. However, further intensification may pose second generation problems of the highly productive ecosystem. Therefore, before suggesting any strategy for its upscaling, sustainability aspects from economic, social and environmental point of views need a thorough analysis. In order to address the issue, a study was conducted in 3 major sugarcane growing regions of Uttar Pradesh *viz*., Eastern, U. P., Central U.P. and Western U. P. From each region, one district, from each district, 2 *tehsils*, from each *tehsil*, 2 villages and from each village 20 farmers practicing sugarcane based dairy farming were selected. Region's Composite average sustainability was 0.43, 0.38 and 0.34 for Western U.P., Eastern U. P. and Central U.P., respectively. Region-wise and dimension-wise highly significant differences existed in sustainability indices demanding separate policies and programmes for different categories of farmers and regions of the state. In this paper an attempt has been made to assess the sustainability of sugarcane based dairy farming for suggesting suitable dairy development strategies.

Key words: Sugarcane based dairy farming, Sustainability, Regions, Uttar Pradesh

Dairying can effectively be used to arrest negative effects of present day challenges to intensive cropping as well as to maintain the sustainability of crop-livestock farming system for a longer period of time with livelihood security to the rural masses. Livestock as an integral part of India's agricultural economy plays a multifaceted role in national economy by employment generation, asset creation, coping -up crop failure and socio-economic security. However, to meet the growing demand of feed and fodders for huge livestock population necessitates the exploration of its alternative sources for sustainable dairy farming. It is in this context that sugarcane crop based dairy farming offers an excellent opportunity as sugarcane *per se* contributes a lot in the form of fodder, fuel, litter and housing materials. Moreover, sugarcane represents an example whose by-products can maximally be utilized in dairy business (Kung and Stanley 1982; Kevelenge *et al.* 1983; Nasseven 1986 and Wanapat 1990). As such there is a scope to improve the status of dairy farming in sugarcane growing areas as the elasticity coefficients in livestock and sugarcane based farming systems have been found significant (Singh *et al*. 2010). Sugarcane is mainly grown under the highly fertile irrigated agri-ecosystem of the country of which, Uttar Pradesh is the main constituent where there is a considerable opportunity for intensification of dairy farming. But any attempt to increase the production and productivity of dairy animals in U. P. will not be successful until and unless, it is increased under sugarcane based dairy farming which is prevalent in 59 out of the 75 districts, however, there is paucity of information on sustainability issue on sugarcane based dairy farming system across the regions of the state.

Keeping this in view, the emerging importance of sugarcane based dairy farming warranted its analysis, hence present study was carried out to assess the sustainability of sugarcane based dairy farming in different regions of Uttar Pradesh.

MATERIALS AND METHODS

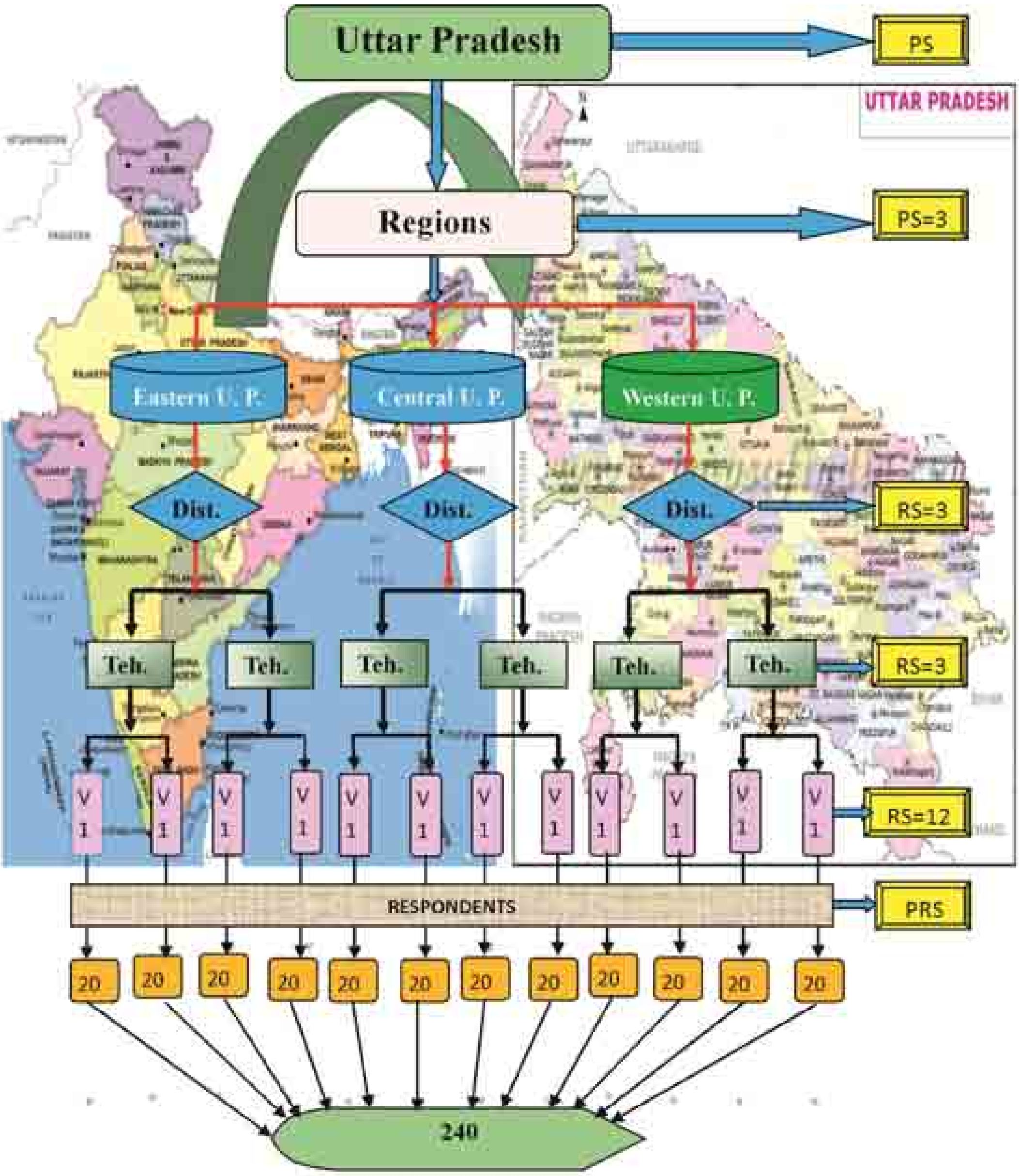
Locale of the study

The study was conducted in the state of Uttar Pradesh. It is one of the oldest states in the country created on 1 April 1937 as the United Province and was renamed Uttar Pradesh in 1950. It is situated between 23°52' and 31°28' North latitudes and 77°3' and 84°39' East longitudes, It covers 243, 290 km^2, equal to 6.88 per cent of the total area of India and is the fifth largest state of the country. With over 200 million inhabitants as per the 2011 Census, it is not only the most populous state in the country but it is the most populous country subdivision in the world. The state contributes 16.16 per cent of India's population. The population density is 828 people per km^2, making it one of the densest states in the country (Statistics of Uttar Pradesh 2011 and Census Report 2011). The climate of the state is sub-tropical, but variations exist because of difference in altitudes.

Sampling plan

The sampling plan is given in Figure 1. Uttar Pradesh was selected purposely for the present study as it had highest

*Corresponding author's E-mail: kp_2013@rediffmail.com



Abbreviations: Dist-District, Teh.-Tehsil, V-Village, PS-Purposive Sampling, RS-Random Sampling and PRS- Proportionate Random Sampling

Fig. 1. Sampling plan of study on sugarcane based dairy farming in different regions of Uttar Pradesh

area 22.12 lakh ha under sugarcane crop in the year 2012-13 with a production and productivity of 134.85 million tonnes and 60.96 tonnes ha^{-1}, respectively. The state produced 25.19 million tonnes of milk during 2014-15 occupying the first rank in milk production in the country (DAHD&F, Annual Report 2014-15). Uttar Pradesh is one of the largest states in the country with a large livestock population, representing 10 per cent of the cattle, 23 per cent buffaloes and 10 per cent goats' population in the country and as per the Nineteenth Livestock Census (2012), it has highest (50.18 million) bovine population. To conduct the study, three sugarcane growing regions namely Eastern U. P., Central U. P. and Western U. P. were selected purposely. Faizabad, Sitapur and Muzaffarnagar districts from Eastern U.P, Central U. P. and Western U. P., respectively were randomly selected. From each selected district, two *tehsils* and from each selected *tehsil*, 2 villages were selected randomly. Thus, a total of 3 regions, 3 districts, 6 *tehsils* and 12 villages were selected for conducting the study. For selection of the respondents, a pilot survey of the selected villages was carried out and a list of farmers practising dairy farming from 5 years, having at least one milch animal, generating substantial part of agricultural income from sugarcane crop related activities either through its cultivation or doing related jobs such as labour, running crushers, transportation of sugarcane, *etc.* were shortlisted as they are the farmers who are practising sugarcane based dairy farming irrespective of whether they are having their own land or not. Farmers were categorised on the basis of land holdings into the categories *viz*., landless, marginal, small, semi-medium, medium and large categories. On the basis of proportionate random sampling method, from each selected village, a total of 20 farmers representing proportionately the respective categories were selected, however, at least one farmer from each category was included. Thus, a total of 240 such farmers constituted the sample size. To measure the sustainability, Sugarcane Based Dairy Farming Sustainability Index containing 44 indicators covered under the economical, social and environmental dimensions by the Normalized Rank Order Method suggested by *Guilford* (1954) was developed. The sustainability was calculated using the following formula:

The first step is to construct the index (Iij) for each i^{th} indicator representing j^{th} dimension of composite sustainability index. For making indicator scale free following method was applied:

$$I_{ij} = \frac{Xij - MinXij}{Max\ Xij - MinXij}$$

Where, i = 1, 2, 3……..n Indicators

j = 1, 2, 3 Dimensions of sustainability

X_{ij} = Value of i^{th} indicators of j^{th} dimensions

Having calculated, the I_{ij} for all the indicators, the second step is to calculate the indices for various dimensions of composite sustainability index. It is calculated as the simple mean of their respective variables, that is:

$$ESI = \frac{\sum_{i=1}^{n} Iij}{n},\ SSI = \frac{\sum_{i=1}^{n} Iij}{n} \text{ and } EnSI = \frac{\sum_{i=1}^{n} Iij}{n}$$

Where,

ESI= Economical Sustainability Index

SSI=Social Sustainability Index

EnSI=Environmental Sustainability Index

Iij= Index for the j^{th} dimensions containing n indicators

n= No. of indicators

Then, the composite Sugarcane Based Dairy Farming Sustainability Index (SBDFSI) for each respondent was calculated as a weighted mean of the indices obtained for different dimensions of the sustainability in following manner (Chand and Sirohi 2013):

$$SBDFSI = \frac{W1*ESI + W2*SSI + W3*EnSI}{\text{Sum of the scale values of all dimensions}}$$

Where,

W = Scale value (weight) assigned to the respective dimension of composite sustainability index.

An appropriate interview schedule containing all relevant questions and statements related to variables was prepared to collect the required data. The schedule was pre-tested in the non-sample area and on the basis of responses, necessary modifications were made in the schedule to make it more comprehensive and presentable. The actual data collection with the help of pre-tested interview schedule was done through personal interview and observation methods from October, 2015-January, 2016. The data after collection were compiled, tabulated and analysed in view of the objectives of the study. Mean, frequency, ANOVA, CD, *etc*. were used to draw the meaningful conclusions.

RESULTS AND DISCUSSION

Region-wise sustainability indices under different dimensions

Region-wise average economic sustainability in descending order was 0.45, 0.32 and 0.31 for the Western U.P., Central U.P. and Eastern U. P., respectively. The overall economic sustainability for the state as a whole was 0.36. The social sustainability was found to be 0.39, 0.37 and 0.29 for Western U.P., Eastern U. P. and Central U.P., respectively. The overall social sustainability for the state was 0.35. The environmental sustainability of Eastern U. P., Western U.P. Central U.P. and state as whole was found to be 0.47, 0.46, 0.40 and 0.44, respectively. Region's overall (Composite) average sustainability was 0.43, 0.38 and 0.34 for Western U.P., Eastern U. P. and Central U.P., respectively. The overall (Composite) average sustainability of sugarcane based dairy farming for the state as a whole was found to be the 0.38 (Table 1).

Dimension wise sustainability of Eastern U. P. was 0.47, 0.37 and 0.31 under environmental, social and economic sustainability, respectively with an overall average sustainability of 0.38. In case of Central U.P., the environmental, economic and social sustainability were found to be 0.40, 0.32 and 0.29 with composite sustainability of 0.34 for the region. The sustainability of sugarcane based dairy farming under different dimensions in Western U. P. was found to be 0.45, 0.43 and 0.39 in case of economic, environmental and social dimensions of sustainability, respectively. The composite sustainability of the region was found to be 0.43 (Table 1).

Region-wise variation in sustainability indices in Uttar Pradesh

For comparison among the different regions of Uttar Pradesh, analysis of variance and calculation of critical difference were carried out. The data are presented in Table 2 and discussed under following sub-heads:

Economic sustainability: Results revealed that on account of economic sustainability, Eastern U.P. and Central U. P. did not differ, however, Western U.P. significantly outperformed other regions. This may be attributed to the better marketing network in the region.

Social sustainability: Western U. P. and Eastern U. P. had more social sustainability than the Central U. P. Further, Western U. P. had an edge over Eastern U. P. It is inferred that Central U. P. exhibited significantly lower social sustainability as compared to other regions. This might be due to the

Table 1 Region-wise sustainability under different dimensions

(n=240)

Farmers Categories	Region wise levels of sustainability under different dimensions									
	Economic		Social		Environmental		Region's composite sustainability		Difference within the region	
	Average	Range	Average	Range	Average	Range	Average	Range	F	CD
Eastern U.P.	0.31	0.00-0.75	0.37	0.08-0.86	0.47	0.03-0.86	0.38	0.05-0.69	15.1121**	0.0435
Central U.P.	0.32	0.00-0.94	0.29	0.00-0.81	0.40	0.00-0.77	0.34	0.08-0.70	6.509025**	0.0457
Western U.P.	0.45	0.06-1.00	0.39	0.16-1.00	0.46	0.03-1.00	0.43	0.13-0.72	3.46813*	0.0350
Overall U.P.	0.36	0.00-1.00	0.35	0.00-1.00	0.44	0.00-1.00	0.38	0.05-0.72	15.9868**	0.0267
F	15.5238**		8.6979**		3.4481*		10.5300**		-	-
CD	0.0437		0.0363		0.0337		0.0323		-	-

**p<0.01 and *p<0.05

Table 2 Region-wise variation in sustainability indices in Uttar Pradesh

n=240

Dimensions of sustainability	Average sustainability for different regions			F	CD
Economic	0.45[a]	0.32[b]	0.31[b]	15.5238**	0.0437
	C	B	A		
Social	0.39[a]	0.37[a]	0.29[b]	8.6979**	0.0363
	C	A	B		
Environmental	0.47[a]	0.46[a]	0.40[b]	3.4481*	0.0337
	A	C	B		
Composite	0.43[a]	0.38[b]	0.34[c]	10.5300**	0.0323
	C	A	B		

[abc] bearing different superscript is significantly different at *p<0.05 and **p<0.01
A=Eastern U. P., B= Central U. P. and C=Western U. P.

comparatively higher level of social stratification suppressing the involvement of resource poor farmers in such activities.

Environmental sustainability: Eastern U. P. and Western U. P. being at par between themselves had more environmental sustainability than the Central U. P. Central U. P. had significantly lowest (F=3.4481*) environmental sustainability of 0.40 (Table 2). This may be because of inadequate awareness about environmental implications of improper management of dairy farming business. In this region, immediate actions for improving the environmental sustainability are of the utmost importance.

Overall (composite) sustainability: As far as composite sustainability was concerned, all the regions differed highly significantly (10.5300**). The Western U. P. outperformed other regions with overall average sustainability of 0.43 followed by Eastern U.P. (0.38) and Central U. P (0.34). Thus, Central U.P. had one of the lowest sustainability of sugarcane based dairy farming (Table 2). It might be due to the dominance of non-descript milch animals, high level of social stratification restricting the participation of resource poor farmers in development activities and improper management of dairy farming by-products.

Variation in sustainability indices within the region of Uttar Pradesh

Comparison within the region with respect to the different dimension of sustainability was carried out based on the critical difference to ascertain the magnitude of difference (Table 3) and suggest the appropriate strategies.

Eastern U.P.: Results revealed that all the dimensions were found to be poles apart (F=15.1121**& CD=0.0435). Environmental sustainability was significantly more than the social and, social was greater than the economic sustainability. Low economic sustainability might be the outcome of dominance of un-productive non-descript milch animals in the herd and non-remunerative prices of milk. Thus, in this region economic sustainability should be given priority in dairy development programmes. The economic sustainability can be improved by breed up-gradation, strengthening of marketing networks, providing skill oriented training to the farmers for increasing the productivity of animals and farmers to be motivated to increase the number of *Murrah* buffalo in the herd.

Central U.P.: Economical and social dimensions of sustainability did not differ significantly. However, environmental sustainability was significantly greater than remaining dimensions, therefore, economic and social dimensions should be given due attention while framing the policies and programmes for dairy development for this region.

Western U.P.: A close scrutiny of the data clearly indicate that environmental and economic sustainability were at par

Table 3 Variation in sustainability indices within the region of Uttar Pradesh

(n=240)

Regions	Average sustainability for different dimensions			F	CD
Eastern U.P.	0.47[a]	0.37[b]	0.31[c]	15.1121**	0.0435
	C	B	A		
Central U.P.	0.40 [a]	0.32 [b]	0.29 [b]	6.509025**	0.0457
	C	A	B		
Western U.P.	0.46 [a]	0.45 [a]	0.39 [b]	3.46813*	0.0350
	C	A	B		
All U. P.	0.44 [a]	0.36 [b]	0.35 [b]	15.9868**	0.0267
	C	A	B		

[abc] bearing different superscript is significantly different at *p<0.05 and **p<0.01
A=Economic sustainability, B= Social sustainability and C=Environmental sustainability

with each other, however, these differed significantly (F= 3.46813* and CD=0.0350) from social sustainability which was found to be the lowest amongst the dimensions of the sustainability. This may be attributed to the erosion in social values, polarization of diverse population and diminishing people's participation in the different social activities. Opinion leaders should be motivated to persuade their fellow farmers for increased participation in the different social activities.

Overall U.P.: Considering the results for the state as a single entity, it was observed that economic and social sustainability did not differ significantly while, environmental sustainability was significantly greater than the other dimensions (Table 3) suggesting that the people are environment savvy. It might be due to frequent coverage of environmental issues in mass media which created awareness among the people. Further, the economic and social sustainability were found to be low which warranted immediate actions for improvement. Reasons for this state of affairs may be high level of social stratification, subsistence level of dairy farming and poor marketing network resulting in non-remunerative prices of milk which forced the farmers to limit the number of milch animals to the level sufficient to meet their own demand. Other reasons might be the inadequate infrastructural facilities, poor support services, dominance of non-descript animals, increasing cost of inputs, low success rate of AI resulting in repeat breeding, improper management of animals and inadequate training facilities. The economic sustainability can be improved by improving marketing network, easy availability of support services, up-gradation of non-descript breeds of animal, promotion of high yielding indigenous breeds and ensuring prompt availability of semen of required breeds for AI.

CONCLUSION

Dimension wise as well as composite sustainability was found be below 0.50 reflecting poor state of affairs of sugarcane based dairy farming in different regions of U. P. On the basis of region-wise and dimension-wise order of sustainability indices, it is concluded that Eastern U. P. lacks economic sustainability while Central and Western U.P. lag behind in social sustainability. On the other hand, the values of all the sustainability dimensions barring economic one were the lowest for Central U. P. Economic and social sustainability in Western U. P. and environmental sustainability in Eastern U. P. had an edge over others. In order to provide livelihood security to landless, marginal and small farmers in face of further land fragmentation as well as decreasing crop productivity, the system to be made highly sustainable by educating farmers to use viable innovative technologies, rear productive animals like indigenous breeds of cow, buffalo and cross bred cow, diversification of enterprises to increase the profitability and to adopt highly efficient way of waste recycling. Since region wise and dimension wise highly significant differences existed in sustainability, separate policies and programmes for different categories of farmers and regions need to be launched.

Region wise dairy development strategies: The dairy development strategies for different regions are as follows:

Eastern Uttar Pradesh: The different need based dairy development strategies based on the findings of present study are given as under:

1. Farmers may be motivated to increase the herd size. The medium and large farmers may be advised to practice commercial dairy farming by replacing non-descript animals with high milk producing one.
2. Up-gradation of non-descript animals to be carried out on priority by the Government.
3. Separate training policies for different categories of farmers should be evolved and executed. The landless, marginal, small and semi-medium farmers should be provided the basic training on dairy farming, while, medium and large farmers may be trained on commercial dairy farming.
4. Training on supplementation and enrichment of sugarcane tops as well as paddy straw should also be provided
5. Regular advanced training to the veterinarians and para-veterinarians.
6. Government breeding farms may be established to supply high yielding breeds of animals as well as their semen.
7. Marketing network may be strengthened urgently through revival of dairy cooperative, encouragement of

private companies to establish milk processing plants and establishment of mini processing plants at block levels.

Central Uttar Pradesh: The values of sustainability indices were below 0.50 indicating ample opportunities for improvement in dairy farming. The suggested strategies for development of sugarcane based dairy farming are given below:

1. For increasing the productivity of animals, up-gradation of non-descript animals should be initiated urgently to increase the number of established breeds of milch animals by providing the females of 1-1.5 years of age. These animals can be afforded by each category of farmers due to less cost.
2. Resource rich farmers can be advised to replace non-descript animals with in-milk animals of high producing breeds like *Murrah* buffalo, *Sahiwal*, *Tharparker* and *Rathi* breeds of cow.
3. Farmers may be persuaded to increase the herd size of milch animals.
4. Marketing network may be strengthened urgently through revival of dairy cooperative, encouragement of private companies to establish milk processing plants and establishment of mini processing plants at block levels.
5. Basic infrastructural facilities need to be created and improved.

Western Uttar Pradesh: The data showed that farmers of this region were having good breeds of buffalo and cross-bred cow. The region is also having fair marketing network with big markets like Delhi, Ghaziabad, Meerut, etc. Though Western U.P. fared well as for as dimensions of sustainability and composite sustainability of sugarcane based dairy farming were concerned, but the sustainability indices were below 0.50 indicating further opportunities for dairy development. The strategies for dairy development are given below:

1. Male animals of cross-bred cow are not suitable for agricultural work and are of no market value the farmers. Nowadays these are becoming the menace in large numbers. A suitable policy for their management and utilisation be evolved.
2. Semi-medium, medium and large farmers may be provided advanced training on dairy farming including the value addition to milk. They should also be encouraged to adopt commercial dairy farming as farmers were having good breeds consisting of indigenous breeds like *Sahiwal*, *Red Sindhi*, *Tharparker* and *Rathi* of cow, cross-bred cow and *Murrah* buffalo.
3. Training on supplementation and enrichment of sugarcane tops must be provided to each category of farmers to reduce repeat breeding which is caused by mineral deficiency in animals resulting due to continued feeding of sugarcane tops for 5-6 months in a year.
4. Advanced training to the veterinarians and para-veterinarians be organised regularly.

REFERENCES

Annual Report. 2014-15. Department of Animal Husbandary, Dairying & Fisheries, Ministry of Agriculture, *http:// www.Deptt.animal husbandry & dairying.india.gov.in*. Accessed on 14.04.2016.

Census. 2011. Census Report, Office of the Registrar General and Census Commissioner, Ministry of Home Affairs, Government of India, New Delhi.

Chand P and Sirohi S. 2013 Sustainability of dairy breeding practices: Empirical evidences of semi-arid eastern zone of Rajasthan. *Res. J. Animal Hus. & Dairy Sci.,* **4**(2):47-50.

Guilford J P. 1954. Psychometric Methods (2nd ed.). *McGraw-Hill, New York*, pp. 1-597

Kevelenge J E E, Said A N and Kiflewahid B. 1983. The nutritive value of four arable farm by-products commonly fed to dairy cattle by small scale farmers in Kenya. The utilization of nutrients by withers sheep. *Trop. Anim. Prod.,* **8**(2):171-179.

Kung J L and Stanley R W. 1982. Effect of stage of maturity on the nutritive value of whole-plant sugarcane preserved as silage. *Journal of Animal Science,* **54**(4):689-696.

Nasseven M R. 1986. Sugarcane tops as animal feed. In: Sancoucy R, Aarts G. and Preston T R (eds.). Proceeding of a FAO Expert Consultation on Sugarcane as Feed, FAO, Santo Domingo, Dominican Republic, Rome, *Italy*, **72**:106-122.

Nineteenth Livestock Census. 2012. All India Report. Ministry of Agriculture Department of Animal Husbandry, Dairying and Fisheries, GOI, *Krishi Bhawan, New Delhi*, 1-121.

Singh S P, Gangwar B, Singh M P and Singh S P. 2010. Identification and resource productivities of existing farming systems in western U.P. *Prog. Agric.,* **10**(1):8-17.

Statistics of Uttar Pradesh. 2011. Directorate of Statistics, Government of UP. http://upgov.nic.in/upstateglance.aspx. Accessed on 17.07.2014.

Wanapat M. 1990. Nutritional aspects of ruminant production in Southeast Asia with special reference to Thailand. *Funny Press Ltd., Bangkok*.

Indian Journal of Sugarcane Technology **32(01)**: 31-34, June 2017

'CoS 08276': A new sugarcane variety for Uttar Pradesh

V K SRIVASTAVA*, B D SINGH, ARVIND KUMAR, KRISHNA PAL, M M DAS, N K KARMA, A P SINGH and B L SHARMA

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

ABSTRACT

'CoS 08276' was developed from biparental cross ('CoLk 8102' x 'CoSe 92423') at Sugarcane Research Institute, Shahjahanpur during 2007-08 to 2013-14. It was tested for cane yield and quality traits against 'CoS 767' as standard in plant and proceeding ratoon crops. 'CoS 08276' recorded average cane yield 103.09 t/ha as compared to 'CoS 767' (73.75t/ha), which is 39.78 per cent higher in plant crop, where as it is 15.48 per cent higher in ratoon crop. Similarly, sugar yield CCS (t/ha) was 13.40, which is 43.46 per cent higher than 'CoS 767' (9.34). It exhibited 0.06 and 0.53 unit higher pol per cent in cane during January and March respectively in plant crop, while 0.19 and 0.23 unit higher in November and December respectively in ratoon crop. Length of millable cane, diameter of cane and single cane weight were also higher in 'CoS 08276' than standard. Based on overall good performance in station trials and evaluation at various sugar factory farms of the state, 'CoS 08276' has been released for the general cultivation in UP during 2014 by State Varietal Release Committee.

Key words: Mid late maturing, seedling raising, sugar yield, clonal selection

Sugarcane is the most important cash crop of Uttar Pradesh and plays an important role in rural economy of the country in general and U.P. in particular. Selection of variety is the kingpin of sugarcane cultivation, so development of high yielding and high sugared varieties with economically superior yield and quality over the standard varieties has always been the priority among the breeders. Identification and release of such superior genotype plays a decisive role in augmenting sugar productivity by directly imparting higher sugar yield per unit area per unit time.

Sugar yield levels over the years have remained stagnant or in some years decreased resulting in economic losses to sugarcane farmers and sugar industries. The release of more than 200 sugarcane varieties in U.P. since 1918 contributed a lot in elevating yield level from 28 t/ha to 72.4 t/ha but, still it is lagging behind national target average of 75.0 t/ha, hence there is an urgent need to increase sugarcane productivity by identifying and adopting high yielding varieties with different maturity periods to maintain an ideal varietal balance for obtaining quality cane throughout the crushing period in the state. Some clones have been reported to give higher millable canes while others build up their yield by the vigour of individual cane (Rathore *et al.* 1987). 'Co 08276', having good quality and yield characters with inbuilt insect pest and disease resistance, is an outcome of breeding efforts made over the years and its release will add to varietal diversity in the state. This paper aims to discuss the details of development of this variety and its salient features (Table1; Figs 1, 2 and 3).

*Corresponding author's E-mail: vinayksri62@gmail.com

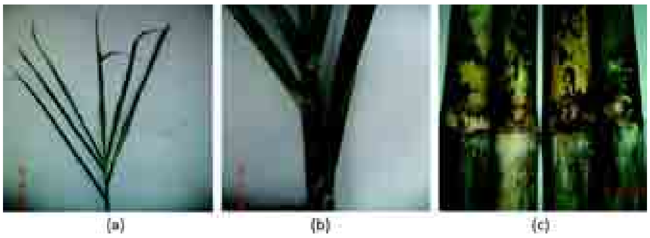


Fig 1. Carriage (a), Shape of auricle (b) and bud (c) of 'CoS 08276'

MATERIALS AND METHODS

'CoS 08276' has been developed from an inter-varietal cross 'CoLk 8102' x 'CoSe 92423'. Both the parents selected were highly productive and widely adapted.

Seedling were raised using "U.P. method of sugarcane seedling raising" (Agrawal *et al*. 1977). Well established seedlings were transplanted in the month of May/June in rows 90 cm apart and plants were placed 45 cm apart. After rigorous selection in seedling population regarding general appearance and other qualitative and quantitative traits, the selected clone was named 'S 534/03'. Preliminary Varietal Trial (PVT) was conducted in augmented design along with other canes and standards in subsequent years and desirable cane and quality traits were recorded. Different elite clones selected in PVT were advanced to Standard Varietal Trial (SVT) in a Randomized Block Design (RBD) in plant and ratoon crops from 2007 to 2014. Natural incidence of diseases especially red rot, smut and pests were also observed during various developmental stages of selection. Artificial inoculation was done for

Table 1 Distinguishing morphological features of sugarcane variety 'CoS 08276'

i.	Name of variety	:	'CoS 08276'
ii.	Parentage	:	'CoLk 8102' x 'CoSe 92423'
iii.	Name of proposing station	:	Sugarcane Research Institute, Shahjahanpur (U.P. Council of Sugarcane Research)
01.	Clone number	:	'S. 534/03'
02.	Stool habit	:	Erect
03.	Stem colour (exposed)	:	Greenish yellow with back and upper side white
04.	Stem colour (unexposed)	:	Yellow
05.	Ivory marks	:	Absent
06.	Weather marks	:	Absent
07.	Internode shape (as per Artschwager 1940)	:	Cylindrical
08.	Internode alignment	:	Straight
09.	Pithiness	:	Absent
10.	Splits on internode	:	Absent
11.	Wax on internode	:	Medium
12.	Node swelling	:	Not swollen
13.	Root zone colour (exposed)	:	Blackish green
14.	Root zone colour (unexposed)	:	Yellow
15.	No. of root eye rows	:	Two
16.	Arrangement of the root eye	:	Irregular
17.	Bud size	:	Medium
18.	Bud shape (as per Artschwager 1940)	:	Round
19.	Bud germ pore position	:	Apical
20.	Bud groove	:	Absent
21.	Growth ring colour	:	Yellow
22.	Leaf length (1^{st} transverse leaf at 180^{th} day	:	108.0 cm
23.	Leaf width (1^{st} transverse leaf at 180^{th} day)	:	4.2 cm
24.	Lamina colour	:	Green
25.	Leaf carriage shape	:	Semi erect
26.	Leaf sheath colour	:	Yellowish green
27.	Leaf sheath waxiness	:	Light
28.	Leaf sheath spines	:	Present (sparse)
29.	Leaf sheath clasping	:	Semi clasping
30.	Dewlap colour (at 10^{th} month)	:	Yellowish green
31.	Ligular process	:	Present
32.	Shape of the auricle	:	One side lanceolate and one side dentoid
33.	Percentage of flowering	:	Non flowering
34.	Erectness	:	Non lodging
35.	Distinguishing morphological character	:	'CoS 08276' is characterized by its green foliage, medium thick cylindrical canes, erect habit, self detrashing, non-lodging, non flowering, good ratooner, moderately resistant to red rot with low incidence of top borer, stem borer and shoot borer.

screening against red rot in PVT and SVT as per standard procedures (Srinivasan and Bhat 1961)

Clone 'CoS 08276' was finally evaluated during 2007-08 to 2013-14 at Sugarcane Research Institute, Shahjahanpur in plant and ratoon crops under recommended fertility levels and normal irrigation. Its yield, quality, ratoonability, disease and pest resistance were studied against standard 'CoS 767'.

The data on cane yield was recorded at harvest and quality was estimated as sucrose per cent in juice and pol per cent in cane at different maturity stages in various months (January and March) in plant crop and (November and December) in ratoon. Fibre content in this clone was also estimated by procedures as described by Meade and Chen (1971). The commercial cane sugar yield (t/ha) was calculated by the following formulae:

CCS (t/ha) = {S-(B-S) x 0.4} x 0.73 x Cane yield (t/ha)

Where S- is sucrose content (%) in juice and

B- Brix (%) of cane juice. Cane yield and sucrose improvement percent over standard 'CoS 767' were also calculated.

RESULTS AND DISCUSSION

Cane yield characteristics

'CoS 08276' has been found good in germination, tillering behaviour and millable cane formation with a good ratooning ability. It produced medium thick, erect, solid stalks of 222 cms length, 2.6 cms mean diameter and 984 gram single cane weight. During the study over years, 'CoS 08276' recorded an average cane yield (103.09 t/ha) as compared to standard 'CoS 767' (73.75 t/ha) which is 39.78 per cent higher in plant crop (Table 2) and 15.48 per cent in ratoon (Table 3).

Table 2 Comparative performance of 'CoS 08276' with standard 'CoS 767' over the years for cane yield, resistance to red rot and quality traits in plant crop

Year	Yield (t/ha)	Sucrose (%) in juice		Pol (%) in cane		Commercial Cane Sugar (%)	Commercial sugar yield (t/ha)	Fibre (%)	Reaction to red rot
		January	March	January	March				
'CoS 08276' ('CoLk 8102' x 'CoSe 92423')									
2007-08	112.16	17.59	19.59	12.63	13.74	13.60	15.25	13.80	
2008-09	104.94	16.39	18.69	12.80	13.54	12.98	13.62	13.01	
2009-10	97.00	16.81	18.08	12.69	13.79	12.43	12.06	13.62	
2010-11	101.94	17.73	18.24	12.01	13.67	12.80	13.04	13.68	Moderately resistant
2011-12	100.35	16.60	19.25	12.33	13.39	13.36	13.41	-	
2012-13	105.35	15.66	17.89	11.93	12.67	12.36	13.02	13.68	
2013-14	99.89	16.01	19.23	11.72	13.94	13.41	13.40	13.63	
Mean	**103.09**	**16.71**	**18.71**	**12.30**	**13.53**	**12.99**	**13.40**	**13.57**	
'CoS 767' ('Co 419' x 'Co 313')									
2007-08	73.01	17.84	19.03	12.54	13.26	13.22	9.65	14.50	
2008-09	75.48	17.37	18.19	12.60	13.13	12.58	9.50	13.74	
2009-10	76.54	17.01	18.49	12.92	13.89	12.74	9.75	13.66	
2010-11	74.60	16.71	17.61	11.96	12.55	12.36	9.21	13.79	Moderately resistant
2011-12	70.19	16.44	18.33	12.35	12.84	12.66	8.89	-	
2012-13	75.10	15.44	17.93	11.61	12.65	12.40	9.31	14.44	
2013-14	71.38	16.07	18.35	11.73	12.74	12.79	9.13	14.16	
Mean	**73.75**	**16.69**	**18.27**	**12.24**	**13.00**	**12.67**	**9.34**	**14.05**	
Increase over standard	**39.78%**	**+ 0.02**	**+ 0.44**	**+0.06**	**+ 0.53**	**+ 0.32**	**43.46%**	**- 0.48**	

Table 3 Comparative performance of 'CoS 08276' with standard 'CoS 767' over the years for cane yield, resistance to red rot and quality traits in ratoon

Year	Yield (t/ha)	Sucrose % in juice		Pol % in cane		Commercial Cane Sugar (%)	Commercial sugar yield (t/ha)	Resistance towards red rot
		Nov.	Dec.	Nov.	Dec.			
'CoS 08276' ('CoLk 8102' x 'CoSe 92423')								
2008-09	77.95	16.25	17.63	11.77	12.52	12.11	9.44	
2009-10	62.08	16.05	16.42	11.53	12.16	11.14	6.91	
2010-11	71.78	16.88	17.22	12.97	12.59	11.80	8.47	
2011-12	78.04	15.16	15.79	11.17	11.78	10.72	8.37	Moderately resistant
2012-13	70.19	15.57	16.64	11.34	11.98	11.39	7.99	
2013-14	85.39	16.78	17.10	12.25	12.44	11.72	10.01	
Mean	**74.23**	**16.11**	**16.80**	**11.83**	**12.24**	**11.48**	**8.53**	
'CoS 767' ('Co 419 x Co 313')								
2008-09	66.31	15.83	16.68	11.23	12.01	11.36	7.51	
2009-10	65.61	15.85	16.15	11.32	11.86	10.97	7.20	
2010-11	61.90	16.92	17.53	12.27	11.54	11.79	7.30	
2011-12	64.55	15.84	16.74	12.04	12.30	11.47	7.40	Moderately resistant
2012-13	60.49	15.20	16.40	11.15	12.26	11.22	6.79	
2013-14	66.87	15.87	16.51	11.84	12.15	11.28	7.54	
Mean	**64.28**	**15.91**	**16.66**	**11.64**	**12.01**	**11.34**	**7.29**	
Increase over standard:	**15.48%**	**+ 0.20**	**+ 0.14**	**+ 0.19**	**+ 0.23**	**+ 0.14**	**17.01%**	

Table 4 Comparative performance of 'CoS 08276' *vis-a-vis* 'CoS 767' regarding pol per cent in cane in zonal trials at various factories

S. N.	Variety	Year	Pol per cent in cane (Mean)				
			December	January	February	March	Average
		2011-12 (P)	11.31	11.68	12.11	12.74	
		2012-13 (P)	11.33	11.88	12.19	12.47	
1.	'CoS 08276'	2013-14 (P)	12.01	12.07	12.50	13.38	
		2012-13 (R)	11.88	-	-	-	
		Average:	**11.63**	**11.88**	**12.27**	**12.86**	**12.16**
		2011-12 (P)	11.43	12.07	12.16	12.74	
		2012-13 (P)	10.73	11.20	11.57	12.83	
2.	'CoS 767'	2013-14 (P)	10.50	11.67	12.58	12.66	
		2012-13 (R)	11.81	-	-	-	
		Average:	**11.12**	**11.65**	**12.10**	**12.74**	**11.90**
	Gain		**+ 0.51**	**+ 0.23**	**+ 0.17**	**+ 0.12**	**+ 0.26**

(P= Plant Crop, R- Ratoon crop)

Sugar yield (t/ha)

Commercial cane sugar (CCS t/ha) is one of the important parameters for selection of any genotype because it has a direct impact on economic returns. 'CoS 08276' exhibited an average of 13.40 (t/ha) CCS over years which was 43.46 per cent higher than 'CoS 767' (9.34) (Table 2).

Quality characteristics

Quality traits of 'CoS 08276' were estimated as sucrose per cent in juice and pol per cent in cane in different months (January and March) in plant crop and (November and December) in ratoon. It exhibited 0.06 and 0.53 unit higher pol per cent in cane in January and March respectively in plant crop, whereas 0.19 and 0.23 unit in November and December months in ratoon.

'CoS 08276' was also tested at various sugar factory farms of Uttar Pradesh *viz*. *Daurala*, *Baheri*, *Mawana*, *Seohara*, *Gola*, *Rozagaon* over years (2011-12 to 2013-14) for pol % cane during months of December, January, February and March. The average (plant and ratoon) pol % cane recorded was 11.63, 11.88, 12.27 and 12.86 in December, January, February and March respectively, while it was 11.12, 11.65, 12.10 and 12.74 in 'CoS 767'. 'CoS 08276' recorded 0.51, 0.23, 0.17 and 0.12 higher units for pol per cent cane over the control in different months (Table 4). Based on consistent performance of 'CoS 08276' for growth, yield, quality and resistance characters over years and locations, it has been released by SVRC for general cultivation in U.P. during the year 2014 in mid late maturity group.

Behaviour towards disease and pests

'CoS 08276' showed moderate resistance towards red rot; the incidence of top borer, stem borer and shoot borer were also low.

Thus, this released cultivar 'CoS 08276' exhibited its superiority over 'CoS 767' which is suffering from grassy shoot disease (GSD) since last couple of years and needs its replacement to safeguard the sugarcane growers and industry in the state. Release and cultivation of new cultivar 'CoS 08276' will add to varietal diversity in mid late group besides providing higher cane yield and recovery.

ACKNOWLEDGEMENT

Authors are grateful to Dr. Bakshi Ram, Ex. Director, U.P. Council of Sugarcane Research, Shahjahanpur for critically reviewing the performance of 'CoS 08276', fellow scientists of Plant pathology and Entomology divisions of Sugarcane Research Institute, Shahjahanpur and various sugar factories mentioned for providing information.

REFERENCES

Agrawal M L, K M Bhardwaj and Singh R. 1977. Development of sugarcane varieties in Uttar Pradesh. *Cooperative sugar,* **9**(2): 55-63.

Artschwager E. 1940. Morphology of the vegetative organs of sugarcane. *J. Agric. Res.* **60:** 503–549.

Meade G P and Chen J C P. 1977. Cane sugar hand book. 10th edition, John Wiley and Sons, New York.

Rathore D N, Pawar B S and Srivastava S N L. 1987. Performance of some promising sugarcane varieties in Haryana. *Indian Sugar*, **36**(8): 439-443.

Srinivasan K V and Bhat N R. 1961. Red rot of sugarcane- criteria for grading resistance. *Journal of Indian Botanical Society*, **40**: 566-577.

Indian Journal of Sugarcane Technology **32(01)**: 35-37, June 2017

Effect of microbial consortium as biofertilizer on the growth and yield of sugarcane

C THAMARAI CHELVI*

Main Bio-control Research Laboratory (Unit of Tamil Nadu Cooperative Sugar Federation), Venpakkam, Chengalpattu-601111, Tamil Nadu

ABSTRACT

Impact of microbial consortia as biofertilizers on sugarcane productivity was assessed through field experiments conducted at Kallakurichi I Cooperative Sugar Mill, Tamil Nadu, India. 100% of chemical fertilizers (as control), carrier biofertilizers with 75% NPK and liquid biofertilizers with 75% NPK were tried as treatments. Plots applied with liquid biofertilizers with 75% NPK showed improved cane weight, height and yield. Quality parameters such as commercial cane sugar%, pol%, purity% and ^{0}brix% of sugarcane were also improved with the application of liquid biofertilizers as compared to control. The results indicated that the application of liquid biofertilizers would help in improving the profitability of the farmers through higher sugarcane productivity along with sustaining soil fertility. Besides, the quantity of application of nitrogen, phosphorus and potash fertilizers can also be reduced by 25%.

Key words: Liquid biofertilizer, Nitrogen, Phosphorus, Potash, Sugarcane, Cane yield and sugar content.

INTRODUCTION

The green revolution increased agricultural production worldwide, saving about one billion people from starvation and undernourishment, and was founded on the development of chemical fertilizers along with other advances. Synthesis of chemical fertilizers consumes enormous amounts of energy which is around 1% of the total energy consumption of the world, contributing heavily to the climate change. However, their application in the field has an efficiency of just 60–70% and it has been shown that they produce negative effects on human health and the environment.The principal goal of organic farming is to produce abundant yield and good quality products without using chemical fertilizers and pesticides in order to reduce their adverse effect on the environment. N, P and K are major essential macronutrients for plant growth and development and hence they are commonly added as fertilizer to optimize yield. Sugarcane (*Saccharum spp.*) is a tropical and subtropical crop, which produces a large amount of biomass and requires substantial inputs of both water and nutrients to produce maximum yield. The soil fertility has declined in many sugarcane growing areas due to improper and distorted fertilizer schedules adopted over the years under intensive cultivation of the crop. Nitrogen (N), Phosphorus (P) and Potash (K) are the three essential nutrients for plant growth and development. Nitrogen, required for the formation of amino acids and proteins, is the most limiting nutrient for plants. On an average, sugarcane crop yielding 100 t ha^{-1} would remove 200-250 kg of N, 120-150 kg of P and 175-225 kg of K from soil. Intensive farming practices that achieve high yield, require chemical fertilizers that are not only costly but also create environmental problems. The extensive use of chemical fertilizers in agriculture is currently under debate due to environmental concern and questions are raised regarding the consumers health.Therefore, development of more efficient and sustainable agriculture, guaranteeing food supply for an expanding world population and minimizing damage to the environment, is one of the greatest challenges for humankind today (García-Fraile *et al*. 2015). The ability to take advantage of the natural resources is a major step towards economic prosperity for a country like India as usage of chemical fertilizers for crop production is expensive, mainly because of shortfall in availability and the problems of environmental pollution. In agricultural eco-system, microorganisms have vital role in fixing / solubilising/mobilizing / nutrient recycling. These microorganisms occur in soils naturally, but their populations are often scanty. In order to increase the crop yield, the desired microbes from rhizosphere are isolated and artificially cultured in adequate count and are either mixed with suitable carriers or used as they are, in suitable combinations (Microbial consortium) by artificial culturing.

Increasing and extending the role of inoculation with microorganisms (biofertilizers) may reduce the need for chemical fertilizers and thereby decrease adverse environmental effects (Govindarajan *et al.* 2008).The process by which atmospheric nitrogen is combined into organic forms that can be assimilated by plants is exclusive to prokaryotes (Raymond *et al.* 2004). Some examples of free-living nitrogen-fixing organisms are *Gluconacetobacter* and *Azospirillum*, commonly associated with cereals in temperate zones (Tejera *et al.* 2005). The use of plant growth promoting rhizobacteria (PGPR), including phosphate and potassium solubilizing bacteria (PSB and KSB), as biofertilizers has become of interest in many countries as significant areas of cultivated soils are

*Corresponding author's E-mail: chelvithamarai1@gmail.com

deficient in soil available nutrient which are P and K.

Carrier based biofertilizers have already proved to be the best over the agro chemicals and have been showing the tremendous effect on the global agriculture productivity since the past two decades. Rectifying the disadvantages of the carrier based biofertilizers, liquid biofertilizers have been developed which would be the only alternative for the cost effective sustainable agriculture. These liquid formulations facilitate long shelf life, minimum contamination, carrier free activity, handling comfort, storage and transport convenience, easy quality control, enhanced export potentials and are preferred by the farmer community as well as manufacturers (Pindi and Satyanarayana 2012). The impact of microbial consortia as biofertilizers on sugarcane productivity was assessed through field experiments in the current study.

MATERIALS AND METHODS

Field trials were conducted at Kallakurichi I Cooperative Sugar Mill cane farm in Randomized Block Design (RBD) with three treatments and four replications. Standard agronomic practices were followed in all treatments. Consortia of micro-organisms consisted of *Gluconacetobacter diazotrophicus* (commonly referred as *Acetobacter*) as a nitrogen source, *Bacillus megaterium* (commonly referred as PSB) as phosphate solubilizing bacteria, and Potash mobiliser *Frateuna aurantia* as potash source and *Pseudomonas fluorescens* as PGPR. Liquid biofertilizer was sprayed on 60th day after planting at the rate of 500 ml /acre. 75 % of the recommended split doses of chemical fertilizers were applied as per the standard method of fertilizer application.

Treatment details are as follows:

T_1- 100% NPK chemical fertilizers (Control)

T_2 – 75% NPK+ Carrier biofertilizers (Lignite based)

T_3 – 75% NPK+ Liquid biofertilizer spray

The cane height, cane weight and cane yield data were recorded at the harvesting stage and the cane yield data was converted to tonne per acre. The quality data was recorded for ^{0}brix% juice, pol% juice and purity% juice from composite juice of 10 canes in each of four replications as per standard procedures described by Chen (1985). Brix was measured by hygrometry. The clarified juice was analysed with Sucromat (digital automatic Saccharimeter) for pol% and purity%. Commercial Cane Sugar per cent (CCS %) was calculated by using Winter's formula.

RESULTS AND DISCUSSION

The findings revealed that growing sugarcane with liquid biofertilizers (LBF) combined with 75% recommended levels of NPK through chemical fertilizers recorded highest individual cane height of 2.73 M, along with maximum individual cane weight of 1.93 kg and yield of 37.27 Kg/acre. The results have been shown in figs. 1, 2 and 3.

Application of biofertilizers positively influenced the quality parameters of sugarcane juice *viz*., brix, purity, and commercial

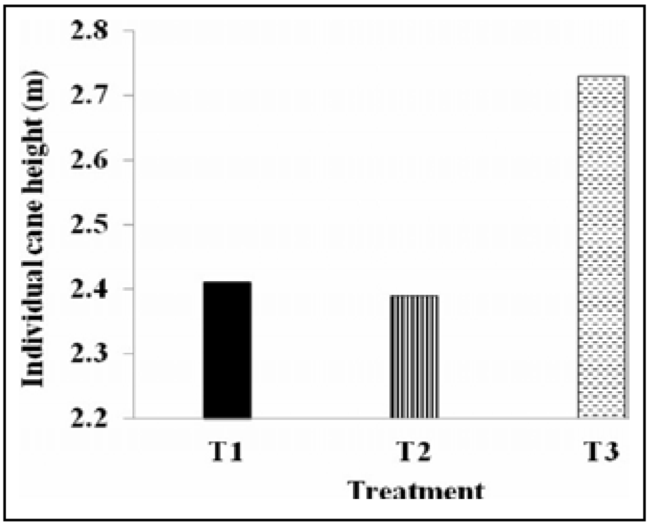


Fig 1. Effect of different fertilizer application treatments on cane height

T_1- 100% NPK (Control), T_2- 75% NPK+ Carrier biofertilizers, T_3- 75% NPK+ Liquid biofertilizer spray

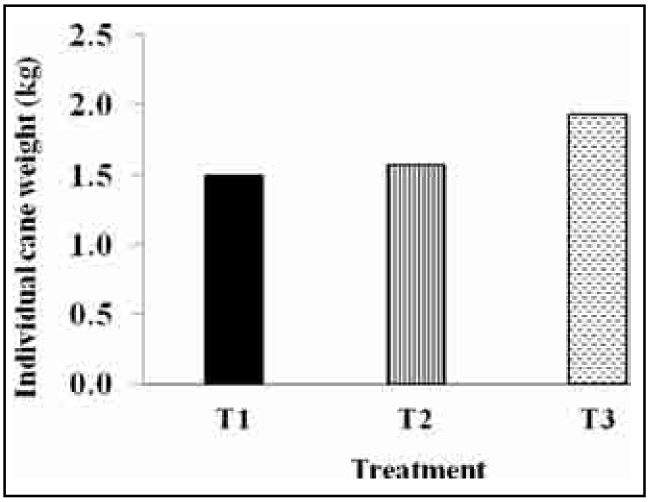


Fig 2. Effect of different fertilizer application treatments on cane weight

T_1- 100% NPK (Control), T_2- 75% NPK+ Carrier biofertilizers, T_3- 75% NPK+ Liquid biofertilizer spray

cane sugar (CCS) content (fig. 4). Highest pol%, purity%, brix% and CCS% were recorded in liquid biofertilizer applied plot as compared to other plots. Our findings revealed that growing sugarcane with liquid biofertilizers along with 75% recommended levels of NPK through chemical fertilizers produced higher number of millable canes. Similarly cane length and weight of the bio-fertilizer applied plots were higher than the control plots. The likely cause for influence of liquid biofertilizer is that they are able to grow beyond the depletion zones around the plant roots and they are able to increase the uptake of immobile nutrients such as P, K and also micronutrients, resulting in the enhanced growth of sugarcane and related yield parameters. Sugarcane yield is mainly

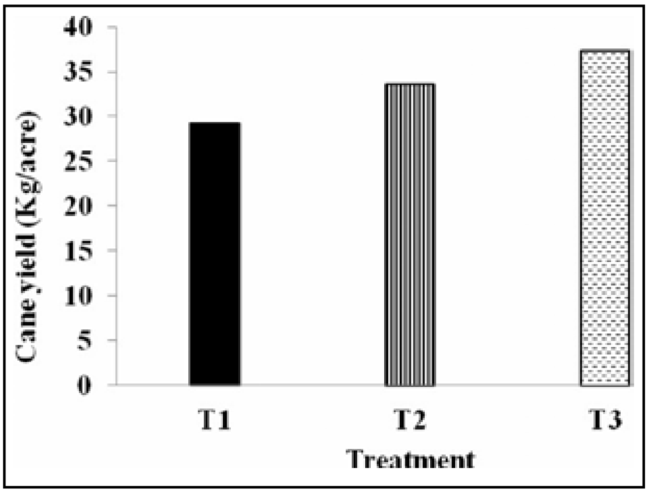


Fig 3. Effect of different fertilizer application treatments on cane yield
T_1- 100% NPK (Control), T_2- 75% NPK+ Carrier biofertilizers, T_3- 75% NPK+ Liquid biofertilizer spray

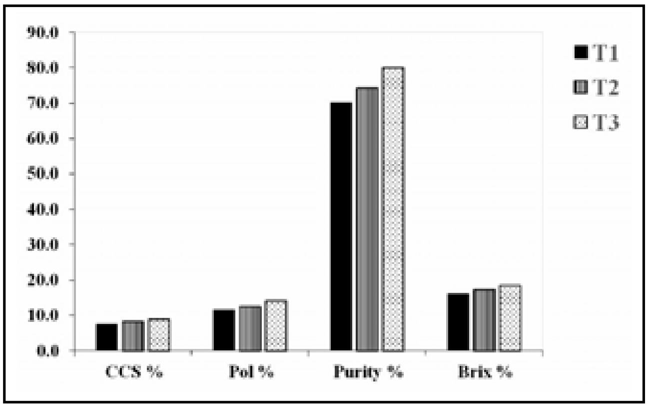


Fig 4. Effect of different fertilizer application treatments on juice quality parameters
T_1- 100% NPK (Control), T_2- 75% NPK+ Carrier biofertilizers, T_3- 75% NPK+ Liquid biofertilizer spray

attributed to the number of millable canes (NMC) available in the field and the composition of mother shoots, primary, secondary and tertiary tillers at the time of harvest, which depends on the tillering behaviour since dynamics of tiller mortality during the grand growth phase is characterized by stem elongation in the monsoon season. It is now well known that higher number of mother shoots and initial tillers bring about higher cane as well as sugar yield. Hari and Srinivasan (2005) have also found better results regarding both the morphological and yield parameters in sugarcane in combination treatment *i.e.* biofertilizer + chemical fertilizer treatments rather than using either treatment alone. Similarly, Shankaraiah and Murthy (2005) recorded positive influence of biofertilizer application on the yield parameters *viz.*, height, weight and diameter of millable canes due to increasing levels of fertility. Combined use of biofertilizers with chemical fertilizers recorded higher benefit at all stages of crop development indicating thereby that, the synergistic interaction between these two can be effectively tapped for enhancing the productivity and profitability of sugarcane. It may, therefore be concluded that use of liquid biofertilizers with PGPR in sugarcane, enhances yield and quality of sugarcane or in other words, sugarcane cultivation using biofertilizers with PGPR as source of nutrients can be more profitable as compared to that with the use of 75% recommended levels of NPK. Besides, PGPR bacteria promote plant growth not only by supplying nutrients to the plant, but also by producing phytohormones, inducing stress resistance, or preventing pathogen-induced plant diseases.

CONCLUSION

The field experiment with microbial consortia of liquid formulation of biofertilizers confirmed its beneficial effect on individual cane height, weight and yield, and juice parameters. These results from the field experiment may help promote the large scale adoption of application of liquid biofertilizers in sugarcane growing soils in order to improve the profitability of the farmers and millers since it has a direct impact on the quality of sugarcane juice.

ACKNOWLEDGMENTS

The author gratefully acknowledges the financial support sanctioned under Sugar Development Fund from the Chief Director (Sugar), Directorate of Sugar, Department of Food and Public Distribution, Ministry of Food and Consumer Affairs, Government of India, New Delhi. The author also gratefully acknowledges the Cane Development Officer, Cane Officer and Cane Assistant of Kallakurichi I Cooperative Sugar Mill for conducting the field trials and collection of final data.

REFERENCES

García-Fraile P, Menéndez E, and Rivas R. 2015. Role of bacterial biofertilizers in agriculture and forestry. *Bioengineering*, **2**(3):183-205.

Govindarajan M, Balandreau J, Kwon S-W, Weon H-Y and Lakshminarasimhan C. 2008. Effects of the inoculation of *Burkholderia vietnamensis* and related endophytic diazotrophic bacteria on grain yield of rice. *Microb Ecol.,* **55**: 21–37.

Pindi P K and Satyanarayana S D V. 2012. Liquid microbial consortium-A potential tool for sustainable soil health. *J Biofertil Biopest,* **3**:1–9.

Raymond J, Siefert J L, Staples C R and Blankenship R E. 2004. The natural history of nitrogen fixation. *Mol Biol Evol,* **21**: 541–554.

Tejera N, Lluch C, Martínez-Toledo M V and Gonzalez-Lopez J. 2005. Isolation and characterization of *Azotobacter* and *Azospirillum* strains from the sugarcane rhizosphere. *Plant and Soil,* **270**: 223–232.

Chen J C P. 1985. Cane sugar handbook, 11th ed, Wiley-Inter science Publication, *New York*, pp.788–790.

Hari K and Srinivasan T R. 2005. Response of sugarcane varieties to application of nitrogen fixing bacteria under different nitrogen levels. *Sugar Tech.,* **7**(2&3): 28–31.

Shankaraiah C and Murthy K K N. 2005. Effect of enriched press mud cake on growth, yield and quality of sugarcane. *SugarTech,* **7**(2&3): 1–4.

Indian Journal of Sugarcane Technology **32(01)**: 38-40, June 2017

Effect of seed cane production and fast replacement of old varieties

SONIA YADAV*, S C SINGH, S P YADAV, A KUMAR and B L SHARMA

U.P. Council of Sugarcane Research, Shahjahanpur –242001, (U.P), India

ABSTRACT

Sugarcane is a vegetatively propagated crop and approximately 10- 12 per cent of the total cane production is used annually as seed material. The quantity and quality of seed used determine the performance of a crop. An improved variety with good quality seed cane can increase cane yield up to 20 - 25% because good quality seed ensures better germination. The quality of seed depends on age of the crop, growing conditions, varietal purity, non lodging crop habit, no incidence of pests and diseases *etc*. Good quality seed from a well maintained seed nursery certainly reduces the seed cost which is about 25% of the total cost of sugarcane cultivation. The first step in any business is to have good quality raw material. The business of sugarcane farming is no exception. Thus to improve profitability from cane farming, one needs to commence with good quality planting material or else potential yields would never be achieved. The need to achieve the potential yields along with disease control is a valid reason for seed cane production. A seed cane nursery provides sugarcane growers with diseases free seed cane which could be the single most important factor to increase sugar and cane yields. Quality planting material helps to provide seed cane that germinates well, has varietal purity and is free from diseases and pests. These healthy planting materials can be produced in well-managed seed cane nurseries.

Key words: Quality seed cane, Heat therapy, Breeder seed, Foundation seed, Certified seed, Fungicide, Sugarcane.

Seed is the basic, cheapest and dependable input for increasing agricultural production. Sugarcane seed used in commercial planting is the vegetative part of the stem (cane stalk) called sett. A sett may contain one, two or three buds. Normally, three budded setts are used for planting. The quantity and quality of seed used determine the performance of crop. Many diseases of sugarcane are transmitted through seed cane and are required to be controlled (Singh 1977). For this purpose, genetically pure good quality healthy seed of newly released varieties is required to be produced regularly for enhancing sugarcane production and management of diseases. Therefore, establishment of seed production chain for sustained sugarcane production with three tier seed production programme is advocated to fulfill the requirement of quality seed in sugarcane cultivation (Misra, 2003).

The use of healthy and vigorous seed plays a vital role in the cane development programme. Seed borne diseases are responsible for considerable crop losses (Singh and Singh 2002). This problem is more in vegetatively propagated crops like sugarcane, in which there may be a progressive decline in production along with sugar recovery with increasing trend of diseases. Therefore, production and supply of quality planting materials assumes greater significance.

MATERIALS AND METHODS

Single or two budded setts, from well-maintained seed nurseries are treated with hot water at 50 °C for two hours. After treatment, the setts are soaked in fungicide solution (0.1% Bavistin) for 05 to 10 minutes and planted in a well prepared field, wherein sugarcane was not grown during the previous year. The field should be well prepared and organic manures such as Farm Yard Manure or sulphinated press mud cake should be applied @ of 10 or 05 t/ha, respectively before planting. Spacing of 90 cm between row to row is recommended. Trench method of planting is also in use to produce breeder seed with spacing of 4 feet in a double row and 90: 30: 90 in wide paired row planting systems. A slightly higher seed rate of 75,000 setts/ha (two budded setts) is recommended for raising breeder's seed to compensate germination loss due to heat therapy. The seed crop is monitored regularly for genetic purity and free from pests and diseases up to 8-10 months in the field, earthing and propping up practices, seed multiplication technique. Breeder seed nurseries of improved varieties of sugarcane are certified under the supervision of seed production officer and scientists of other disciplines namely, breeding, plant pathology, entomology and agronomy.

RESULTS AND CONCLUSION

Seed production programme has played an important role in fast replacement of old varieties by high yielding newly released varieties (Kumar *et al*. 2014). Varietal multiplication was carried out as per the demand of sugar factories as well as sugarcane growers of concerned area. All recommended

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

agronomical practices and seed production practices were followed and the recommendation of soil testing, plant protection and post monsoon irrigation were adopted. Breeder seed production was carried out under the supervision of breeder, pathologist, entomologist and agronomist. The breeder seed cane of newly released varieties was utilized for raising foundation seed nurseries through trench method.

On an average, one lakh quintal breeder seed cane was produced for raising foundation seed cane nurseries from UPCSR. During 2011-12, 130246.19q and in year 2015-16, 231733.21q breeder seed cane were produced from 243.75ha and 384.00 ha area respectively (Table 1).

In the year 2011-12, area of breeder seed cane was 250.75 ha in which early varieties and mid late varieties occupied 191.82 ha and 58.93 ha respectively. In recent year (2015-16) early and mid late varieties were planted in 76.61 ha and 73.40 ha respectively, *i.e.* a total of 150.00 ha for breeder seed cane (Table 2 and 3). Due to this breeder seed cane production programme, Uttar Pradesh has ended the sugar season 2016-17 as the state having highest sugar recovery (10.61%), cane productivity (72.37 t/ha) and as the highest sugar producer (87.50 lakh tonnes) by beating Maharashtra.

Under this programme it is proposed to replace area under old varieties with newly released early and mid-late maturing varieties. By replacement with newly released variety *viz.,* 'Co 0238' which covered approximately 35% of total area in Uttar Pradesh, the sugar recovery has gone up to 10.61 percent (Table 4).

Table 1 Distribution of breeder seed cane by UPCSR, Shahjahanpur (2011-12 to 2015-16)

S. No.	Year	Area (ha.)	Quantity (q)
1	2011-12	243.75	130246.19
2	2012-13	281.29	150431.60
3	2013-14	373.89	195205.06
4	2014-15	360.15	210753.13
5	2015-16	384.00	231733.21
	Total	**2969.81**	**1626021.43**

Table 2 Area under breeder seed cane production (2011-2016) at UPCSR, Shahjahanpur

S. No.	Year	Variety	Autumn season			Spring season			Autumn + spring season		
			Research farms	Farmer's field	Total	Research farms	Farmer's field	Total	Research farms	Farmer's field	Total
1	2011-12	**Early**	19.36	06.08	**25.44**	23.03	10.46	**33.49**	42.39	16.54	**58.93**
		Midlate	62.37	25.64	**88.01**	65.99	37.82	**103.81**	128.36	63.46	**191.82**
		Total	**81.73**	**31.72**	**113.45**	**89.02**	**48.28**	**137.30**	**170.75**	**80.00**	**250.75**
2	2012-13	**Early**	17.94	23.98	**41.92**	17.47	32.27	**49.74**	35.41	56.25	**91.66**
		Midlate	57.76	54.50	**112.26**	44.93	126.38	**171.31**	102.69	180.88	**283.57**
		Total	**75.70**	**78.48**	**154.18**	**62.40**	**158.65**	**221.05**	**138.10**	**237.13**	**375.23**
3	2013-14	**Early**	18.58	11.56	**30.14**	33.92	81.91	**115.83**	52.50	93.47	**145.97**
		Midlate	47.52	31.81	**79.33**	37.69	97.16	**134.85**	85.21	128.97	**214.18**
		Total	**66.10**	**43.37**	**109.47**	**71.61**	**179.07**	**250.68**	**137.71**	**222.44**	**360.15**
4	2014-15	**Early**	27.56	01.12	**28.68**	47.57	123.46	**171.03**	75.13	124.58	**199.71**
		Midlate	16.15	02.74	**18.89**	51.02	114.38	**165.40**	67.17	117.12	**184.29**
		Total	**43.71**	**03.86**	**47.57**	**98.59**	**237.84**	**336.43**	**142.30**	**241.70**	**384.00**
5	2015-16	**Early**	26.48	00.00	**26.48**	50.13	00.00	**50.13**	26.48	50.13	**76.61**
		Midlate	23.52	00.00	**23.52**	49.88	00.00	**49.88**	23.52	49.88	**73.40**
		Total	**50.00**	**00.00**	**50.00**	**100.01**	**00.00**	**100.01**	**50.00**	**100.01**	**150.01**

Table 3 Impact of breeder seed cane on area of early and mid late varieties in U.P.

S. No.	Year	Area of early varieties (%)	Area of mid late varieties (%)	Area of rejected varieties (%)
1	2010-11	8.93	78.54	12.53
2	2011-12	9.23	76.08	14.67
3	2012-13	14.70	70.21	15.09
4	2013-14	21.35	63.71	14.94
5	2014-15	34.47	40.14	25-38 CoSe 92423 (14.57%)

Table 4 Impact of breeder seed cane on productivity, production and recovery in U.P.

S. No.	Year	Cane productivity (t/ha)	Total Cane production (Lakh ton)	Sugar Recovery (%)	Total Sugar production (Lakh/ton)
1	2010-11	56.34	-	9.14	58.87
2	2011-12	59.35	1335.72	9.07	69.74
3	2012-13	61.63	1493.98	9.18	74.85
4	2013-14	62.72	1480.93	9.26	64.95
5	2014-15	65.14	1389.02	9.55	71.00
6	2015-16	66.46	1363.75	10.61	68.55

REFERENCES

Kumar S, Singh J, Singh P K, Pandey D K and Siraree A.(2014). Implementing effective seed cane production chain and its distribution network for replacing old sugarcane varieties. *In Proceedings:* National Seminar on Recent Advances and Challenges in Sugarcane Researches, UAS, Dharwad : 30p.

Misra S R. (2003). Recent advances in seed production of sugarcane. *Cooperative Sugar*, **34** (10): 805-8.

Singh V and Singh J. (2002). Healthy Seed Production. *Indian Farming*, **51** (11): 37-43.

Singh K. (1977). Sugarcane diseases and three tier seed programme. *Sugar News*, **9** : 81-9.

Indian Journal of Sugarcane Technology **32(01)**: 41-44, June 2017 **Short Communication**

Contributions of sugarcane researches in development of biology and agriculture: A historical perspective

A K SHRIVASTAVA*, V MISRA, SANGEETA SRIVASTAVA, S P SHUKLA AND A D PATHAK

ICAR-Indian Institute of Sugarcane Research, Lucknow-226 002 (Uttar Pradesh), India

ABSTRACT

Researches on living beings, plants, animals and microbes have played an effective role in unraveling the mysteries of nature as well as contributed to the development of biology and agriculture; and sugarcane has an important place among these. The sugarcane plants is a proud contributor to the discovery of C_4 photosynthesis, sucrose synthesis and translocation, and, inter-specific and inter-generic hybridization. The concept of crop logging used in agriculture has been developed in this crop. Diazotrophic nitrogen fixation was first utilized in sugarcane, for economizing nitrogen application to sustain/ increase sugarcane productivity. The carbon sequestration ability of sugarcane (as Phytoliths formation) is important in reducing the CO_2 levels in the atmosphere. Augmented design developed in this crop has paved way for judging the superiority of a new variety in spite of very little seed available. It is a live herbarium of cytogenetic peculiarities like 2n+n transmission, *en-block* elimination of chromosomes, etc. Besides, sugarcane has the honour to have the first ever crop specific journal- The Sugar Cane published in 1869.

Keywords: C_4 photosynthesis, carbon sequestration, crop logging, cytogenetic peculiarities, nitrogen fixation, source and sink

Biological sciences have enriched from the researches on various plants, animals and microbes which have helped unraveling the mysteries of nature. Unlike other Poaceae plants, a highly heterozygous polyploid sugarcane is endowed with innumerable cytogenetic peculiarities such as 2n+n gametic transmission instead of n+n (in certain crosses) and *en-bloc* elimination of chromosomes during cell division; its stalks are not merely a support-frame for translocation channels and inflorescence or ear heads bearing seeds, but also a unique "*sink*", wherein sugar is stored both in the vacuole as well as in the cytoplasm of the parenchymatous cells (Williams *et al*. 1988); exhibits huge tillering potential (as many as 144 millable canes have been reported to emerge from one bud of sugarcane (Shamel 1924); and vast ratoonability reported since 1757 in Fujian Province in People's Republic of China (Sang 1980). The sweet reed, sugarcane was earlier called *Arundo saccharifera* (Bauhin 1623). Carl Linnaeus, grouped all the sweet reeds as *Saccharum officinarum* (Linnaeus 1753). Botanically sugarcane belongs to monocotyledonous angiosperm genus *Saccharum,* placed in the family *Gramineae* (also called Poaceae), sub family *Panicoideae,* tribe *Andropogoneae,* groups of sub-tribe *Saccharinae* Benth and sub-tribe *Saccharastrae* (Daniel and Raoch 1987). Researches on sugarcane have led to some unique discoveries and concepts which proved as forerunner in biological sciences or were utilized for the benefit of the crop for the first time, on a commercial scale. Some of these features/ concepts that led to the development of biology and agriculture are mentioned below:

(i) Inter-specific and inter-generic hybridization

Utilization of *Saccharum spontaneum* in breeding modern sugarcane in India by Sir T.S. Venkataraman resulted in the development of the first commercial hybrid 'Co 205' which ushered a new era of sugarcane research not only in India but also in entire world (Anonymous 1987).

At the Imperial Sugarcane Breeding Station, Coimbatore (now Sugarcane Breeding Institute), the first successful inter-generic hybrid between sugarcane and *Narenga porphyrocoma* was developed by Dr. C. A. Barber during 1912-1916 (Anonymous 1987; Barber 1916). Subsequently, attempts for inter-generic hybridization of *Saccharum* with other genera were also made, *e.g.*, with *Sorghum* (Thomas and Venkataraman 1930), *Imperata* (Janaki Ammal 1935), *Narenga* and *Sclerostachya* (Parthasarathy and Venkataraman 1942), *Zea* (Janaki Ammal 1938), *Narenga* (Janaki Ammal 1942), *Miscanthus* (Li *et al*. 1948) and *Erianthus* sec. *Ripidium* Henard (Rumke 1934). Attempts were also made to cross sugarcane with bamboo (*Bambusa*) but no successful hybrids could be obtained (Anonymous 1987; Rumke 1934). These efforts revolutionized the breeding of sugarcane in the world. Inter-generic hybrids have been successfully used for sugarcane improvement (Sreenivasan and Sreenivasan 2000). When *E. arundinaceus* was used as a pollen parent, there was no significant reduction in sucrose content (Sreenivasan *et al.* 2001).

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

(ii) Discovery of a new carboxylation mechanism

Photosynthesis is the most important physiological process which converts solar energy into chemical energy mediated by fixation of carbondioxide in the chloroplasts in the presence of water. The CO_2 fixation or reduction was elucidated by M. Calvin and A. A. Benson in 1948 (Calvin and Benson 1948) and later by J. A. Bassham, A. A. Benson and M. Calvin in 1950 (Bassham *et al.* 1950). In 1957, Hugo P. Kortschak, a sugarcane scientist, observed that during photosynthesis sugarcane leaves produced malate- a C_4 organic acid instead of phosphoglycerate, the already known pathway of CO_2 fixation (Kortschak *et al.* 1957; Nickell 1993). Later Y. S. Karpilov (1960) observed a similar distribution of radioactive carbon in metabolic intermediates in maize leaves. In 1966, M.D. Hatch and C.R. Slack in Australia, elucidated the C_4 pathway of photosynthesis in sugarcane (Hatch and Slack 1966). Subsequently, aspartate and malate forming C_4 plants, anatomical and physiological characteristics of these plants as well as many exceptions to this pathway were also worked out (Hatch 2002).

(iii) Sugar synthesis and translocation

The work initiated by Madam Constance E. Hartt and associates in Hawaii on sugar synthesis and translocation of photosynthates in sugarcane, formed the basis of our present day understanding of sugar synthesis and its translocation (Hartt 1934, 1943a,b,c, 1963; Hartt *et al.* 1963).

(iv) Crop logging

Crop logging, is essentially the maintenance of crop records for dry matter production, nutrient analyses and weather parameters to diagnose the limitations and optimization of resources so as to improve crop productivity. The term '*Crop log*' was given by Hamilton Agee, of the Hawaiian Sugar Planter's Association Experiment Station, Hawaii. Most of the crop log studies in sugarcane are credited to Harry F. Clements (1980). This concept has been used in the management of many crops such as maize, alfalfa, *etc.,* to optimize their productivity *per se* (Clements, 1980). Later on using the nutrient ratio, E.R. Beaufils at the University of Natal in South Africa developed a comprehensive system called DRIS (Diagnosis and Recommendation Integrated System) which identifies nutritional factors limiting crop growth so as to improve fertilizer recommendations *vis-à-vis* improving crop production (Beaufils 1973; Tisdale *et al.* 1990; Walworth and Summer 1987). Sugarcane Nutritional Analysis Programme (SNAP), a simple diagnostic expert system, using a diagnostic key logic, linking coloured pictures with text, based on the Field Guide, Sugarcane Nutrition by Anderson and Bowen (1990) to diagnose sugarcane nutritional problems was developed (Lentini *et al.* 1995).

(v) Diazotrophic endophytes for biological nitrogen fixation, for economizing N application

Diazotrophic endophytic bacteria (*Acetobacter diazotrophicus, Herbaspirillum* spp. and *Azospirillium* spp.) occur in high population not only in the roots but also in the stem, leaves, trash and contribute significantly to biological nitrogen fixation (BNF) in sugarcane (Boddey *et al.* 1991; Boddey and Döbereiner 1995). These studies were initiated by J. Döbereiner in 1961 in Brazil (Döbereiner 1961). Variable estimates for per cent nitrogen derived from air (Ndfa) for sugarcane are available to the tune of 60 to 80% (Döbereiner 1961), 60% (Boddey *et al.* 1995) and 29.5 % (Li *et al.* 2015). This has led to economizing nitrogen fertilization in sugarcane to an appreciable extent.

(vi) Augmented design of statistical analysis

Augmented (*Hoonuiaku*) design for statistical analysis was introduced by W.T. Federer (1956) working with sugarcane at the Experimental Station of Hawaii Sugarcane Planters Association, Hawaii. Normally for statistical evaluation, the new clones developed have to be replicated *on par* with check varieties, however, sometimes the seed of a newly developed clone may not be sufficient to have a replicated trial. In the experimental design proposed by Federer (1956; 1961), check varieties are replicated but the newly developed clones are not; thus they augment the standard experimental design used. The standard error obtained could be effectively used to compare superiority among the clones under testing *vis-à-vis* check varieties used.

(vii) Carbon sequestration in sugarcane

Sugarcane possesses a unique sequestration process for making *phytoliths or* phyto-occluded carbon (PhytOC). Australian Scientists, J.F. Parr and his associates have estimated that this process extracts around 300 Mt of CO_2/ year from atmosphere and stores it in the soil for thousands of years (Parr and Sullivan 2007; Parr *et al.* 2009). They have estimated the PhytOC yield of a sugarcane crop to be 18.1 g C m^{-2} yr^{-1} which is comparable with carbon sequestered when a cultivated land is converted to forest or grassland, or conventional tillage is changed to no-tillage. Such a carbon sequestration ability of sugarcane along with its low CO_2 compensation point of 0-10 ppm and high rates of photosynthesis (39-47 mg $CO_2/dm^{-2}h^{-1}$) is important in the emerging climate change scenario (Shrivastava *et al.* 2016) where the level of CO_2 in the atmosphere has reached to 402.25 ppm as per Mona Loa Observatory, Hawaii, which was entrusted to monitor the world CO_2 concentration regularly; and the level of CO_2 is increasing @ 2 ppm per year (http://www.esrl.noaa.gov/gmd/ccgg/trends/,12.9.2016).

(viii) A live herbarium of cytogenetic peculiarities

Sugarcane, a highly heterozygous polyploid displays certain unique cytogenetic peculiarities such as 2n+n gametic transmission instead of n+n (in certain crosses) (Narayanaswami 1940) and *en-bloc* elimination of chromosomes during cell division (Raghavan 1951; 1954). Besides many other anomalies like chromosome mosaicism, abnormal behaviour during cell division (desynapsis, cytomixis, presence of B chromosomes), parthenogenesis, male sterility, variation in number of nucleoli, induced chromosomal changes, *etc*. have also been observed, which affect gametogenesis *vis-à-vis* directed breeding efforts (Srivastava 2000; Srivastava and Srivastava 1995).

(ix) First ever scientific journal devoted to a crop

The first ever crop-specific scientific journal, *The Sugar Cane* owes its inception in 1869 in U.K. to sugarcane. The detailed analysis of sugarcane juice- a monumental work in sugarcane crop by a Mauritian scientist was published in its first volume (Icery 1869). It was published in the form of two journals for some time, *Sugar Cane International* (which was later named *Sugar Cane*) and *International Sugar Journal*. Nowadays, it is published as only one journal *viz*., *International Sugar Journal.*

Being a proud contributor to these scientific landmarks and possessing some exceptional features like its stalks being a unique "sink" to store ample sugar coupled with vast tillering and ratooning potential, a sugarcane plant has immensely contributed to the development of biological sciences and thus it stands tall in comparison to other plants.

ACKNOWLEDGEMENTS

Authors are grateful to the Director, ICAR-Indian Institute of Sugarcane Research, Lucknow, India for support in this study.

REFERENCES

Anderson D L and Bowen J E. 1990. Sugarcane Nutrition: Field Guide, *Library of Congress Catalogue*, Card No. 91-62030, ISBN 0-9629598-0-4, pp. 47.

Anonymous. 1987. Research Achievements: 1912-1987, Platinum Jubilee Profile (David, H., ed.), *Sugarcane Breeding Institute, Coimbatore, India*, pp. 121.

Barber C A. 1916. Studies in Indian sugarcanes. *No.2, Mem.Dept. Agric. India Bot. Ser.,* **8**: 103-99.

Bassham J A, Benson A and Calvin M. 1950. The path of carbon in photosynthesis. *J.Biol. Chem.* **182**(2): 781-7.

Bauhin C. 1623. Theatri Botanici. (Known as Bauhin Pinax). *Basel, Switzerland. In: 2d ed.,* 1671. (*c.f.* Daniels and Roach, 1987).

Beaufils E R. 1973. (*c.f.*Beaufils E.R. and Sumner M.E. (1977). Effect of time sampling on the diagnosis of the N, P, K, Ca and Mg requirement of sugarcane by the DRIS approach. *Proc. S. Afr. Sugar. Tech. Assoc*., **51**: 62-7.

Boddey R M and Döbereiner J. 1995. Nitrogen fixation associated with grasses and cereals: Recent progress and perspectives for the future. *Fert. Res.,* **42**(1): 241-50.

Boddey R M, Urquiaga S, Reis V and Döbereiner J. 1991. Biological nitrogen fixation associated with sugar cane. *Plant and Soil*, **137**(1): 111-7.

Boddey R M, Oliveira de O C, Urquiga S, Reis V M, Olivares de F L, Baldani V L D and Döbereiner J. 1995. Biological nitrogen fixation associated with sugar cane and rice: Contributions and prospects for improvement. *Plant & Soil,* **174** (1/2): 195-209.

Calvin M and Benson A A. 1948.The path of carbon in photosynthesis. *Science,* **107**(2784):476-80.

Clements H F. 1980. Sugarcane Crop Lodging and Crop Control: Principles and Perspectives, *The University Press of Hawaii*, *Honululu*, pp. 520.

Daniels J and Roach B T. 1987. Taxonomy and evolution, Chapter 2 in Sugarcane Improvement through Breeding (Heinz, D.J., editor), *Elsevier, Amsterdam-Oxford-New York-Tokyo*, pp.7-84.

Dobereiner J. 1961. Nitrogen-fixing bacteria of the genus *Beijerinckia* Derx in the rhizosphere of sugar cane. *Plant and Soil*, **15**(3): 195-209.

Federer W T. 1956. Augmented designs. *Hawaiian Planters Record,* **55**, 191-208.

Federer W T. 1961. Augmented designs with one way elimination of heterogeneity. *Biometrics*, **17:** 447-73.

Hartt C E. 1934. The synthesis of sucrose by invertase in sugarcane. Paper presented at the 11th *Annl. Meet. American Soc. Pl. Physiology*.

Hartt C E. 1943 a. The synthesis of sucrose in the sugarcane plant I. *Hawaiian Planter's Rec*., **47**: 113-32.

Hartt C E. 1943 b. The synthesis of sucrose in the sugarcane plant II. *Hawaiian Planter's Rec.,* **47**: 155-70.

Hartt C E. 1943 c. The synthesis of sucrose in the sugarcane plant III. *Hawaiian Planter's Rec.,* **47**: 223-55.

Hartt C E. 1963. Translocation of sugar in cane plant. *Rept. Hawaiian Sugar Technol.,* pp. 151-67.

Hartt C E., Kortschak H P, Foster A J and Burr G O. 1963. Translocation of ^{14}C in sugarcane. *Pl. Physiol*., **38**: 305-18.

Hatch M D. 2002. C_4 photosynthesis: Discovery and resolution. *Photosynthesis Res.,* **73**: 251-57.

Hatch M D and Slack C R. 1966. Photosynthesis in sugarcane leaves: A new carboxylation reaction and pathway of sugar formation. *Biochem. J.,* **101**: 103-11.

http://www.esrl.noaa.gov/gmd/ccgg/trends/,12.9.2016

Icery 1869. Research on the juice of sugarcane; and on the modifications to which it is subject during manufacture in the Island of Mauritius. *The Sugar Cane,* **1**: 17-32; 71-85; 135-146; 202-23.

Janaki Ammal E K. 1938. A *Saccharum-Zea* cross. *Nature* **142**: 618-19.

Janaki Ammal E K. 1941. Intergeneric hybrids of *Saccharum*. *J. Genet.* **41**: 217-53.

Janaki Ammal E K. 1942. Intergeneric hybrids of *Saccharum* IV. *Saccharum* x *Narenga* J. *Genetics,* **44:** 23-32.

Karpilov Y S. 1960. The distribution of radioactivity in carbon-14 among the products of photosynthesis in maize. *Proc. Kazan Agric. Inst.,* **14**: 15-24.

Kortschak H P, Hartt C E and Burr G O. 1957. Abstracts, *Annl. Meeting of the Hawaiian Academy of Sciences*, pp. 21.

Lentini R S I, Anderson D L and Bowen J E. 1995. Sugarcane nutritional analyses Program (SNAP): A simple expert system. *Proc. Int. Soc. Sugar Cane Technol.,* **XXII** (Abst. Papers. *c.f. Sugar Cane* No. **6**: 30, 1995).

Li H W, Loh C S and Lee C L. 1948. Cytological studies of sugarcane and its relatives. I. Hybrids between *Saccharum officinarum, Miscanthus japonicus* and *Saccharum spontaneum*. *Bot. Bull. Acad. Sin. (Taipei)*, **2**: 147-60.

Li Y R, Zhou X Z and Yang L T. 2015. Nitrogen fixation in sugarcane and nitrogen transfer from sugarcane to cassava in an intercropping system. *Int. J. Sci. & Nature,* **6**(2): 214-18.

Linnaeus C. 1753. Species Plantarum. 2 vols. Stockholm. In: 1959 Facsimile edition, Ray Society, London. (*c.f.* Daniels and Roach, 1987).

Narayanaswami S. 1940. Megasporogenesis and the origin of triploid in *Saccharum*. *Indian J. Agric. Sci*., **10**: 534-55.

Nickell L G. 1993. A tribute to Hugo Kortschak. *Photosynthesis Research,* **35**: 201-04.

Parr J, Sullivan L and Quirk R. 2009. Sugarcane phytoliths: Encapsulation and sequestration of a long-lived carbon fraction. *Sugar Tech,* **11**(1): 17-21.

Parr J F and Sullivan L A. 2007. Sugarcane-the champion crop at carbon sequestration. *Australian Cane Grower*, **17:** 14-5.

Parthasarathy N and Venkataraman T S. 1942. Yet more parents for sugarcane breeding. *Curr. Sci.,* **11**: 150.

Raghavan T S. 1951. The sugarcanes of India: Some cyto-genetic considerations. *J. Heredity,* **42** (4): 199-206.

Raghavan T S. 1954. Cytogenetics in relation to sugarcane breeding. *Cytologia,* **19**: 133-43.

Rumke C L J. 1934. *Saccharum, Erianthus bastardan*. *Arch. Suik. Ned. Indie,* **42**(2): 211-61 (*c.f.* Sreenivasan *et al.,* 1987).

Sang T. 1980. The world's oldest cultivated ratoon. *International Sugar,* **82**: 146.

Shamel A D. 1924. *Hawaiian Planter's Rec.*, **13**: 400-28.

Shrivastava A K, Srivastava T K, Srivastava A K, Misra V**,** Srivastava S, Singh V K and Shukla S P. 2016. *Climate change induced abiotic stresses affecting sugarcane and their mitigation*, ICAR-Indian Institute of Sugarcane Research Lucknow, pp. 108+VI.

Sreenivasan T V, Amalraj V A and Jebadhas A W. 2001. Catalogue on Sugarcane Genetic Resources IV. *Erianthus* species, Sugarcane Breeding Institute, Coimbatore, India, pp. 98.

Sreenivasan T V and Sreenivasan J. 2000. Intergeneric hybrids for sugarcane improvement. *SBI Newsl.,* **19** (2): 1-2.

Srivastava S. 2000. Cytogenetics of sugarcane, 50 Years of Sugarcane Research in India, (Shahi, H. N., A. K. Shrivastava and O. K. Sinha, eds.), *ICAR-Indian Institute of Sugarcane Research, Lucknow, India*, pp. 55-71.

Srivastava S and Srivastava H M. 1995. Cytological studies on sugarcane cultivar CoLk 8102. *Indian J Sugarcane Technol,* **10**(1): 23-25.

Thomas R and Venkataraman T S. 1930. Sugarcane-Sorghum hybrids. *Agric. J. India,* **25**: 164.

Tisdale S L, Nelson W L and Beaton J D. 1990. Soil Fertilizer and Fertilizers, 4th edition, Mac Millan Pb. Co., New York, pp. 754.

Venkataraman T S. 1937. Sugarcane x Bamboo hybrids. *Indian J. Agric. Sci.,* **7**: 513-514.

Walworth J L, Sumner M E. 1987. The diagnosis and recommendation integrated system (DRIS). *Adv. Soil Sci.,* **6**: pp.149-88.

Williams L E, Maretzki A and Thom M. 1988. Sugar accumulation in stalk parenchymatous tissues and cell cultures of sugarcane. *Annl. Rept. Hawaiian Sugar Planter's Association Experiment Station*, pp.21.

INDIAN JOURNAL OF SUGARCANE TECHNOLOGY

Guidelines to Authors

The Indian Journal of Sugarcane Technology is published half yearly. The following types of material are considered for publication on meeting the style and requirements of the journal (The format of articles in June 2012 Issue should be considered as example):

1.a Articles on original Research completed, not exceeding 4000 words (up to 15 typed pages, including references, tables, etc).The article should present a connected picture of the investigation and should not be split into parts.

1.b Short Research Notes, not more than 1300 words (maximum 5 typed pages) dealing with completed research results which do not warrant comprehensive treatment; and short descriptions of new materials, equipments, etc along with supporting data are also accepted.

1.c Relevant, critical and comprehensive Research Review Articles can also be accepted but in general such articles are invited from eminent scientists.

1.d Research articles submitted for publication should have direct relevance with the sugarcane, sugar and other sugar producing crops and technologies.

1.e The author should indicate the period (years) of conducting the experiment and the article should be submitted immediately after the completion of the experiment.

2.a Title should be short, specific and informative. It should be phrased to identify the content of the article and include the nature of the study along with the specific technical approach.

2.b A Short Title not exceeding 35 letters should also be provided for running headlines.

2.c The By-line should contain, in addition to the names and initials of the authors, the place (organization) where research was conducted. Details of addresses can be given as footnote.

3 Abstract, written in complete sentences, should have maximum 150 words. It should contain a very brief account of the materials, methods, results, discussion and conclusion. It should not include any references.

4.a Introduction part should be brief and limited to the statement of the problem or the aim of the experiment. Key words should be given before the introduction.

4.b Relevant details should be given in Materials and Methods section including the experimental design and techniques used. Units of measurement, symbols and standard abbreviations should conform to those recommended by the International Union of Bio-Chemistry (IUB) and the International Union of Pure and Applied Chemistry (IUPAC). Metric measurements are preferred, and dosages should be expressed entirely in metric units (SI units).

4.c The Results and Discussion should be combined to avoid repetitions. Results should be presented in tabular form and graphs when feasible but not both. The colour figures and plates, are printed when information would be lost if reproduced in black and white. Mean result with the relevant standard errors should be presented rather than detailed data. The data should be so arranged that the tables would fit in the normal layout of the page. Self-explanatory tables should be typed on separate sheets and carry appropriate titles. The tabular matter should not exceed 20% of the text. Any abbreviation used in a table must be defined in that table. Use Arabic numerals with abbreviated units of measure: 2 g, 5 d, $4.00, 3% and numerical designations in the text: exp 1, group 3, etc.

4.d Author is required to submit high-resolution images. A number of different file formats are acceptable Portable Document Format (PDF).

4.e Authors must obtain permission to reproduce any copyright material, and include an acknowledgement of the source in their Article.

4.f The conclusion should be brief and relevant normally not exceeding one typed page.

5 Reference citations in the text are typed as follows: Pandey (1991) or (Pandey 1991); Srivastava *et al.* (2004) or (Srivastava *et al.* 2004); Tiwari and Singh (2007) or (Tiwari and Singh 2007). Groups of references cited in a sentence in the text must be listed in chronological order as in the previous sentence. References lists should be typed in alphabetical order. The reference list should be first sorted alphabetically by author(s) and secondly chronologically.

6. The articles in this journal have been published on good faith that the material provided by author(s) is based on original work and the Association will not be held responsible for any plagiarism issue.

The Association of Sugarcane Technologists of India

ICAR-Indian Institute of Sugarcane Research
Dilkusha P.O., Lucknow-226 002

Application Format for Membership

Affix
Recent
Color
Photograph

1. **Full name (in block letters):**
2. **Date of Birth and Age:**
3. **Nationality:**
4. **Occupation/Designation:**
5. **Employer:**
6. **Address (in detail):**

   i. Permanent:

   ii. Correspondence:

   iii. Telephone, Fax & Mobile Nos.:

   iv. E-mail:

7. **Request for Enrolment as:**

   Patron Member ☐ Life Member ☐ Companion Member ☐ Fellow Member ☐ Student Member ☐ Library Member ☐

8. **Agreement: I shall abide by the Rules and regulations of the Association.**

Signature____________________

Membership and Journal Subscription

Sustaining Member Rs. 50000/- Patron member - Contributing not less than Rs. 10000 and above / Life Member Rs. 3000* / Companion member (Companies & firms) Rs. 5000*/ Fellow member (Annual) Rs. 300*/ Student member (Annual) Rs. 100*/ Library Member (Annual) Rs. 1000*

Note: The payment to be made by cash/multicity cheque/demand draft in favour of the Secretary, ASTI payable at Lucknow.

*Revised rate will be effective from January 01, 2018

1. Dr. A.D. Pathak, President, ASTI & Director, ICAR-IISR, Lucknow. Off: 0522-2480726, Fax: 0522-2480738
2. Dr. Sanjeev Kumar, Secretary, ASTI & PS (Plant Breeding), ICAR-IISR, Lucknow. Mob: +91-9450356968
   Off: 0522-2480735-37 ext. 135, E-mail: secretaryasti@gmail.com

INDIAN JOURNAL OF SUGARCANE TECHNOLOGY

Statements about Ownership and Other Particulars

Place of Publication	:	Lucknow
Periodicity of Publication	:	Half Yearly (June and December)
Publisher's Name	:	Dr. Sanjeev Kumar
Nationality and Address		Indian Hony. Secretary, The Association of Sugarcane Technologists of India, ICAR-Indian Institute of Sugarcane Research, Dilkusha P.O., Lucknow – 226002 India
Chief Editor's Name	:	Dr. Sangeeta Srivastava
Nationality and Address	:	Indian ICAR-Indian Institute of Sugarcane Research, Dilkusha P.O., Lucknow – 226002 India
Printer's Name and Address	:	Stuti Enterprises 326, Subhash Mohal, Sadar Lucknow - 226 002 India
Owner's Name and Address	:	The Association of Sugarcane Technologists of India, ICAR-Indian Institute of Sugarcane Research, Dilkusha P.O., Lucknow – 226002 India

I, Dr. Sanjeev Kumar, hereby declare that to the best of my knowledge and belief the particulars given above are correct.

Sd/

(SANJEEV KUMAR)
Secretary

INDIAN JOURNAL OF SUGARCANE TECHNOLOGY

ISSN 0970-3233 Issue: Volume 32 No.1 June 2017

CONTENTS