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किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch

# Vision 2050


भाकृअनुप
ICAR

Indian Institute of Sugarcane Research

Indian Council of Agricultural Research

IISR
भारतीय गन्ना अनुसंधान संस्थान, लखनऊ
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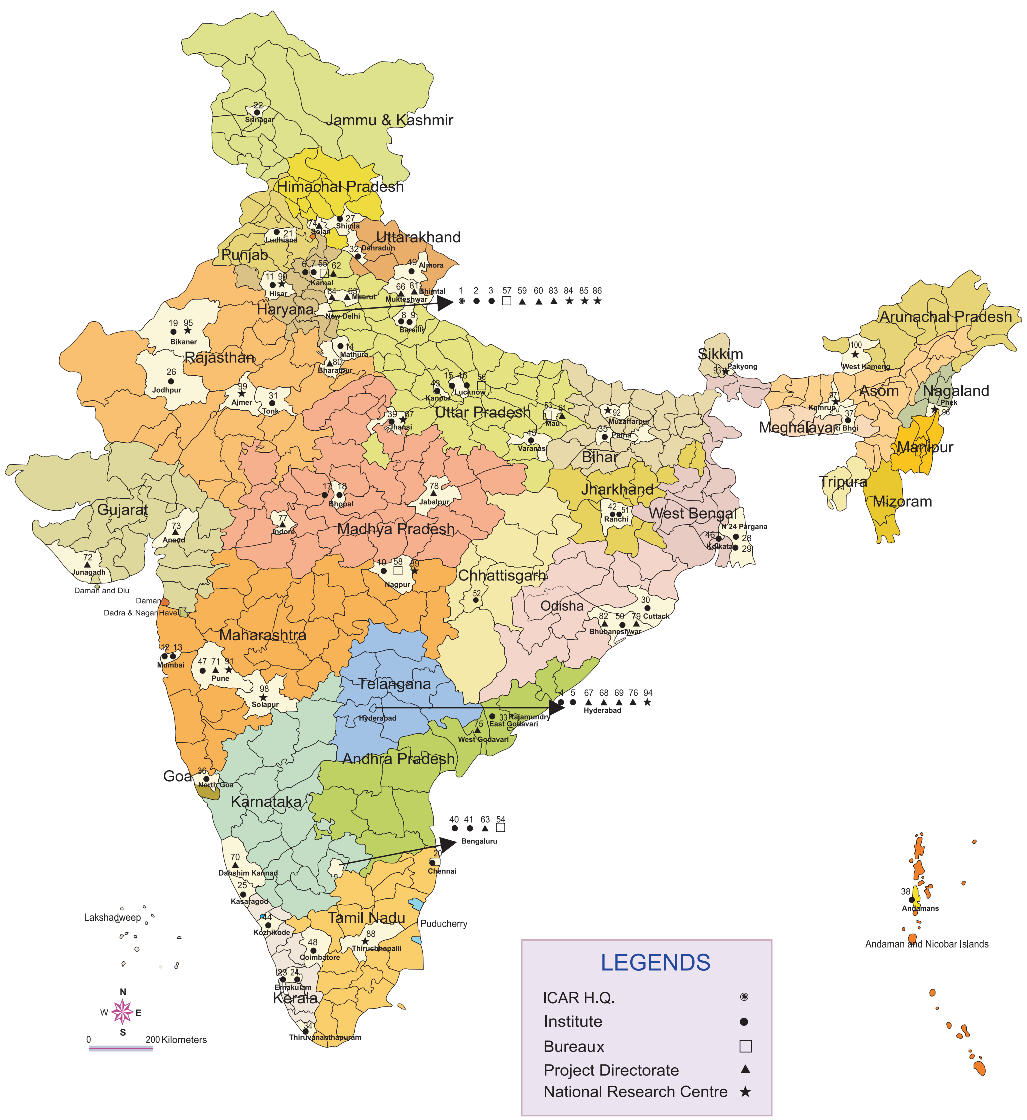


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# Vision 2050

भारतीय गन्ना अनुसंधान संस्थान, लखनऊ
ISO 9001 : 2008

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# संदेश

भारतीय सभ्यता कृषि विकास की एक आधार रही है और आज भी हमारे देश में एक सुदृढ़ कृषि व्यवस्था मौजूद है जिसका राष्ट्रीय सकल घरेलू उत्पाद और रोजगार में प्रमुख योगदान है। ग्रामीण युवाओं का बड़े पैमाने पर, विशेष रूप से शहरी क्षेत्रों में प्रवास होने के बावजूद, देश की लगभग दो–तिहाई आबादी के लिए आजीविका के साधन के रूप में, प्रत्यक्ष या अप्रत्यक्ष, कृषि की भूमिका में कोई बदलाव होने की उम्मीद नहीं की जाती है। अतः खाद्य, पोषण, पर्यावरण, आजीविका सुरक्षा के लिए तथा समावेशी विकास हासिल करने के लिए कृषि क्षेत्र में स्थायी विकास बहुत जरूरी है।

पिछले 50 वर्षों के दौरान हमारे कृषि अनुसंधान द्वारा सृजित की गई प्रौद्योगिकियों से भारतीय कृषि में बदलाव आया है। तथापि, भौतिक रूप से (मृदा, जल, जलवायु), बायोलोजिकल रूप से (जैव विविधता, हॉस्ट–परजीवी संबंध), अनुसंधान एवं शिक्षा में बदलाव के चलते तथा सूचना, ज्ञान और नीति एवं निवेश (जो कृषि उत्पादन को प्रभावित करने वाले कारक हैं) आज भी एक चुनौती बने हुए हैं। उत्पादन के परिवेश में बदलाव हमेशा ही होते आए हैं, परन्तु जिस गति से यह हो रहे हैं, वह एक चिंता का विषय है जो उपयुक्त प्रौद्योगिकी विकल्पों के आधार पर कृषि प्रणाली को और अधिक मजबूत करने की मांग करते हैं।

पिछली प्रवृत्तियों से सबक लेते हुए हम निश्चित रूप से भावी बेहतर कृषि परिदृश्य की कल्पना कर सकते हैं, जिसके लिए हमें विभिन्न तकनीकों और आकलनों के मॉडलों का उपयोग करना होगा तथा भविष्य के लिए एक ब्लूप्रिंट तैयार करना होगा। इसमें कोई संदेह नहीं है कि विज्ञान, प्रौद्योगिकी, सूचना, ज्ञान–जानकारी, सक्षम मानव संसाधन और निवेशों का बढ़ता प्रयोग भावी वृद्धि और विकास के प्रमुख निर्धारक होंगे।

इस संदर्भ में, भारतीय कृषि अनुसंधान परिषद के संस्थानों के लिए विजन–2050 की रूपरेखा तैयार की गई है। यह आशा की जाती है कि वर्तमान और उभरते परिदृश्य का बेहतर रूप से किया गया मूल्यांकन, मौजूदा नए अवसर और कृषि क्षेत्र की स्थायी वृद्धि और विकास के लिए आगामी दशकों हेतु प्रासंगिक अनुसंधान संबंधी मुद्दे तथा कार्यनीतिक फ्रेमवर्क काफी उपयोगी साबित होंगे।

**( राधा मोहन सिंह )**

केन्द्रीय कृषि मंत्री, भारत सरकार

# Foreword

Indian Council of Agricultural Research, since inception in the year 1929, is spearheading national programmes on agricultural research, higher education and frontline extension through a network of Research Institutes, Agricultural Universities, All India Coordinated Research Projects and Krishi Vigyan Kendras to develop and demonstrate new technologies, as also to develop competent human resource for strengthening agriculture in all its dimensions, in the country. The science and technology-led development in agriculture has resulted in manifold enhancement in productivity and production of different crops and commodities to match the pace of growth in food demand.

Agricultural production environment, being a dynamic entity, has kept evolving continuously. The present phase of changes being encountered by the agricultural sector, such as reducing availability of quality water, nutrient deficiency in soils, climate change, farm energy availability, loss of biodiversity, emergence of new pest and diseases, fragmentation of farms, rural-urban migration, coupled with new IPRs and trade regulations, are some of the new challenges.

These changes impacting agriculture call for a paradigm shift in our research approach. We have to harness the potential of modern science, encourage innovations in technology generation, and provide for an enabling policy and investment support. Some of the critical areas as genomics, molecular breeding, diagnostics and vaccines, nanotechnology, secondary agriculture, farm mechanization, energy, and technology dissemination need to be given priority. Multi-disciplinary and multi-institutional research will be of paramount importance, given the fact that technology generation is increasingly getting knowledge and capital intensive. Our institutions of agricultural research and education must attain highest levels of excellence in development of technologies and competent human resource to effectively deal with the changing scenario.

Vision-2050 document of ICAR-Indian Institute of Sugarcane Research (IISR), Lucknow has been prepared, based on a comprehensive assessment of past and present trends in factors that impact agriculture, to visualise scenario 35 years hence, towards science-led sustainable development of agriculture.

We are hopeful that in the years ahead, Vision-2050 would prove to be valuable in guiding our efforts in agricultural R&D and also for the young scientists who would shoulder the responsibility to generate farm technologies in future for food, nutrition, livelihood and environmental security of the billion plus population of the country, for all times to come.

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# Preface

The challenge of feeding an ever increasing population coupled with the changing situations demands concerted efforts to address the food and nutritional insecurity of the nation. An integrated approach involving different crops and farming systems as a whole is essential in tackling this challenge. Sugarcane, being the principal source of sugar and other sweeteners in India, continues to be an important component of the national economy. With increasing awareness towards health, there is a shift in consumption of sugar to jaggery and other non-saccharide sweeteners. Besides, sugarcane has been recognized as an important energy source in terms of bio-ethanol production from molasses as well as cellulosic material and co-generation of electricity. To meet the expected combined demands posed by burgeoning population and consumption increase, along with the other challenges, India will have to produce 51 million tonnes of white sugar by 2050. This in turn, will necessitate a quantum jump in sugarcane productivity and sugar recovery. The limited scope for an increase in area under the crop demands an increase in productivity of the crop through use of innovative and state-of-the art technologies. With approximately 7.5% of the rural population engaged in various aspects of sugarcane farming, this increase in productivity and recovery needs to be examined in the context of profitability and sustainability. It is imperative that new varieties, innovative methods and practices need to be in place to suit the demands of stakeholders, in order to overcome the various challenges. This calls for a well planned long term strategy, visualizing the future scenario. This **Vision 2050** document is an attempt to foresee the future scenario with respect to sugarcane agriculture and products and to chalk out ways and means to meet the demands.

The present situation of cane productivity and sugar recovery as well as sugarcane as a feedstock for producing bio-ethanol calls for a judicious use of the available resources to meet the projected requirements of 2050. This has to be done keeping in mind the strength and weaknesses in the sugarcane production and processing system in order to make use of the opportunities available to the maximum extent. The blue-print of the future activities of the Institute has to be in place, involving conventional and cutting-edge technological interventions to improve the cane productivity and sugar recovery as well as developing sugarcane for second generation (2G) ethanol production.

The **Vision 2050** document aims to achieve the combined goal of enhanced production, productivity, profitability and sustainability in sugarcane agriculture, harnessing the domestic and global opportunities for the welfare of the various stakeholders. The multi-disciplinary and holistic research envisaged here, I am sure, will help us in exploiting the potential of modern science and technology thereby aiding in delivery of technological interventions with the necessary policy support.

I am grateful to Dr. S. Ayyappan, Secretary, DARE and Director General, ICAR, Dr J.S. Sandhu, Deputy Director General (CS), and Dr N. Gopalakrishnan, ADG (CC) for their guidance, support and constant encouragement.

I am thankful to Dr. S. K. Duttamajumder Principal Scientist, Division of Crop Protection, Dr A.K. Sharma, Principal Scientist & Incharge, PME Cell, Head of Divisions, and Dr. M. Swapna, Principal Scientist, Division of Crop Improvement for their efforts in bringing the document in its present form.

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Director,
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Lucknow

# Contents

# Context

Agriculture is the backbone of India which has approximately 70% of the rural population engaged in agriculture. The agro-based industries like sugar and cotton play an important role in the national economy and socio-economic development of the country. Sugar industry, the second most important among the agro-based industries with an annual turnover of approximately Rs 80-85 thousand crores per annum, has a significant contribution to the national GDP.

## Sugarcane and Sugar Scenario

Sugarcane is being grown in about 126 million ha in the world with a total cane production of approximately 1850 million tonnes. Three-fourth of the total sugar produced comes from sugarcane and the rest from sugarbeet. More than 115 countries cultivate sugarcane with a total sugar production of 177 million tonnes. Brazil is the largest producer of sugar followed by India. About 172 million tonnes of sugar is being consumed globally. Sugarcane is also a source of alternate products like feed, fibre and energy, esp., biofeul and co-generation, apart from sugar. The crop being one of the most efficient converter of biomass to energy and thereby an excellent source of biofuel production, there has been a heightened focus on sugarcane cultivation, sugar trade and that of other related products at national as well as international level. Out of the total global sugar output, developing countries contribute approximately 70% of the total production. In most of the developing countries, the production is mostly consumer centric except in Brazil, where the annual growth rates have enabled the country to turn its attention towards global sugar export market.

Indian sugar industry is very vibrant, supporting approximately 6.0 million people through sugarcane cultivation and other related industries. The crop is grown in about 5.0 million ha i.e., in around 3% of the total cultivated area which produces approximately 350 million tonnes of sugarcane annually. Although national average productivity is ~71.0 t/ha, tropical states record higher productivity ranging from 80.0 to 105.0 t/ha. The sugar recovery is hovering around 10.5% for the past decade with maximum recovery of 12.4% in southern Maharashtra. There are two distinct sugarcane growing zones in India- the tropical zone comprising of the southern region below the Tropic of Cancer and the sub-tropical zone comprising of the northern states (26°N to 32°N latitude). The tropical zone contributes 45% of the total area under sugarcane and the sub-tropical zone around 55% of the area. But the average cane productivity in the sub-tropical zone is lower (approximately 65 t/ha) than that of the tropical zone (approximately 80 t/ha). The lower cane productivity in subtropical north zone is primarily due to availability of shorter period (3-4 months) of favourable environmental conditions for crop growth and shorter crop cycle (10-12 months) as compared to the tropics (12-14 months).

### Sugar Industry Turning into Bio-refinery for Sugar as well as Energy Production

India is a major producer as well as consumer of sugar in the world and its annual sugar production comes to 25-26 million tonnes. Currently, 516 mills are operational with an average recovery of 10.23% (2013-14). The contribution of Indian sugar was nearly 14 per cent of the total sugar production of the world. Due to its potential as a feedstock for renewable energy, sugarcane is becoming the preferred crop not only for sugar production but also for bio-fuel, green energy and other by-products like bio-plastics, bio-polymers etc. Bio-ethanol is emerging as a preferred renewable and eco-friendly energy source. Government of India has initiated several programmes for ethanol production and its use as biofuel during the past decade. National Biofuel Mission (NBM) with its Ethanol Blending Programme (EBP) initiatives has proposed specific ethanol blending targets of 5%, 10% and 20% with automobile fuel in a phased manner. National Policy on Biofuel of the Govt of India has proposed a target for 20% blending of ethanol with the automobile fuel by 2017. At present, only 5% blending is operational. The emerging scope of sugarcane as renewable energy crop in terms of sugar, bio-ethanol, co-generation etc., is gradually becoming the guiding force to increase the sugarcane production further. Brazil has made a major stride in this direction and presently diverts approximately 50% of its sugarcane for ethanol production.

In India, molasses, a by-product of sugarcane processing will remain the main raw material for ethanol production. Bagasse, the other by-product of sugar processing, will continue to remain the basic raw material for co-generation in sugar mills. In fact, by 2050 it is visualized that every sugar mill in India may become a bio-refinery, with energy production in terms of electricity through co-generation and second generation (2G) ethanol from surplus bagasse and left over cellulosic plant material through enzymatic degradation of cellulosic material and microbe-assisted fermentation of fragmented sugars. Of course, sugar production from sugarcane juice will continue.

## Requirements for Future

According to estimates of the National Commission on Agriculture (1976) and by various agencies, the population of the country is expected to swell to 1.65 billion by 2050. It is estimated that the per capita consumption of sweetener is likely to increase up to 35 kg (28 kg white sugar and 7 kg *gur*) by 2050. At this rate of consumption and expected rise in population, the country may require nearly 51 million tonnes of white sugar by 2050. With decreasing trends in *gur* and *khandsari* production, the demand for white sugar is likely to increase. In order to meet the growing demand of sugar and energy by 2050 in India, around 630 million tonnes of sugarcane with a recovery of 11.5 per cent will be required. Of the total sugarcane produced, 70% would be crushed for white sugar, 20% for *gur* and *khandsari* and remaining 10% for seed and other purposes. This will entail an average cane productivity requirement of 105 tonnes/ha, as the area under sugarcane cultivation may not increase beyond 6.0 million hectares. It is further assumed that the additional area may come from increase in intercropping of sugarcane with other crops. Sugarbeet as an intercrop in sugarcane may also supplement sugar production and the crop is also visualized as a potential one for bioethanol production from beet juice.

## IISR, Lucknow : Research and Development

The Indian Institute of Sugarcane Research in Lucknow (Uttar Pradesh) established (by the erstwhile Indian Central Sugarcane Committee) in February 16, 1952 is dedicated for research on fundamental and applied aspects of sugar crops in India in general, and in sub-tropical part of the country in particular. The Government of India took over the administrative control of the Institute from the Indian Central Sugarcane Committee on January 1, 1954. Later on, it was transferred to the Indian Council of Agricultural Research (ICAR) on April 1, 1969. Research on sugarcane improvement was strengthened by establishment of All India Coordinated Research Project on Sugarcane in 1970, with its headquarters at IISR, to coordinate the research work going on in all the major cane growing states of the country by providing a platform for multi-location testing of technologies. With the passage of time, the Institute has undergone a thorough reorientation of its activities confirming to the shift in stakeholders' demand and the global scenario. A need was felt to have a vision and future road map to better comprehend the Indian sugar scenario by 2050, and also to be a key contributor to Indian agriculture in general and specifically to the core sugar and bio-energy sectors. This document, Vision 2050, outlines the strategies for Indian Institute of Sugarcane Research, Lucknow to become a centre of excellence in sugar crops research and development and to bring out a demand based and technology driven growth in cane agriculture in India.

From a modest beginning in 1952, the Institute has expanded considerably in terms of infrastructure and human resource development. The Institute conducts multidisciplinary research on basic, strategic and applied nature under five Divisions namely, Crop Improvement, Crop Production, Crop Protection, Agricultural Engineering and Plant Physiology & Bio-chemistry, and two Sections, namely, Agricultural Economics & Statistics and Agro-meteorology. The Institute has one Regional Centre at Motipur in Bihar with 50 acres of farm land, for breeder seed production and for varietal breeding with special reference to red rot disease and waterlogging. There is one Sugarbeet Breeding Outpost at IVRI campus, Mukteswar for seed production in sugarbeet and one Bio-control Centre at Pravaranagar in Distt. Ahmednagar (Maharashtra). The Institute has research support facilities like farm, agricultural machinery workshop, controlled growth chambers, a well stacked library, guest house, conference halls, auditorium, and staff welfare facilities for outdoor and indoor games and physical exercise. Since its inception, the Institute has been working on different aspects of sugarcane cultivation, aiming towards the upliftment of cane cultivators in India through enhanced productivity, profitability and sustainability.

## Benefits and Outcomes Accrued

In its efforts to cater to the demands of its stakeholders, IISR has made great strides in the development and fine-tuning of technologies for enhancing cane productivity and sugar recovery.

Development of agro-techniques for enhanced yield and higher returns per unit area in sugarcane-based cropping systems is an area of major emphasis in the Institute research agenda. Several improved planting techniques like nursery-cum-transplanting system, deep furrow-cum-trash vein system, etc., were developed at this Institute. For summer planting during May after wheat harvest, transplanting single-bud setts raised in polythene bags gave a better establishment of the settlings in the field, thereby leading to better yield. Double row planting system was developed for increasing population of millable canes under stress situations. Three-bud setts are currently planted end-to-end horizontally in 12-15 cm deep furrows at 30:60 cm spacing. This method gave a higher yield than conventional method.

Nursery raising for STP

**Spaced Transplanting Technique (STP)** involving nursery raising from single-bud setts followed by transplanting resulted in saving of seed cane to to the tune of 4 t/ha, i.e., approximately 70%. The technique gave a relatively higher population of millable canes, and a uniform crop stand. Moreover the seed cane : output ratio improved to 1:40 compared to that of 1:10 in conventional planting. A better yield was reported in the ratoon crop and this method was found to be suitable for late-planted conditions.

**Cane node priming** technique is another improved method recently developed. Use of primed cane nodes with organic slurry (cattle dung: cattle urine : water in the ratio 1:2:5) saves seed cane by 50% and reduces the period of germination from conventional 30-45 days to 20 days. The buds start sprouting within 5-6 days of priming. By maintaining a uniform crop stand and growth conditions, the technology ensures 25% higher sugarcane production over the conventional method.

**Ring pit method of planting** of sugarcane was also developed in which tillers are eliminated through altered crop geometry and soil manipulation. Pits of 90 cm width and 45 cm depth are made to accommodate higher seed rate and setts are placed horizontally in a circular manner. With the normal agronomic practices, an increase in cane yield up to 100% has been reported with 0.1% unit higher Pol per cent compared to conventional flat planting in sub-tropics. This is suited to drought-prone areas, undulating topography and saline-sodic soils. It also overcomes lodging problem. Approximately 9000 pits can be dug in one hectare. Cane yield up to 125 t/ha has been reported with ring-pit method of planting with an increase by 1.5-2.0 times and a benefit-cost ratio of 1.8. Irrigation water is saved up to 20-40% .

**Furrow Irrigated Raised Bed (FIRB) method of planting** was developed for timely planting of sugarcane in wheat-sugarcane cropping system. 2-3 lines of wheat are grown in the ridges and sugarcane is planted in the furrows in spring with saving in land and irrigation

FIRB system of planting in sugarcane

water. The method ensures optimum time-span for tillering in sugarcane. Compared to sequential planting of sugarcane with wheat, this enhances sugarcane yield by 30% apart from saving in irrigation water. This is suitable for late planting situations esp. in western Uttar Pradesh, where late planting of sugarcane after wheat harvest is a common practice.

**Intercropping in sugarcane** (a long duration crop) with short duration, high value and income generating crops facilitates economic security and household nutrition, especially for small and marginal cane growers. This also helps in improving productivity of winter-initiated ratoon and also promotes autumn planting. Several intercrops have been advocated in autumn planted and spring planted sugarcane and also in winter- initiated sugarcane ratoon. Sugarcane-based intercropping system with potato, wheat, mustard and short duration pulse crops have gained acceptance among the farmers, thereby adding to their economic and nutritional security. An additional income of up to one lakh rupees can be anticipated through intercropping with these crops.


Intercropping with black gram in spring planted sugarcane crop


Intercropping with potato in autumn planted sugarcane crop

**Integrated Weed Management** studies revealed the utility of cultural and mechanical methods for the control of annual weeds in sugarcane. Atrazine as pre-emergence spray @ 2.0 kg a.i./ha, followed by 2,4-D @ 1 kg a.i/ha 60 days after planting (DAP) and hoeing at 90 days after planting controlled the weeds below threshold level. Other treatments like Sulfentrazone as pre- and post-emergence application @ 1 kg a.i./ha, alone or in combination with Atrazine 2.0 kg a.i./

ha was found to be effective against nutsedges. Periodical hoeing at 30, 60 and 90 DAP or hoeing with herbicide application gave the best weed control.

**Integrated Nutrient Management** through the use of biofertilizers and other inorganic fertilizers has been found to sustain the soil fertility status and to increase crop productivity. Integrated use of chemical fertilizers with crop residues, sugar mill wastes like filter cake, effluents, organic manures, green manures and bio-fertilizers is more beneficial than organic fertilizers alone. Apart from the recommended dose of organic fertilizers, application of sulphitation press mud (SPM) along with *Gluconacetobacter diazotrophicus* in plant ratoon system was found to be beneficial. SPM @ 46 t/ha was found to increase cane yield in excessively saline and alkaline soils. Use of sugarcane trash @ 3.5 t/ha as mulch for sequestration of carbon in soil has also been recommended. Nutrient management for organic sugarcane cultivation under different crop rotations gave profitable cane yield with SPM or FYM @ 20 t/ha. Studies on correction of nutrient deficiencies revealed that amelioration of lime- induced iron chlorosis could be achieved by spraying Mn @ 1 kg/ha. Critical limits of bulk density of soil for sugarcane growth were also identified. Soil bulk density in the range of 1.51-1.54 g/cm$^3$ for clay loamy soils and that in the range of 1.53-1.55 g/cm$^3$ for alluvial soils was found to be the critical levels for optimum sugarcane growth.

Many improved sugarcane varieties were developed by this Institute and released for commercial cultivation in the different sugarcane growing regions.

CoLk 8001

CoLk 8102

**CoLk 8001,** a mid-late maturing variety identified in 1988 for commercial cultivation in north western zone of the country, has a yield potential of 90-100 t/ha under good crop management conditions, with 18.45% sucrose. This variety was good for jaggery making. The variety was moderately resistant to red rot and smut and has been evaluated as drought and waterlogging tolerant. **CoLk 8102** is another mid-late variety which was identified in 1989 for commercial cultivation in north-western zone. This has a cane yield potential of 80-85 t/ha with a sucrose content of 18%. It is highly resistant to smut and moderately resistant to red rot and has excellent ratooning ability. Due to its high fibre content (~14 %) the variety is less prone to biotic stresses and helps in better bagasse and power generation per tonne of cane crushed.

CoLk 94184

**CoLk 94184 (Birendra)** is an early maturing variety which was identified in 2007 and released in 2008 for commercial cultivation in north central zone. This has excellent ratooning ability, a rare feature for an early maturing variety and also combines the traits of waterlogging and drought tolerance. The variety also possesses moderate resistance to red rot and smut diseases. This variety has a yield potential of 75-80 t/ha with 18% sucrose content. This variety is spreading fast (approximately 25,000 ha) in eastern U.P. and Bihar.

**CoLk 07201,** an early maturing variety, was identified in 2013 for commercial cultivation in north western zone. It has excellent ratoonability and possesses red rot resistance. It has a potential cane yield of 75-80 t/ha with commercial cane sugar of 8.72 t/ha. **CoLk 9709** another early maturing variety was released by U.P State for commercial cultivation in entire Uttar Pradesh. The variety is moderately resistant to red rot and is a good ratooner. It gives a cane yield of 70-75 t/ha.


**Disease and insect-pest management in sugarcane** through integrated approaches has been another important area of research at this Institute. Several strategies were developed and refined for managing important diseases and insect pests in this crop. **Moist Hot Air Treatment Unit** was developed to eliminate seed transmissible pathogens as a part of three-tier seed production programme. It is a landmark achievement of this Institute in the area of disease management. The nucleus or breeder seed canes are subjected to moist hot air treatment (MHAT) at 54°C and 95-99% RH for two and a half hours.

A **three-tier seed programme** was developed by the Institute for production of healthy seed and its regular supply to the farmers. It consisted of three tiers *viz*., production of Breeder Seed (after heat therapy of Nucleus Seed), production of Foundation Seed and production of Certified Seed or field labelled seed which is finally distributed to growers. **Identification of pathotypes of red rot pathogen** was carried out based on 13 differentials. CF11 was reported by IISR as a new pathotype in sub-tropical India. **An inoculator for inoculation of red rot pathogen** was developed for screening sugarcane varieties against red rot resistance. Work on other sugarcane diseases like smut was also undertaken at the Institute for their management and control. **A staining technique was developed for early detection of smut fungus** within 4 hours inside the meristem of buds and shoot apices. **PCR-based diagnostic kits** were developed for detection of dormant infection of red rot and smut pathogens which is useful in healthy seed production. Studies in endemic areas have shown that **even 2% infected setts can cause epidemic of red rot**. **Population dynamics and management of nematodes** in sugarcane was carried out. Studies on nematodes led to the finding that crop rotation of sugarcane with maize-marigold and paddy-mustard or a combination of these in sugarcane-based cropping system reduced the nematode population. Wilt incidence was found to be aggravated with the multiplication of nematodes in the soil system. For the first time, a leaf hopper (*Deltocephalus vulgaris*) was established as **an insect-vector for transmitting phytoplasma of Grassy Shoot Disease**.

Insect pest management studies in sugarcane have led to the development of management strategies for important sugarcane pests. A **methodology for estimation of stalk borer infestation** on a large scale without destructive sampling was developed. The relationship between superficial infestation level index (% incidence) and joint infestation was worked out to be :

$Y = 0.038\ X^{(1.325)}$, where Y = % intensity and X = % incidence.

**Economic injury level due to top borer** in sub-tropical India was identified. An infestation of 6.48 % in 3rd brood was determined as the economic injury level in spring planted cane. A single factor equation for determining *Pyrilla* population was developed as follows:

$$Y=((E_w - a) + (N_i + mp))\ (k - (k_1 - k_2))$$

where Y= number of adults, Ew is the over wintering eggs, a is the rate of hatching, $N_i$ is the number of nymphs, mp is the nymph mortality owing to low temperature, K is the time of appearance of adults during next season, $k_1$ is the development period of eggs and $k_2$ is the development period of nymphs. Studies on **management of rodents** revealed that rodent infestation can be determined by the degree of rodent burrowing in the respective areas. Chemical control of rodents in this crop by zinc phopshide baiting (2%) followed by bromadiolone baiting was standardized.


IISR-Combo Trap

**IPM schedule including biocontrol** through introduction, inundative release and conservation of parasitoids and predators of pests for borer complex, *Pyrilla*, woolly aphid etc., was developed. **Use of Trichocards** and release of the larval parasitoid of *Cotesia* against borer complex. Release of an egg parasitoid *Trichogramma chilonis* @ 50,000/ha at 10 days interval from July to October has been reported to give 40-90% reduction in incidence of borers. Release of *Dipha aphidivora* @ 1000 larvae/ha or *Micromus igorotus* @ 2000 larvae/ha at 15 days interval (August to October) gave effective control of woolly aphid. Remarkable success was achieved in controlling the pest in Maharashtra and adjoining areas of western UP and Uttarakhand during outbreak of this pest in 2002. **Bio-control of *Pyrilla*** through conservation and redistribution of *Epiricania melanoleuca* @ 4000-5000 cocoons/ha was successfully put to use to manage the outbreak of *Pyrilla* in the states of Uttar Pradesh, Maharashtra and Andhra Pradesh. **Management of white grub and borers** using IISR-Combo trap – an eco-friendly trap combining light (battery/ solar powered) and pheromone was successfully demonstrated in about 200 villages, in the sugar mill command areas in Uttar Pradesh and Maharashtra. The technology has been commercialized and the license for large scale manufacturing of the trap has been given to M/S Fine Traps Ltd., Maharashtra.

**Post-harvest management to reduce sucrose losses** in sugar mills through use of anti-bacterial and anti-inversion chemicals is another achievement of this Institute. Spraying a formulation of benzalkonium chloride 2000 ppm and sodium metasilicate 2 % over freshly harvested cane, followed by covering with a thick layer of trash effectively reduced post harvest sugar losses. An improvement in sugar recovery by over 0.5 units has been observed through this strategy.

Sugarcane being a highly labour-intensive crop, requires about 250-400 man days per hectare. Human labour constitutes more than 50%

Sett cutting machine

Bullock-drawn sugarcane planter

of the labour requirement. This Institute has made its presence felt in the area of **mechanization for sugarcane cultivation** through design, development and commercialization of several machinery *viz*., sugarcane cutter planter, paired-row sugarcane planter, Raised Bed Seeder (RBS), Ratoon Management Device (RMD), Trench maker, Trench planter, Ratoon promoter, Plant residue shredder, Sugarcane detrasher etc.

One hundred and fourteen of these machines were supplied to several organizations/sugar mills/farmers in 11 states. **A tractor operated sugarcane harvester** to suit the small and marginal farmers is being developed and tested by the Institute since harvesting consumes almost 25 % of the manual labour requirement in this crop. The use of these machinery has resulted in saving of ~ 60% of the cost of cultivation through saving of labour, besides ensuring timely operations.

Paired-row Sugarcane Cutter-Planter

Sugarcane-cum-Potato Planter

Raised Bed Seeder for FIRB



Ratoon Management Device

Sugarcane harvester

**Production of hygienic chemical-free jaggery** is another priority area of research at the Institute. A few value-added products like cane-syrup, jaggery powder and vinegar have been made.

Triple Pan Furnace for jaggery making

Moulding of jaggery

**Use of Information and Communication Technology (ICT) in sugarcane agriculture** was initiated at the Institute through CaneDES, an expert system to diagnose disorders in sugarcane caused by various biotic and abiotic stresses. Sugar mills and other stakeholders can take advantage of this system.

As the sole ICAR Institute working on sugarbeet, the Institute has been carrying out research on different aspects of sugarbeet improvement, production and management from late 50s. A well planned breeding programme along with seed production of elite sugarbeet varieties is going on at the Sugarbeet Breeding Outpost at IVRI Campus, Mukteswar for more than three decades. **Two varieties of sugarbeet were released from the Institute.** IISR Comp-1 is an open pollinated diploid variety developed from four diploid exotic parents. This is a multi-germ variety and self fertile, with good germination in normal as well as cold climate. It has good root yield (71.42 t/ha) and gross sugar

IISR Comp-1


LS-6

(11.29 t/ha). LS-6, a multigerm variety is tolerant to high temperature and is suitable for sub-tropical and tropical agro-climates. It is a high yielder (70 t/ha) and has moderate sugar (gross sugar 11.84 t/ha). The variety has less incidence of *Sclerotium* root rot. Plant protection studies showed an effective control of root rot of mature sugarbeet by the application of Brassicol @ 15-20 kg/ha as soil drench. *Trichoderma harzianum* was successfully used to control *Sclerotium* rot in this crop. Pelleting of sugarbeet with a mixture of methyl cellulose (0.1%) and bentonite clay supplemented with fungicide gave a good control of seedling mortality. IISR has also standardized suitable agro-techniques for cultivation of tropicalized sugarbeet. Varieties Shubhra and LS-6, have been identified for tropical Indian conditions.

The Institute has been in the fore-front in the application of modern tools like molecular techniques, to supplement the conventional methods of crop improvement and management. **DNA fingerprinting profiles of important sugarcane clones** including *S. spontaneum* clones have been developed using different marker systems. This Institute has demonstrated for the first time, the utility of **novel molecular markers systems like SSCP-SSR from genomic and EST sequences and CISP markers** for varietal finger printing and diversity analysis in this crop. SSCP of SSR markers - both genomic and EST derived - is based on the differential conformation of single strands of DNA due to difference in nucleotide bases. The markers system was used successfully for genetic diversity analysis and fidelity testing in micropropagated plants. Comparative analysis of publicly available expressed sequence data of sugarcane, sorghum and barley along with whole genome sequence survey in rice gave a set of conserved intron sequences, for which primers were developed. These have been successfully used in sugarcane for diversity studies. **QTL mapping** for important traits like red rot resistance and sugar content are also undertaken, with putative markers for NMC and sugar content identified through association mapping. Expression studies have ascertained the role of soluble acid invertase (SAI) in post harvest deterioration in sugarcane.

**A first-time Indian resource of sugarcane ESTs** was generated in the form of general cDNA libraries for different tissues of sugarcane variety CoS 767. A collection of 26,453 tissue-specific ESTs of which about 1069 are specific to red rot, was developed and deposited in the GenBank. These are being utilized for red rot resistance specific marker development. Subtractive libraries from stressed and non-stressed plants of designated varieties (Co 1148 for drought and red rot resistance and CoS 8118 for waterlogging tolerance) were constructed against drought, waterlogging and red rot. **Micropropagation and quality seed production** of improved sugarcane varieties is being undertaken. The tissue culture laboratory here has been identified as **an accredited laboratory for certification of *in vitro* plantlets** produced by certified laboratories.

To meet the projected requirement, the productivity of sugarcane needs to be enhanced to around 105 tonnes per ha and about 1.0 million ha additional area has to be brought under sugarcane, besides drastically reducing the post-harvest losses. With changes in global sugar scenario in favour of sugarcane due to implementation of WTO, India has to play a far greater role as a self sufficient sugar producing country for ensuring the stability in sugar production and prices. There is also a need for conserving and better utilization of the available natural resources, ensuring high net returns to farmers, lowering the cost of production though mechanization, value addition and better post-harvest management, with an eye on export.

By 2050, the Institute looks forward to achieve its Vision of '**Developing efficient, globally competitive and vibrant sugarcane agriculture"** to meet future sugar and energy requirement of India through technological interventions for enhancement of production, productivity, profitability and sustainability of sugarcane and sugar crops. ❑

# Challenges

With its present level of sugarcane and sugar production in the country, we may boast of self sufficiency in meeting the internal demands of sugar and other sweeteners. Even then we have to face a large number of challenges in the years to come, to meet the future demands for food, fuel and energy. With an ever increasing population, there is immense pressure on the available natural resources like land and water. Challenges ahead for meeting food demands are formidable considering the non-availability of favourable factors of growth, fast declining factor productivity in major cropping systems and rapidly shrinking resource base. There is a need for a second green revolution with an emphasis to produce more without further depletion of natural resources. Therefore, there is a necessity to develop new methods, technologies and know-how for improved varieties, better soil and water management practices, improved cropping systems and better crop management. The area that needs immediate attention in sugar cane farming is the management of water, which is going to be probably the most scarce factor in the twenty-first century. The irrigation efficiency estimated at around 30% needs to be raised to at least 50%. This could contribute significantly in increasing sugarcane production. Resource conservation technologies that improve input use efficiency, and conserve and protect our natural resources need to be promoted aggressively. Climate change has emerged as a major challenge to agriculture in general. The immediate problems that our farmers face relate to intra-seasonal variability of rainfall, extreme events and unseasonal rains. These aberrations cause heavy losses to sugarcane production every year and generate cyclic movements in sugar prices. Therefore, there is an urgent need to speed up our efforts to evolve climate-resilient crop varieties, cropping patterns and management practices.

It is imperative to understand the strengths and weaknesses in the sugarcane production and utilization systems, so that available resources can be judiciously utilized for enhanced sugarcane production. The scenario as outlined envisages a stiff target and needs improvement in all fronts to achieve the desired level, to serve the national interest *per se*.

The acreage under sugarcane from 1980-81 (2.70 million ha) to 2014-15 (5.10 million ha) has increased at an average compound growth rate of 2.15 per cent per annum. There is hardly any possibility of additional area forthcoming under sugarcane, primarily due to decreasing availability of arable land. Sugarcane is also facing stiff competition from food grains, oilseeds, pulses and other high value crops including vegetables in the share of area due to continuous rise in their prices. In view of these, it may not be possible to maintain the same growth rate of area and it will stabilise around 6.0 million hectares by 2050. It is further assumed that additional area will be available from intercropping of other crops in a sugarcane based cropping system. Thus the production target of sugarcane has to be met mainly by increasing the productivity and quality of the crop. The productivity of cane from1980-81 to 2014-15 has increased at an average compound growth rate of 1.07 per cent per annum. The average productivity level needs tremendous boost and it should be around 105 tonnes/ha mark by 2050. To meet the targeted white sugar requirement, average drawal of cane to sugar mills for sugar production has to be increased to at least 70 per cent.

The liberalisation in overall industrial scenario has resulted in more number of sugar mills and consequently, in an increasing demand for more cane. However, due to area limitations, many new processing units have come up in zones having sub-optimal potential for sugarcane. This demands a careful consideration in relation to cane productivity and quality, its production and availability for sugar processing.

#### Limited Water Resources

The irrigation potential of the country is estimated to be 113 million ha of which only 50 per cent is under actual use. The water requirement of sugarcane is very high and it accounts for nearly 30 per cent of the of cane production cost. At present, nearly 80 to 85 per cent of area under sugarcane is supposed to be irrigated, though only 34.6 per cent of the area has assured irrigation. The crop is grown under limited irrigation in the remaining 65.4 per cent of the area. It is estimated that nearly 43 per cent of the cane production comes from about 29 per cent of the area which is irrigated, whereas the rest 57 per cent of the production is obtained from 71 per cent area which is largely under limited irrigation facilities. This calls for development of efficient surface and sub-surface water saving technologies for sugarcane crop.

#### Limited Utilization of Available Germplasm

Despite the fact that India has rich diversity with respect to sugarcane germplasm we are still to tap this vast potential to our advantage. Limited utilisation of basic germplasm (at the species level) in India has, over the years, narrowed down the genetic base of the commercial cane varieties and the plateauing effect has become apparent in terms of sugar recovery and cane productivity. It is imperative to tap the huge available genetic potential to break both recovery and yield barriers.

Varietal spectrum of sugarcane varies from state to state and from region to region depending on the location specific suitability of a particular variety. In the past, many excellent varieties were developed and ruled the sugar industry. These were gradually phased out due to various factors like varietal decline, susceptibility to biotic and abiotic stresses etc. Sustaining sugar productivity at the existing level necessitates quick replacement of the old and denotified varieties. Even if suitable replacement is available, considerable time elapses before it covers sizeable area, primarily on account of limited availability of quality seed, due to slow rate of seed multiplication in sugarcane and also due to lack of an organized quality seed production and replacement system in this crop.

## Sustainability of Sugarcane-based Cropping Systems

The issue of sustainability is foremost in the present scenario and it is very closely linked with the maintenance of productivity potential and soil health. Being a long duration crop, with large canopy, sugarcane is a heavy feeder of N, P and K. Hence, the growing demands of nutrient sources are likely to make the mineral nutrient cost prohibitive in future. Introduction of practices like Integrated Nutrient Management (INM) with synergistic use of green manures, organics and bio-fertilizers, along with judicious blend of minerals in the sugarcane production programme needs to be encouraged. Essential production inputs like fertilizers and irrigation always remained the major constraints for any profitable venture of sugarcane farming and thus, always hindered a steady supply of cane to the mills. In spite of release of disease resistant and pest tolerant varieties, sporadic attacks of pests and diseases always impair the yield and quality of cane. These constraints, coupled with limitations imposed by climatic factors like exposure of the crop to extremes of temperatures that limits the growth phase, lower the average productivity of cane in the subtropical north zone and thus, subtropical cane varieties remained more climate resilient than the tropical cane varieties. Agronomic practices such as planting geometry, fertilizer placement, irrigation scheduling, and cultural operations that sustain a higher shoot population might break the present yield ceiling and bring another revolution in productivity. To sustain high-population shoot density, tiller mortality has to be curbed. Through hormonal treatment and adjustment in planting geometry, tillers are forced to initiate rooting soon after emergence. This method prevents the tillers from remaining dependent on the mother-shoot for growth resources and increases their survival rate.

### Biosecurity

An important challenge in agriculture is ensuring biodiversity which has a direct relevance to sustainability in agriculture and providing crop insurance to growers. Ensuring biosecurity in sugarcane agriculture should cover protection against large scale incidence of diseases and insect pests, long duration drought or waterlogging, introduction of GMOs, etc. In a larger context, biosecurity takes into consideration the security with respect to the crop biodiversity as well as parasites and predators of insect pests.

Development of climate-resilient varieties would be imperative to overcome the adversities of nature. Moreover, crop diversification through intercropping of short duration crops in sugarcane can reduce the monetary loss of growers. Another risk lies with monoculture of single variety. For this purpose at least 4 to 5 varieties need to be developed for a location or zone. To ward off the population of natural enemies of insect-pests, bio-intensive measures have to be developed.

### Mechanization of Sugarcane Agriculture

Manual labour is an important input factor in sugarcane production constituting around 50% of the operational cost of production. The participation of human labour is seen right from preparatory cultivation to harvesting. Being a long-duration crop of 12 months and its planting spreading from October to May, sugarcane is a labour intensive crop, which requires about 250 to 400 man-days labour per ha. Most of the operations are carried out manually and mechanization is mostly limited to field preparation prior to planting. To mitigate the labour scarcity and to ensure timely farm operations along with the reduction in human drudgery, mechanization of cane agriculture from planting to harvesting and loading is necessary. Harvesting consumes maximum labour for which a small capacity sugarcane harvester suitable for Indian condition is the need of the day. Mechanisation of different operations will also improve the overall energy use efficiency of the sugarcane-based farming. However, the size of the farm is very less in India compared to that in other main sugarcane producing countries, and it forms a formidable challenge to mechanization of the sugarcane agriculture.

Being a long duration crop, sugarcane is affected by a wide spectrum of weeds, insect-pests and diseases at various stages of its growth. The pest (weeds, diseases and insects) management programme has primarily been dependent on the chemical formulations with limited use of bio-control measures. Due to the small size of the holdings, cereals are the first preference of an average Indian farmer, and these crops compete with sugarcane for the same land. Also, being a round-the-year crop, sugarcane has to adjust in the rhythm of wheat and rice crops. The increased demand for pulses and oil seeds also has opened up an opportunity for intercropping/crop rotation of these crops in sugarcane-based cropping system.

Keeping in view the cane productivity and recovery patterns during the last 25 years, the target set for 2050, though a stiffer one, demands proper planning and judicious use of the available resources to achieve it. Intensive research efforts are therefore, required to bring about this change in both cane quality and productivity at national level, especially in the subtropics. India has to gear up to the new challenges of higher cane and sugar production to meet the future requirement. With the present trend of sugarcane and sugar production, India will hardly be able to meet 75 per cent of the projected requirement. Therefore, a sustained effort is needed to increase the present trend of cane production to such a level that India becomes a sugarcane/sugar surplus country.

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# Operating Environment

Sugarcane is the main source of sugar in India and the crop has a significant contribution towards the national economy. Being an important agro-based industry, it has a substantial role in the socio-economic development of the rural population in the country. This is apart from the large proportion of workers who are employed in the ancillary units/industries like jaggery, paper, alcohol etc. Besides providing direct employment to approximately 7.5% of the rural population of the country, the sugar industry undertakes various developmental schemes to create infrastructure and socio-economic overhead, thereby playing a vital role in employment generation. The sugar sector as a whole contributes significantly to export earnings, excise revenue etc. , besides supplementing energy generation, reducing pollution through facilitating use of clean/green energy, carbon sequestration etc. The sector also serves as a major source of food, nutritional as well as economic security. The Indian sugar industry through its vast network of sugarcane growers, sugar mills and other infrastructure has been self-sufficient in meeting the huge demand of sugar arising within the country.

Sugarcane is cultivated in around 26 million ha in the world with Brazil, India, China Thailand, Australia, USA, Mexico, Indonesia etc., being the major sugar producers. The global sugar production comes to approximately 177 million tonnes with about 25% of the sugar being produced from sugarbeet. The demand for sugar at the global level is expected to be around 255 million tonnes by 2050. There is a shift in the dynamics of sugar production across the world with sugar production declining in some of the traditional sugar producing countries like Mauritius and Fiji and new sugar industries coming up in the non-traditional sugar producing regions like African countries. Countries like Brazil are moving towards a massive expansion in cane area with a targeted increase in sugar production. Thus the global sugar production is poised to increase and with countries like Brazil increasing their sugar production, the cost of the sugar produced will be low. Thus India, with its high cost of production, will have to face stiff competition with respect to sugar prices at an international level. Thus meeting our rising domestic demand will be the primary concern for India. With the demand for green energy steadily increasing, production of ethanol is bound to go up. Cost-effective production technology for ligno-cellulosic ethanol production is an area that is of great interest. Thus in future, the production and utilization of cane for different uses *viz.* sugar, ethanol, electricity etc., will depend on several factors like demand for the products, the pricing policy etc.

Sugarcane occupies a very prominent position on the agricultural map of India covering large areas in sub-tropics and tropics. The cane productivity and sugar recovery has been static during the past decades (Fig.1). Based on the existing levels of sugarcane availability and sugar recovery, the tropical and sub-tropical belts have the potential to produce around 16 million tonnes and 12 million tonnes of white sugar, respectively every sugar season. Even with reported record yields of 220 t/ha in sub-tropics and 280 t/ha in the tropics, the average national productivity and recovery is not up to the mark. The high yielding high sugar varieties and the improved technologies developed have not been able to bring about the desired improvement in cane productivity and sugar recovery. The wide gap which exists between the cane productivity and sugar recovery in the tropics and that in sub-tropics is a matter of great concern. Several factors contribute towards the low yield and recovery in the sub-tropical zone.

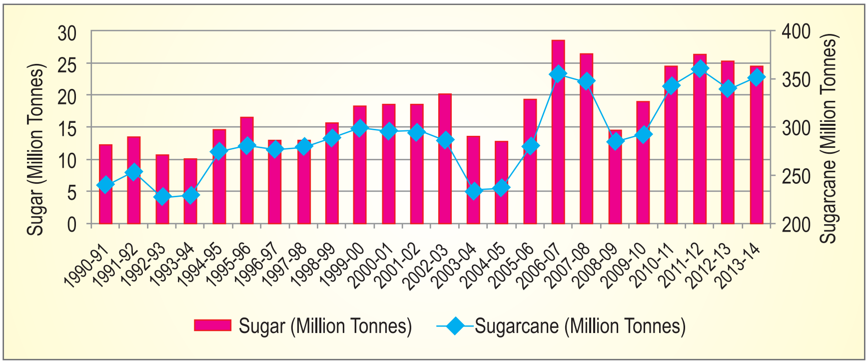


**Fig. 1** Production of sugarcane and sugar in India from 1990-91 to 2013-14

Healthy seed forms the most important component for a good crop and thereby, for a high yield and sugar recovery. In the present set up there is not much of an organized practice of proper distribution and replacement of healthy seed material. Proper varietal replacement practices are also not in place to ensure that healthy seeds of recommended varieties are being used by the farmers. Declining soil health is another factor with the soils having an organic carbon content less than 0.3% in many areas. Deficiency in micronutrients like Cu and Zn is also prevalent in many soils. Green manuring is almost negligible. Taking continuous crops of sugarcane also contributes to soil health deterioration, thereby bringing down the productivity.

Sugarcane cultivation in the sub-tropical zone is characterized by a comparatively shorter grand growth period compared to that available in sub-tropical zone. This results in availability of less time for growth and sugar accumulation which may result in low recovery. Low temperature during the period of December- January results in poor sprouting of ratoons and autumn planted crop under the low temperature conditions. This is bound to have an effect on the crop stand and growth, ultimately leading to low productivity and recovery. Frequent climatic aberrations due to western disturbances, esp. in the sub-tropical region is an important reason contributing to low sugar recovery. Changes in mean minimum temperature, relative humidity, frosty conditions etc., during ripening and crushing period also leads to low sugar recovery. Sugarcane being a long duration crop, is subjected to extremes of temperature in the sub-tropical region. In summers the temperatures may rise up to $45^{o}$ C, while the winter temperatures may fall as low as $5^{o}$C or below. These extremes will invariably have an effect on the cane productivity and sugar recovery. These issues need to be addressed for productivity and recovery enhancement.

Insect-pests form a major cause of yield and recovery losses in sugarcane. Infestation of sugarcane crop by borers, *Pyrilla*, white grubs etc., has been reported during different period. On an average 15-20% losses have been estimated due to insects. Change in insect dynamics due to climatic aberrations is also a cause of concern. Delayed monsoon rains and prevailing high temperature have resulted in changes in incidence/ appearance of disease and pests. Diseases like red rot and GSD are other problems leading to reduced cane productivity. Increasing incidence of GSD in most of the cane growing areas is causing concern. An integrated approach including biological control strategies is needed for managing these biotic stresses. Area-specific abiotic stresses like water logging, drought, non-availability of irrigation, salinity etc., have major impact on cane productivity and sugar recovery in many areas.

Post-harvest loss due to cut-to-crush delay is one of the major factors contributing to low sugar recovery levels in sub-tropical India. In the prevailing supply system of canes to the mills, there is invariably a cut-to-crush delay of 3-5 days, which aggravate the deterioration process in post-harvest canes due to inversion, formation of acids and alcohol polysaccharides etc., leading to microbial deterioration. Even in well-managed sugar mills, this time lag between harvest and crushing leads to substantial sugar losses. In general, for a decline of every 48 hours, there is a decline of sugar by 1%. Approximately 25 kg of sugar per million tonne of cane is estimated to be lost due to this delay during summer seasons. These losses need to be reduced.

The cyclicality of production has been the bane of Indian sugar sector. The peak of sugar production achieved in the country was 28.2 million tonnes, during 2006-07, the graph has not been uni-directional and steady and there have been wide swings. Due to raw material shortage, sugar mills in subtropical belt generally work for not more than 100-130 days. The industry, therefore, has been working below capacity, a handicap which adds to the production costs. In the process, in the years of surplus production, there is a glut leading to crash in domestic prices, as the higher cost structure generally makes Indian exports non-competitive. The payment to the farmers therefore gets affected. There is also a possibility of diversion to other more remunerative crops by the cane growers.

There also exists the unorganised sector - the *gur* and *khandsari* manufacturing units in the country and this sector draws a significant part of sugarcane for making of *gur* resulting in the reduction of its availability to the sugar mills. In tropical belt, about 80 per cent of cane produced by growers is supplied to sugar factories and the rest is consumed for other purposes. On the other hand, in subtropical region, only a half of the cane goes to sugar factories. About 70 per cent of sugarcane produced in the country is utilised for production of sugar and the remaining is left free from price control regulations. It has been estimated that the share of Indian *Gur* and *khandsari* production at about 6 million tonnes annually is 50-55% of the world production of similar products. About 60% of Indian production of *gur* and *khandsari* is in Uttar Pradesh followed by 11% in Maharashtra. Being in the unorganised sector, the Government has little control over the *gur* and *khandsari* units and the prices of cane offered by them to the cane growers.

Sugarcane is a multi-product crop and has immense potential for diversification. Liberalization of sugar policy has attracted more private players in sugar production and this has provided the needed impetus to increase the capacity of existing sugar mills and also to commission new sugarcane mills. It is expected that the new sugar factories will be able to meet the future challenges in the production of sugar, power and ethanol. The enormous fuel potential of sugarcane bagasse is being utilized by both sugar mills and *gur* and *khandsari* processing units. Sugar sector at present contributes nearly 255 MW to the power sector through co-generation against an estimated potential of 5500 MW. With an increase in cane supply by 2050, there is likelihood that cogeneration potential will also increase. The ethanol requirement by 2050 at an already achieved 20% blending will be around 10 billion litres, anticipating a 500% increase in demand. Molasses, a by-product of sugar processing is also used as a cattle feed. The filter mud, another by-product is utilized as manure. The green top of sugarcane is a good fodder for milch cattle thus supporting the vital dairy sector of the country also. Bagasse is an ideal raw material for paper industry and approximately 20% of the paper production in India comes from bagasse as the raw material.

Thus sugarcane is an ideal source for sugar, energy, bio-fuel and fibre requirement in India and its production and productivity needs to be improved substantially. Improved varieties for sugar and cane yield as well as developing energy canes with high biomass are the need of the hour. Utilization of marginal and wastelands for energy canes should be taken up. Supplementing sugar and ethanol production through sugarbeet cultivation is another possibility.

## Research/Technology Development Scenario

The country is endowed with an effective Research and Development network to adequately cater to the needs of sugarcane growers and sugar industry in the country. India has two central research institutes fully devoted to sugarcane improvement and cultivation and one institute for sugarcane processing. Besides, every sugarcane growing state has its own research and development wing. In the non-governmental sector, two institutes are also in operation meeting the immediate need of associated farmers and sugar mills. The All India Coordinated Research Project on Sugarcane provides platform for multi-location testing of sugarcane varieties and technologies developed by the different research Institutes/SAUs.

The development of improved varieties with higher yield, stress resistance, nutrient use efficiency etc., needs to go hand-in-hand with modern technologies like genomics and proteomics. With a strong quality seed production programme incorporating seed treatment and use of *in vitro* disease-free seed production strategies, substantial improvement in the productivity can be realized. Crop improvement programmes need to make use of conventional as well as cutting edge technologies to develop high yielding, high sugar, stress resistant/tolerant varieties which can meet the location-specific demands. With the changing climatic situations, development of climate resilient varieties needs to be taken up. For production of ethanol from cellulosic material, varieties with greater biomass may have to be developed.

Genetic base broadening through gene introgression from wild relatives, pre-breeding programme etc., should go hand-in-hand with the varietal development *per se* . Genome sequencing information from sugarcane and other related crops like *Sorghum* needs to be put to use for favourably manipulating the various metabolic pathways to enhance the productivity and stress tolerance to the desired level. Transformation studies, molecular marker applications and functional genomics should also complement the conventional improvement programmes. The concept of sugarcane as a bio-factory for *in vitro* production of various bio-molecules and industrial enzymes with targeted storage needs to be put to use for large scale production of these bio-molecules. These cutting-edge technologies assume great significance in this crop which is a polyploid with a complex genome, with the conventional techniques having limited application for productivity improvement.

Bio-intensive precision agriculture with location specific manipulation of the sugarcane-based cropping systems like site specific fertilizer application, precision planting techniques using improved planting material and application of nanotechnology have great potential in improving the productivity in this crop. Mechanization of sugarcane agriculture with machinery to suit the need of small/marginal farmers is another priority area.The industry is gradually moving towards use of Information and Communications Technology (ICT) for production management as well as Management Information System to facilitate continuous exchange of information regarding planting, supply schedules and cane payment, and also to bring efficiency in the supply chain management. Comprehensive databases, user-friendly decision support systems etc., are being used by the industry.

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# Opportunities

There is a huge scope for diversification into value added streams like cogeneration, ethanol, industrial and potable alcohol and animal feed. An excellent opportunity exists for promoting the adoption of ethanol for meeting the domestic fuel requirements. In addition, there exists huge operational capacitiy in existing as well as in new upcoming sugar mills. A comparison with the leading world sugar producer Brazil highlights that while Brazil produces around 500 – 550 million tonnes of sugarcane from 6.5-7.0 million hectare of land resources, India produces only 330-360 million tonnes of sugarcane from the committed land resources of around 4.5 -5.0 million hectares. India's productivity is 68-70 tonnes per hectare while Brazilian average is 80 tonnes per hectare. India's sugar recovery is around 10.50% while the average in Brazil is around 13%. Without any further capital investment in the industrial capacities, with the single step of making available sufficient sugarcane by twin strategy of yield enhancements and sugar recovery enhancement, the country can become the world leader in a minimum possible time. There are possibilities of achieving an average productivity of 105 tonnes/ha. and average sugar recovery of 11.5% to meet the anticipated 51 million tonnes of sugar requirement in 2050. Production of second generation ethanol for partial replacement of fossil fuel and use of surplus bagasse in co-generation of electricity has greater potential in future. This in turn will lead to an increased demand of cane, and sugar mills will come forward in a big way to boost cane production to reap this opportunity. This will give rise to a new type of research demand to support enhanced ethanol production. Hence, there exists great scope for R&D interventions in sugarcane to shift the production frontiers upwards.

Despite the availability of an excellent genetic diversity in the germplasm collection, its utilization for commercial breeding has been lagging behind. Out of 2070 clones available at species level, hardly 50 have been utilised in the breeding programme. Further, out of 764 *S. officinarum* (noble cane, the main contributor of genes for sugar) clones available at SBI, hardly 100 accessions flower in nature, and out of which only about 23 have been utilised in breeding programmes, so far. The existing genetic diversity need to be utilized for genetic base broadening leading to development of improved varieties for commercial cultivation.

The clonal propagation in sugarcane is advantageous on one hand for maintenance of purity of sugarcane varieties and on the other hand, it has inherent weakness of accumulation of cryptic pathogens and pests over time, which severely impairs the productivity potential of a genotype. A special *Maintenance Garden* is essential to understand and realize the exact potential of a cane genotype. Research on cryo-preservation of vegetative buds may also be taken up in order to cope with any environmental hazard. Tissue culture/meristem culture may provide some opportunity in removing the cryptic pathogens.

Sugarcane in the prevailing cropping system is one of the most important crops that has sustaining capacity to maintain soil health and crop productivity. Despite being a heavy feeder of soil nutrients, sugarcane with its greater root mass improves soil health. Beneficial associations of microorganisms with sugarcane roots also help in this direction. Association of beneficial microorganisms like *Acetobacter* (for N fixation, growth promotion), *Mycorrhiza* (P solubilization and increased nutrient availability) etc.,helps in sustaining the soil fertility and reduces the dependence on chemical fertilizers.

Also, breakthrough in one area of science opens up doors to the other areas for expanding their horizons. Agriculture is the melting pot of diverse technologies providing requisite impetus and contribution to meet the increasing need of food production along with the reduction of human drudgery in a cleaner environment. It is perceived that there will be endless opportunities with development in different fields of Science & Technology with much scope to harness their benefits in sugarcane agriculture. A few are highlighted below:

- Energy cane is the need of tomorrow. High bio-mass varieties with medium content of sugar could be tolerant to both abiotic and biotic stresses and may also be climate resilient to withstand the impending climate change scenario.
- Nanotechnology will come in a big way in sugarcane agriculture and processing. The use of this technology will increase the durability and effectiveness of agricultural chemicals and those used in the sugar mills.
- Genomics, phenomics and biotechnology may assume greater role in plant breeding. It will help to tailor varieties for very specific environments and locations. It may open up new opportunities for bio-production of different organic molecules in addition to sugar or total conversion of related organic products.
- Utilization of Geo-Information System (GIS) will aid in proper documentation of data, diagnosis of pests and pathogen problems,

assessment of ground water, etc. and it will help us to devise location specific solutions and their timely application for sustainable high sugarcane productivity.

- The information technology has gained momentum and has reached new heights in a very short period. Quick transfer of information has become a reality. Transfer of unambiguous and unadulterated knowledge based information to the end users (farmers) is most important for efficient and timely intervention in decision-making processes of agriculture. Farmers, researchers, policy planners and millers would share the same desk taking sugarcane agriculture to new heights.

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# Goals and Approaches

To achieve the desired growth in area, productivity and recovery of sugarcane in different agro-ecological zones of the country and to disseminate information and technologies to the end users, the following four key issues have been identified which need to be pursued.

- Decline in factor productivity
- High cost of cane cultivation
- Lower sucrose content in cane
- Lesser adoption of agricultural machinery

The issues will be addressed by

*Arresting decline in factor productivity*

a. Introgression of high cane yield contributing untapped genes in the parental gene pool
b. Enhancing selection efficiency through marker assisted selection (MAS)
c. Enhancing soil fertility and cane productivity with organic sources
d. Carbon sequestering through cropping systems

*Reducing the cost of cane cultivation*

a. Improving nutrient efficiency through rhizosphere engineering and INM technology
b. Enhancing water use efficiency through micro-irrigation
c. Increasing land use efficiency through companion cropping
d. Development of bio-intensive IPM module.
e. Mechanizing sugarcane farming

*Improving sugar content in cane*

a. Improving sink strength and source efficiency
b. Metabolic engineering targeting genes/enzymes of sucrose metabolism
c. Minimising post harvest losses
d. Introgression of high sugar genes by conventional breeding and molecular tools

*Popularizing adoption of agricultural machinery*

a. Development of need-based agricultural equipments
b. Demonstration of prototypes and refinement of machinery
c. Transfer of technology to private entrepreneurs for large scale manufacturing

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# Way Forward

Indian Institute of Sugarcane Research a major sugarcane research hub of the sub-tropical India, has been working towards improving cane productivity and sugar recovery since its inception. The technologies emanated from this Institute have played a substantial role in improving the cane yield and sugar recovery. Keeping in view the present sugar scenario in the country, a blueprint of the research and development activities is being formulated for 2050 for meeting the projected targets based on the likely demand, availability of resources, new technological interventions etc.

IISR is committed to bring about a demand driven and technology-led enhanced growth in sugarcane agriculture in the country, for improving the livelihood of farmers and for ensuring sustainable cane agriculture. The Institute firmly believes that the path of sugarcane research and development followed through enhancement of sugarcane production, productivity, profitability and sustainability will help in meeting the future sugar and energy requirement for an ever rising population of India. The Institute is committed to boost sugar productivity per unit area and time. The Institute envisions that innovations made would break yield barriers and transform sugarcane agriculture into an efficient, globally competent and vibrant one. Concerted efforts would be made to transform the Indian Institute of Sugarcane Research to be more sensitive to the needs of the cane farming community, especially of the small landholders. Intensive research and development efforts made so far would be better utilized to provide a base for developing new strategies and programmes in a time-frame mode. The Institute will carry out its research programmes in participatory mode by becoming more vigilant and by developing a culture of responsibility, accountability and integrity in the sugarcane research.

The way forward will encompass the following strategies and the approaches to be followed that will be gradually fine-tuned as per emerging need.

1. Development of cost-effective, profitable and sustainable agro-techniques for improved plant and ratoon productivity.
2. Mechanization to suit location specific needs of small and marginal farmers.
3. Development of improved varieties for high yield, high biomass and

high sugar, encompassing multiple stress tolerance, input efficiency and better ratoonability under sub-tropical conditions through conventional breeding and molecular methods.
4. Conventional and non-conventional approaches to enhance cane yield, sucrose content, red rot resistance, tolerance to abiotic stresses and thermo-insensitivity.
5. Location-specific bio-intensive crop-protection strategies
6. Climate change mitigation strategies including development of climate resilient varieties
7. Crop production and diversification *vis-a-vis* value addition for enhanced profitability and sustainability.
8. Technology assessment, transfer and refinement.
9. Impact assessment of technologies.
10. Capacity building

**Development of Cost-effective Profitable and Sustainable Agro-techniques for Improved Plant and Ratoon Productivity**

a. Precision agriculture including location/site specific input management for better yield and recovery under normal and stress conditions using remote controlled (computer controlled) sensor based automatic experimental strategies
b. Use of GIS for site-specific crop management
c. Nanotechnology for micro- management in plant and ratoon crops
d. Design, development and fine-tuning of precision machinery for planting, interculture, harvesting and other operations
e. Varietal development and precision agriculture for mechanization and intercropping
f. Rhizospheric engineering and manipulation of microbes for biofertilizers for improved soil health in plant and ratoon crops
g. Micro-manipulation of metabolic pathway for tolerance to abiotic stresses in sugarcane
h. Farmer-friendly decision support system for crop management

**Mechanization to Suit Location Specific Needs of Small and Marginal farmers**

a. Design, development and fine-tuning of precision machinery for planting, interculture, harvesting and other operations
b. Varietal development and agro-techniques suitable for mechanization in sugarcane

**Development of Improved Varieties for High Yield, High Biomass and High Sugar, Encompassing Multiple Stress Tolerance, Input Efficiency and Better**

**Ratoonability Under Sub-tropical Conditions through Conventional Breeding and Molecular Methods**

a. Pre-breeding for quality attributes, stress resistance, high biomass and input use-efficiency
b. Genetic base broadening through introgression of desirable genes using conventional and micro-manipulative techniques
c. Varietal development with special reference to better partitioning towards sucrose and its accumulation, using conventional methods, and comparative genomics
d. Temporal and spatial manipulation of sugarcane genome for production of short-duration sugarcane crop, without compromising on sugar accumulation
e. Manipulation of regulatory pathway for need-based flowering of parental lines in sugarcane
f. Nanotechnology for manipulation of genome/metabolic pathways for metabolite partitioning through transformation, functional genomics, metabolomics , bioinformatics etc., for improved productivity and sugar recovery
g. Genome manipulation for multi-ratooning , improved ratoon productivity and stress resistance
h. Genetic manipulation of $C_4$ pathway regulation for enhanced efficiency under sub-tropical conditions
i. Quality seed production and management through sensor based automated strategies

**Conventional and Non-conventional Approaches to Enhance Cane Yield, Sucrose Content, Red Rot Resistance, Tolerance to Abiotic Stresses snd Thermo-Insensitivity**

a. Introgression of genes of desired trait.
b. Assessing sucrose accumulation in relation to internodal enzymes.
c. Use of anti-inversion and biocidal compounds to minimize post-harvest losses.
d. Minimizing post harvest sucrose losses through RNAi approach.
e. Use of nanotechnology in sugarcane for minimizing post-harvest losses in the field and mill.
f. Marker Assisted Selection of sugarcane clones.

**Location-specific Bio-intensive Crop Protection Strategies**

a. Integrated pest management modules for disease/pest management
b. Management of diseases through systemic acquired resistance
c. Use of GIS for estimating disease/pest associated losses.

d. Development of a multiplex diagnostic kit for detection of dormant infections of pathogens.
e. Use of proteomics, functional genomics bio-informatics including RNAi/antisense strategies for disease and pest management
f. Need-based manipulation of metabolic pathway in bio-control agents for sensitivity to temperature and other stresses

### Climate Change Mitigation Strategies Including Development of Climate Resilient Varieties

a. Use of GIS for climate change assessment and forecasting
b. Development of climate resilient varieties through conventional and non-conventional methods
c. Precision agriculture for mitigating climate change effects
d. Management of shift in insect-pest dynamics in relation to climate change

### Crop Production and Diversification *vis-a-vis* Value Addition for Enhanced Profitability and Sustainability

a. Varietal development in sugarbeet with special reference to better partitioning towards sucrose accumulation and root formation using conventional and MAS strategies
b. Varietal development and precision agriculture for tropicalized sugarbeet through conventional and non-conventional techniques
c. Nanotechnology for manipulation of genome/metabolic pathways for improved productivity and recovery in sugarbeet and for production of tropicalized sugarbeet.
d. Manipulation of flowering/seed set in sugarbeet for quality seed production in plains
e. Automated sensor based production systems for value added hygienic production and packaging of jaggery and other by-products

### Technology Assessment, Transfer and Refinement

a. Organizing training programme on sugarcane production, protection and management to farmers, cane development personnel, extension workers and other stakeholders.
b. Demand based consultancy/advisory services to sugar mills.
c. Conducting location specific techno-economic feasibility studies and upscaling the improved technologies in target domain.
d. Local networking of development departments' local communities for capacity building for effective transfer of technologies.
e. Use of information technology

f. IPR protection of technologies
g. Management and optimised use of the biological diversity available in the country for the overall benefit of the society

### Impact Assessment of Technologies

a. Impact assessment analysis.
b. Forecasting parameters of sugarcane and sugar production, market trend, demand and supply using business forecasting models.
c. Identification of production and marketing constraints.
d. Pricing policies for sugarcane and its end products.
e. Development of transportation models.
f. Reducing cost of sugarcane production for boosting farmers' income and sugar exports as well.

### Capacity Building

a. Training of manpower in frontier areas and research management.
b. Training to sugar factory and cane development personnel for improving and managing cane agriculture.
c. Short-term training of University students and guidance in doctoral programme.

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