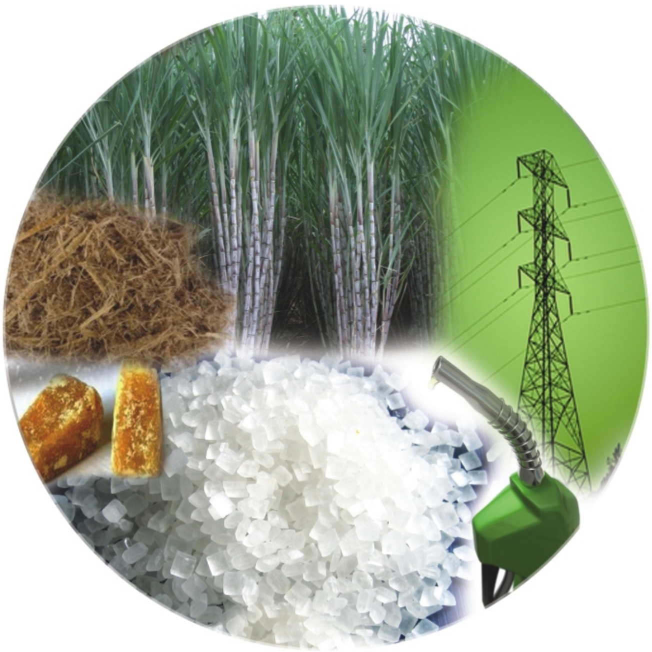
VISION 2030



गन्ना प्रजनन संस्थान

Sugarcane Breeding Institute

कोयम्बत्तूर–641 007.

Coimbatore - 641 007.

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FOREWORD

The diverse challenges and constraints as growing population, increasing food, feed and fodder needs, natural resource degradation, climate change, new parasites, slow growth in farm income and new global trade regulations demand a paradigm shift in formulating and implementing the agricultural research programmes. The emerging scenario necessitates the institutions of ICAR to have perspective vision which could be translated through proactive, novel and innovative research approach based on cutting edge science. In this endeavour, all of the institutions of ICAR, have revised and prepared respective Vision-2030 documents highlighting the issues and strategies relevant for the next twenty years.

Challenges in sugarcane agriculture are formidable both in terms of demand and sustainability. India is the largest consumer of sugar in the world and the demand for sugar and sweeteners is ever increasing with the growth in population and increased per capita consumption. By 2030, the domestic requirement of sugar is expected to cross 36 million tonnes as against the current requirement of 23 million tonnes. The area under sugarcane is not likely to increase and the increased sugar production has to be achieved through vertical growth in productivity. This would be a serious challenge to research and development establishments in the face of declining natural resources, climate change impacts, threats of new diseases and pests, high input costs and non-availability of labour etc. The research efforts at Sugarcane Breeding Institute (SBI), Coimbatore are to be focused on overcoming these constraints while targeting for higher productivity to meet the projected demand of sugar and other sweeteners by 2030.

It is expected that the analytical approach and forward looking concepts presented in the '*Vision 2030*' document will prove useful for the researchers, policymakers, and stakeholders to address the future challenges for growth and development of the agricultural sector and ensure food and income security with a human touch.

(S. Ayyappan)

Dated the 29th June, 2011
New Delhi

Preface

Sugarcane is the second most important industrial crop in the country occupying about 5 million hectares in area. India is the second largest producer of sugar after Brazil with an annual production of 20-24 million tonnes, which is barely adequate to meet the domestic requirements. The sugar requirement is expected to grow substantially in the coming years due to the population growth and increase in per capita consumption. Besides, sugarcane is also emerging as a multi-product crop contributing to the production of sugar, ethanol, electricity, paper and other allied products. Consequently the overall demand for sugarcane for its varied uses will increase significantly. However the area under the crop is not likely to increase and the increased demand for sugarcane is to be met only through the vertical growth in productivity. The crop is also associated with inherent inconsistencies in area and production due to various factors like climate, cane and sugar pricing, pricing of other commodities, cost of inputs and labour, labour availability etc. The last decade saw the widest fluctuation in sugar production ranging from 12.7 million tonnes to 28.4 million tonnes leading to either deficit or surplus situations. Thus the sugar sector demands not only increase in sugarcane production but stability as well for its sustained growth.

The growth in cane area and sugar production in the country during the last eight decades had been spectacular. There had been a nearly fivefold increase in cane area and tenfold increase in sugarcane production during the period. This growth is largely attributable to the development of superior varieties and improved technologies for crop management. The challenges in improving productivity include unfavourable climatic conditions under which the crop is grown in subtropical India, biotic and abiotic stresses, declining soil productivity due to continued monocropping of sugarcane for several decades, depletion of natural resources, the high cost of production and climate change. The current average productivity in the country is hardly 25% of the theoretical yield potential of the crop and there is considerable scope for improvement in productivity.

The Vision 2030 of the Sugarcane Breeding Institute articulates the Institutes' perspective of the likely crop scenario in the coming years and the research efforts needed for meeting the production targets. It is hoped that this document will serve as a road map for charting the research agenda of the Institute to achieve the production targets envisaged.

I am extremely grateful to Dr. S. Ayyappan, Secretary, DARE and Director General, ICAR and Dr. S. K. Datta, Deputy Director General (CS) for their guidance and constant encouragement. I also thank Dr. S. Gopalakrishnan, ADG (CC) for his continued support.

27th June 2011

N.VIJAYAN NAIR
Director

Preamble

India is the second largest sugar producer in the world after Brazil and the largest consumer. The current sugar production in the country is 24.5 million tonnes against the demand of 23 million tonnes for domestic consumption, leaving limited scope for exports. Though our export share is limited, the Indian sugar sector fulfils the important role of meeting the huge domestic demand of sugar which otherwise has to be met through imports. However the inconsistency and the cyclic nature of sugar production in the country is of grave concern. The sugar production which stabilised to about 18-20 million tonnes at the start of this decade, thereafter showed wide fluctuation from 12.7 million tonnes in 2004-05 to a record production of 28.4 million tonnes in 2006-07, resulting in deficit or surplus situations.

The demand for sugar is growing steadily in the country and by 2030 the domestic requirement of sugar is estimated to be 36 million tonnes which is almost 50% higher than the current production. The byproducts sector viz., alcohol and electricity are also taking centre stage in view of the growing energy needs of the country. The alcohol requirement of the country for fuel, potable and industrial uses is estimated to be 5700 million litres by 2030 which is more than double that of the current production. The current installed capacity for cogeneration is 2200 MW and the potential is 5000 MW. Thus the overall demand for sugarcane for its varied uses will increase significantly by 2030. The projected demand for sugarcane has to be met by improved productivity and higher sugar recovery, which is possible only through the development of superior varieties and improved crop management practices.

SBI has contributed significantly towards the growth and expansion of the sugarcane agriculture in the country through continuous development of improved varieties and technologies. The varieties evolved at the Institute or in collaboration with the State Agricultural Universities through the National Hybridisation Garden / Fluff Supply Programme occupy over 90% of area under sugarcane cultivation in the country. The National Hybridisation Programme operated by the Institute with 23 participating centres has been largely responsible for the development and spread of location specific sugarcane varieties in the country. The Institute holds the largest sugarcane germplasm in the world, which is its main strength. The Institute has also integrated the biotechnological tools in breeding programmes to improve precision and efficiency. The sugarcane transgenics developed by the Institute are the first in the country and their potential for pest management had been demonstrated. Considerable progress has also been made in sugarcane genomics, proteomics, molecular diagnostics, precision farming and biological control.

The SBI vision 2030 focuses on the key challenges and opportunities in sugarcane production in the next two decades to develop a strategic approach to achieve the production targets and ensure sustainable and stable sugar production in the country.

Contents

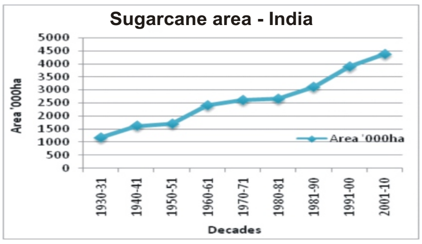
Crop Scenario

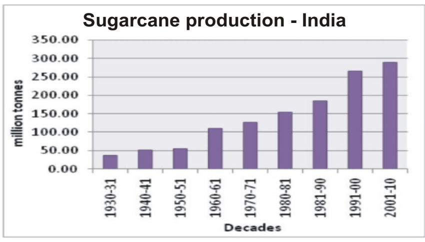
Sugarcane is the second most important industrial crop in the country occupying about 5 million hectares in area. India is the second largest producer of sugar after Brazil. About 4 million growers are involved in the cultivation of sugarcane. Sugar industry contributes significantly to the rural economy as the sugar mills are located in the rural areas and provide large scale employment to rural population. The various byproducts of sugar industry also contribute to the economic growth by promoting a number of subsidiary industries. Sugarcane is emerging as a multiproduct crop used as a basic raw material for the production of sugar, ethanol, electricity, paper and boards, besides a host of ancillary products. Molasses is the cheapest feedstock for the distilleries and the large part of the ethanol requirements is met by the distilleries in the country. The ethanol requirement of the country is going up steadily and the potential of ethanol as a bio-fuel is seriously debated. Generation of electricity using bagasse has become a standard option for the sugar industry. The use of bagasse as a substitute raw material for wood pulp in paper industry is vital for economic and environmental sustainability.

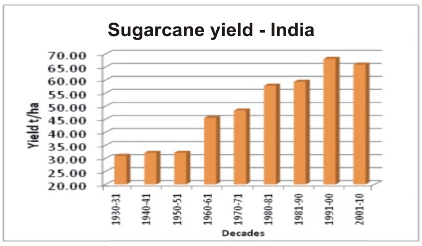
Sugarcane agriculture in the country is associated with inherent inconsistencies in area and production due to various factors like climate, cane and sugar pricing, pricing of other commodities, cost of inputs and labour, labour availability etc. The last decade saw the widest fluctuation in sugar production ranging from 12.7 million tonnes in 2004-05 to the record production of 28.4 million tonnes in 2006-07, leading to either deficit or surplus situations. The present requirement of sugar in the country is 23 million tonnes which is the highest in the world. The current production can meet the domestic requirements with occasional surplus. Despite being the second largest producer of sugar, our export share is minimal due to huge domestic demands. The importance of the sugarcane agriculture is that it is able to meet the huge domestic requirement, which otherwise would have warranted massive imports. Domestic sugar price of sugar in India is among the lowest in the world. The production cost of Indian sugar is estimated to be in the medium range - costlier than

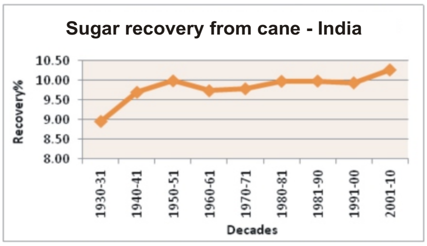
Australia and Brazil but lower than that of USA. In future, we may face stiff competition from African countries, whose production costs are lower than India.

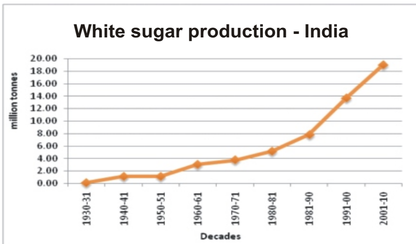
The growth of the sugarcane agriculture in the country had been spectacular. From 1.17 m ha in 1930-31, the cane area increased to 5.1 million ha by 2006-07; almost a fourfold increase. During this period the productivity went up by from 31 t/ha to 68 t/ha, sugarcane production increased from 37 million tonnes to 355 million tonnes and sugar production had gone up from 0.12 million tonnes to 28.4 million tonnes. Sugar recovery also showed an improvement from 9.05% to 10.27%. The number of sugar factories went up from 29 to over 500 at present. The growth in cane and sugar production was contributed by two factors; a fourfold increase in cane area and improvement in productivity by more than 100%. Both these were possible because of the development of new, well adapted varieties and efficient crop production and crop protection technologies.

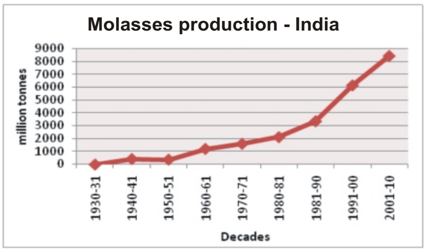












Between 1961 and 2008-09, the production of sugarcane increased at a compound annual growth rate (CAGR) of 2.42 per cent. This was due to increase in area (1.55%) and improvement in yield (0.86 %). The improvement in sugar recovery during the period was only marginal. There was a slowdown in the average annual growth rate during this decade mainly due to drought in major sugar producing states during 2003-04 and 2004-05.

Sugar Cycle

The Indian sugar industry is cyclical in nature. One or two years of excess sugar production is followed by a few years of shortage. Surplus cane and sugar production leads to low sugar prices and accumulated stocks resulting in losses to the sugar factories. Consequently the cane prices are not paid in time to the farmers forcing them to switch over to other crops leading to reduction in cane area and sugar production and thereby bringing down the sugar production. Shortages lead to higher sugar prices and the sugar mills hike the cane prices to entice the farmers back to sugarcane cultivation and the cane area and sugar production once again goes up and the cycle is repeated. The rainfall pattern also influences the cane area and production seriously.

Contribution to the Economy

Contribution of sugarcane to the National GDP is 1.1% which is significant considering that the crop is grown only in 2.57% of the gross cropped area. Contribution of sugarcane to the Agricultural GDP has steadily increased from about 5 % in 1990-91 to 10% in 2010-11. During the last two decades, the average annual growth of sugarcane agriculture sector was about 2.6% as against overall growth of 3% in agriculture sector in the country (NAAS, 2009). Sugar industry contributes an estimated Rs.17 billion annually to national exchequer and treasuries of various state governments by way of excise duty and purchase tax on sugarcane alone.

Sugar factories are located in rural areas and support substantial economic activities in the rural areas. Nearly 4 million sugarcane farmers and their dependents are involved in sugarcane agriculture. Besides, the industry also provides employment for nearly 4% of the rural population directly or indirectly. In India sugar is an essential item of mass consumption and the cheapest source of energy, supplying around 10% of the daily calorie intake. Apart from sugar, sugarcane also supplements the energy sector through ethanol and electricity production.

Crop Profile

Sugarcane cultivation in the country extends from 7° to 32° N latitude covering both tropics and sub tropics. The regions located south of 23° N latitude are ideally suited for growing sugarcane in view of long sunshine hours throughout the year which facilitates continued growth. The yield levels in subtropical areas are significantly less (~56 t/ha) compared to the tropics (~82 t/ha), since sprouting and growth during winter months are severely affected. Development of varieties capable of winter sprouting and growth is most essential if the current yield levels of subtropics are to be improved.

A large number of improved high yielding, well adapted location specific varieties are currently available. Over 90% of the varieties grown in the country are either varieties developed by SBI or varieties developed from the crosses made by the Institute for the state research stations in the National Hybridisation Garden. Uttar Pradesh ranks first in cane area accounting for over 40% of the total cane area. Maharashtra ranks second in cane area and first in sugar production. Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh together account for 90% of the total sugar production in the country. The crop is grown under a wide range of agro climatic conditions and the productivity ranges from 25 t/ha in Chhattisgarh to 105 t/ha in Tamil Nadu while the average productivity in the country is about 65 t/ha. The average sugar recovery in the country is about 10.2%. Sixty to seventy per cent of cane produced in the country is used for sugar production while rest is used for seed, chewing, juice and for the production of jaggery and khandsari. Over the years the consumption of jaggery and khandsari has been declining with a corresponding increase in sugar consumption.

Sugarcane has now emerged as a multiproduct crop used for food, fuel, energy and fibre. Sugarcane, as a C_4 plant, is photosynthetically one of the most efficient crops, fixing 2-3% of solar radiation. One hectare of sugarcane may produce 100 tonnes of green matter every year, which is more than twice the agricultural yield of most other commercial crops. Though sugarcane is used as a source of sugar, it forms an ideal raw material for the biological production of higher value fuels, because it can produce both fermentable sugars in the juice and a combustible fuel in the form of the fibrous part (bagasse) of the plant. One hectare of sugarcane land with a yield of 82 t/ha produces about 7000 litre of ethanol.

Effective conversion of bagasse to ethanol is a major research focus today. The global availability of bagasse is estimated to be about 425 million tonnes annually. This huge biomass can be an important feed stock for the production of bio-ethanol. This is particularly important for countries like India, where scope for increasing the production of ethanol from molasses or sugarcane juice is very limited. However the limitation so far had been the lack of cost effective technologies to convert bagasse to ethanol.

Butanol is an aliphatic saturated alcohol that can be used as a transportation fuel. Butanol has higher octane value than ethanol, can be used in the existing engines and is non hygroscopic and non corrosive to engines. Butanol can be produced from sugarcane juice and molasses using bacterial strains. New strains of *Clostridium bejerinckii* capable of efficient conversion of sugarcane juice and molasses to butanol had been identified and the technology holds promise as an alternate biofuel.

Co-generation is the combined generation of steam and electricity in sugar mills using bagasse as feed stock. Bagasse being a renewable feedstock does not result in the GHG emissions on its combustion and thus generates clean energy. The huge amount of bagasse produced by the Sugar Industry every season facilitates generation of electricity to meet the operational requirements of the sugar plants, besides exporting surplus power to the grid. The installed capacity for cogeneration in India is 2200 MW while potential is 5000 MW.

Bagasse pulp is an ideal substitute for wood pulp in paper industry. The large scale use of wood pulp for paper manufacture is of grave concern for environmentalists, in view of the dwindling forest resources. This has forced the Industry to look for alternative raw material for paper production. Sugarcane bagasse, which has comparable fiber properties has been used for paper manufacture in India and Thailand since long. At present sugarcane bagasse accounts for nearly 20% of all paper production in India, China and South America. The paper industry utilizes 10% of the world bagasse production.

Yield Gaps

The experimental maximum yield in sugarcane is 325 t/ha, which is hardly achieved though individual farmers have reported yields close to this. There is a wide gap in productivity between the tropical and the sub-tropical regions of the country, the former averaging about 82 t/ha per ha and the latter 56 t/ha. Wide gap exists between the potential yield and the yield levels achieved at present in all the states/regions without exception. Bridging this yield gap which ranges from 40% in Haryana to 60% in Maharashtra should be the primary focus for attaining the projected targets for the future.

Production Constraints

Sugarcane cultivation in the country falls under 5 agro climatic region viz, Peninsular, East Coast, North West, North Central and North East Zones. The productivity in each zone is affected a varied number of factors. Yield in subtropical India is affected by the prolonged winter, which reduces the effective growing period. Drought, waterlogging, salinity and alkalinity affect cane production significantly in many states. Approximately 2.97 lakh ha of cane area is prone to drought, affecting the crop at one or other stage of growth. Drought can bring down the yields by 30-50% and in severe drought situations the loss could be as high as 70%. Floods and waterlogging are serious problem in Eastern UP, Bihar, Orissa, Coastal Andhra and parts of Maharashtra. Approximately 2.13 lakh ha of sugarcane area is flood prone in different states. Waterlogging affects all stages of crop growth and can reduce germination, root establishment, tillering and growth resulting in reduced yield. Sugarcane is cultivated in about 7-8 lakh hectares under saline conditions. Though the crop is moderately tolerant to salinity, the losses are significant.

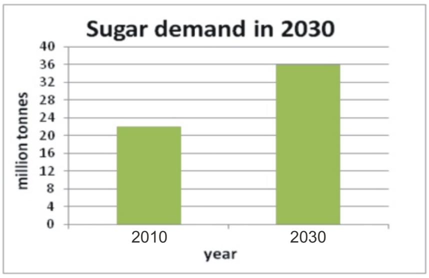
Among the sugarcane diseases, red rot is prevalent throughout the country and the disease can cause substantial loss. The emergence and spread of yellow leaf disease across the country is a major cause of concern. Wilt in North Central and North Western Zones and also in Gujarat and parts of Andhra Pradesh is a serious production constraint. Borer pests are present almost throughout the country with top borer and stalk borer dominating the subtropics and shoot borer and internode borer in tropics.

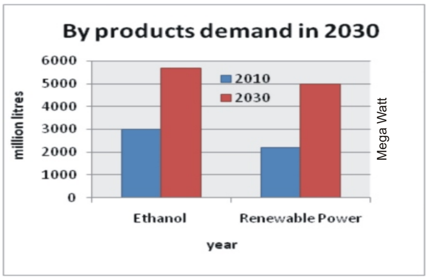
Continued mono-cropping of sugarcane without crop rotation and organic recycling for several decades have depleted the soil fertility considerably. Singh (2008) reported that there is an estimated loss of 4.5 to 7.9% in sugarcane due to soil degradation in India. Productivity of the soils has come down due to the degradation of the physical and chemical properties and decline in rhizosphere microbial activities. Decline in soil organic carbon content has been very apparent over the years affecting productivity. Significant reduction in soil organic content following continued sugarcane cultivation had been reported from Philippines (Alaban et al, 1990) and Brazil (Cerri and Andreux, 1990). Sugarcane is a water intensive crop, requiring 30-40 irrigations on an average in tropics. Continued monocropping of sugarcane also has resulted in depletion of water resources at an alarming rate.

Sugarcane is a labour and input intensive crop which remains in the field for more than a year. The cost of cultivation of sugarcane has gone up significantly due to the increase in cost of labour and inputs. Labour availability for major operations like harvest also has become scarce due to migration of labourers seeking urban employment. Cost of harvest is Rs. 450-650/ ton in the tropics which is more than 25% of the sale value of the product. Development of varieties and technologies suited for mechanization has become imperative now in view of this. The steep rise in cost of production, non-availability of labour in adequate numbers and in time for harvesting and high cost of inputs are eroding the profits, making sugarcane cultivation less sustainable. Sugarcane agriculture can be sustained only if profitability can be ensured through reduction of cost of cultivation and improving productivity per unit area. This is possible only through mechanization and adoption of other technological interventions in cane agriculture.

Demand for Sugar and allied products

Sugarcane is the basic raw material for sugar production, while molasses and bagasse which are the byproducts of sugar industry form the feedstock for Ethanol production and cogeneration respectively. The demand for sugar, ethanol and electricity is increasing due to growing population and rising per capita income. The projected requirement of sugar in 2030 is 36 million tonnes, which is about 50% higher than the present production. To achieve this target, the sugarcane production should be about 500 million tonnes from the current 350 million tonnes for which the production has to be increased by 7-8 million tonnes annually. The increased production has to be achieved from the existing cane area through improved productivity and sugar recovery since further expansion in cane area is not feasible.





The demand for eco friendly commodities (such as ethanol, renewable green power through co-generation) is expected to grow by more than 100% by 2030. Though 5% ethanol blending with petrol was made mandatory from 2003 in 9 states and 4 union territories, the target could not be achieved due to limited availability of bioethanol, even necessitating imports. National Policy on Biofuel proposes to scale up the blending to 20% by 2017, which may necessitate significant increase in domestic ethanol production. At present there are about 300 distilleries operating in the country which have a total installed capacity of 4000 million litres of alcohol in a year. However the highest production ever achieved has been only 2700 million liters in the year 2006-07. In India sugarcane molasses is the only feedstock for production of ethanol, except for a small number of distilleries producing potable liquors from grains and other feedstocks and thereby ethanol production is totally dependent on sugar production. The estimated ethanol requirement for fuel, potable and industrial use would be 5700 million liters in 2030 which means that the production should be more than doubled to meet the projected requirements.

Promotion of cogeneration and generation of electricity from renewable sources is a declared policy of the GOI. Cogeneration based on bagasse is an environmentally safe and viable option to augment the power requirements of the country. The over 500 sugar mills in the country have a potential to generate 5000 MW of electricity. However the current installed capacity is only 2200 MW. Full capacity realization to the extent of 5000 MW has to be achieved to suitably augment the growing power requirements. This is possible only when the sugar plants operate to their full capacity to generate the required quantity of bagasse. Obviously the cane availability should increase to meet the capacity utilization of the mills. Already considerable research is in progress in countries like China, Japan, Brazil, USA and Australia to develop energy canes with high fiber and low sugar or dual purpose canes with high fiber and moderate sugar to meet the energy requirements.

The ethanol production and cogeneration are totally dependent on sugar production as the respective feedstocks are generated as byproducts during the sugar production. If the sugar production goes up the cogeneration and ethanol production will also correspondingly go up.

Global trends

The current global sugar production is about 165 M tonnes, nearly 80% of which is contributed by cane sugar. The global demand for sugar at present is close to 167 M tonnes and it is estimated that by 2030 the requirement will go up by over 50% to 257 M tonnes. The major producers are Brazil, India, China, Thailand, USA, Mexico and Australia. New sugar Industries are coming up in many African countries like Uganda, Tanzania, Zambia, Nigeria, Ethiopia, Guinea etc. while sugar production in some of the traditional sugar producing countries like Fiji and Mauritius has come down significantly for various reasons. Massive expansion in cane area is proposed in Brazil and the cane area is expected to reach 13.9 M ha and sugar production to 45 million tonnes by 2020. Expansion of cane area is also taking place in other South American countries. On the whole it is expected that the sugar production will increase substantially in the coming years. India will be in a disadvantageous position since the increased production is from African countries and Brazil, where the cost of sugar production is lower compared to India and we may face stiff competition in International markets. The sugar prices are likely to stabilise at about 18-20 US cents/ lb mark in the next 20 years as against the current 14.5 US cents/lb, in which case the Indian sugar will not be competitive in the international market because of its higher cost of production. The demand for ethanol is also steadily going up with more and more countries opting for green fuels, which may impact the sugar production. Considerable research efforts are going on in developing technologies for the cost-effective production of ligno-cellulosic ethanol. Any breakthrough in this area will reduce the dependence on cane juice for ethanol production. In such case it will seriously affect the cogeneration, since the entire bagasse will be diverted for ethanol production. However the pricing of the different products viz., sugar, electricity and ethanol will decide how and in what proportion the crop is likely to be used for the production of these commodities in the coming years.

Opportunities in Sugarcane Agriculture

Cane agriculture offers new opportunities which were not previously available in the form diversified products and processes. Sugarcane juice and molasses form the feedstock for ethanol production while bagasse contributes to electricity generation. The bagasse also forms a raw material for Paper and board industry. A new market is emerging in India for packaged sugarcane juice, for which the demand is likely to go up.

Sugarcane is most efficient converter of solar energy and the highest biomass producer which render it the most ideal plant to be engineered as a biofactory. High value products like vaccines, therapeutics, bioplastics, industrial enzymes etc. can be expressed in high volumes and in easily extractable forms in sugarcane.

Impact of Climate change

The predicted outcomes of climate change in the Indian context includes rise in temperature, decreased rainfall, altered rainfall pattern, drought, floods, waterlogging and increased CO_2. High temperature is the most eminent threat to plant growth, development and yield. Increased temperature during maturity period may adversely affect the juice quality especially juice sucrose content. Increased summer drying of the crop could result in substantial yield loss. Moisture stress usually coincides with the hot weather period. Therefore, the situation gets aggravated due to higher evaporative demand and direct high temperature effect on the crop. There will be risk of both droughts and untimely floods, under the increased temperature regimes depending on the locations. Consequent to changes in the soil temperature, soil moisture, composition of gases in the root zone, there are likely changes with respect to root growth, composition of root exudates, soil processes, nutrient dynamics, decomposition etc.

The increase in CO_2 content will have a beneficial effect on C_3 crops and the dicot weeds may compete with the sugarcane crop. There could be higher incidence of pests and diseases under the altered temperature regime. If the ambient temperature remains within the favorable range for pests, insect species will complete more generations thereby leading to larger populations than normal. In the context of sugarcane pests, a predominantly summer pest like shoot borer is likely to extend its activity beyond the month of May under spring planting in subtropical situation which is hitherto not the case. However, if the ambient temperature rises above the favourable ranges of different pests in the long-run, pest populations may be adversely affected.

Climate change is likely to affect the pathogen, host or the host-pathogen interaction. The change in climatic conditions will have an impact on the pathogen biology, thus influencing the virulence pattern and pathogen variability. Given the changing climatic conditions, the overall disease scenario in sugarcane suggests that besides resistant varieties other approaches are needed to be taken care for disease management.

Overall scenario that is emerging is that climate change will affect sugarcane productivity through reduced growth, increased weed competition and increased incidence of pests and diseases. Studies conducted in Mauritius, South Africa and Trinidad and Tobago showed that sugarcane production decreased significantly due to rise in temperature. It was estimated that for every 2°C rise in temperature sucrose yield will be reduced by about 30%. The decrease in yields is attributed to increased moisture stress caused by the warmer climate.

Technology Landscape

Development of molecular technologies has lent precision and strength to sugarcane breeding programmes over the conventional approaches. The complexity of the polyploid genome of sugarcane could be deciphered through various approaches of structural and functional genomics. Genetic linkage maps could be developed for *Saccharum* species and hybrids and fine mapping of some of the genes like rust resistance could be achieved for the first time. Trait specific markers could be developed and used in marker assisted selection. Species and genus-specific markers were developed and used for monitoring the introgression of wild genomes. Molecular markers also found application in diversity analysis, fingerprinting of hybrids and germplasm to protect PBR and IPR, genetic fidelity testing, genotyping of pathogens and pests, molecular diagnosis of diseases, virus indexing, etc. *In situ* hybridisation techniques facilitated the study of the component genomes in interspecific and intergeneric hybrids.

Next Generation Sequencing (NGS) technologies have revolutionised whole genome sequencing projects. Whole genome sequencing of sugarcane is in progress and once completed it will provide a comprehensive picture of sugarcane genome covering the entire suite of genes and regulatory elements. Sugarcane ESTs have been developed from different varieties and tissues and over 300,000 ESTs are currently available based on which sugarcane gene indices were developed. Several technologies are available now for large scale expression profiling of sugarcane genes including cDNA microarrays, cDNA macroarrays, long and short oligonucleotide microarrays, SAGE, MPSS etc. Considerable progress has been achieved in sugarcane proteomics and metabolomics. Developments of techniques like 2-D gel electrophoresis and MALDI-TOF-MS greatly facilitated the study of proteins. Heat shock proteins in sugarcane have been characterised using proteomic approach.

Study of metabolites is challenging in view of their dynamic behaviour in terms of time and space and their fundamental chemistry. Here again a combination of chromatography, GS-MS, LC-MS form basic approaches in the analysis of the metabolites. Metabolic analysis of different aspects of sucrose accumulation like carbon partitioning gene expression, activity of sucrose transporters, metabolite concentrations etc. has been carried out. With the knowledge gained on synthesis and accumulation patterns of metabolites of interest, it is possible to engineer the metabolic pathways to produce desirable metabolites using the recombinant DNA technology. By down regulating the activity of the UDP-glucose dehydrogenase (UGD), it was possible to increase the sucrose accumulation in sugarcane.

Discovery of new genes and promoters facilitated their incorporation in transgenics. Both biolistic and Agrobacterium mediated genetic transformation protocols are now well in place in sugarcane and sugarcane transgenics for various traits like weedicide resistance, pest and disease resistance, drought resistance etc. have been produced and many transgenics are now under field evaluation in several countries including India. A breakthrough in sucrose improvement was achieved with the incorporation of sucrose isomerase gene tailored for vacuolar compartmentation which resulted in remarkable increase in total sugar levels.

One of the most attractive and practically demonstrated molecular approaches to develop resistance against viral diseases is the use of pathogen derived resistance (PDR) genes. The use of PDR genes to develop resistance to SCMV, SrMV, SCYLV and FDV has already been demonstrated in sugarcane. Significant increase in resistance to SCMV was shown by plants engineered with SCMV coat protein gene. RNAi technology has been demonstrated in sugarcane and holds promise in imparting disease and pest resistance and improving productivity.

Genetic engineering sugarcane as a biofactory has been attempted to produce high value products like pharmaceuticals, vaccines etc. A human pharmaceutical protein, human granulocyte macrophage colony human pharmaceutical protein, human granulocyte macrophage colony stimulating factor (GM-CSF) used in clinical applications for the treatment of neutropenia and aplastic anemia was successfully produced in sugarcane. Sugarcane has also proved to be a novel system for the production of industrial products such as poly-3-hydroxybutyrate (PHB) which has biodegradable and thermoplastic properties. In Australia cellulolytic enzymes were expressed in sugarcane for the large scale production of these enzymes in sugarcane itself in an effort to develop economically viable technologies for conversion of bagasse to fermentable sugars.

The integration of nanotechnology is likely to provide a significant thrust to agricultural research. Nanotechnology offers scope for developing more efficient fertiliser and pesticide formulations. Biosensors using nanoparticles will facilitate disease diagnosis and management.

Use of geospatial analysis will be vital in crop management studies particularly with reference to management of nutrition and water. Use of IT in developing suitable decision support system will facilitate effective crop management to improve crop productivity.

Sugarcane Breeding Institute

Sugarcane Breeding Institute (SBI) established in 1912 had been serving the sugarcane farming community of the country for nearly a century by developing high yielding, well adapted sugarcane varieties. The Institute is engaged in the development of superior varieties suited for the different agro climatic conditions integrating conventional and the newer biotechnological approaches. Ninety percent of the area under sugarcane cultivation in the country is occupied by the varieties developed by the Institute or varieties developed by the State Sugarcane Research Stations from the crosses made at SBI. The most popular variety in the country at present is Co 86032 which occupies nearly 90% area in Tamil Nadu and over 50% area in Maharashtra and Karnataka and sizable areas in Gujarat, Andhra Pradesh and Orissa. The area under Co 0118 and Co 0238, the new varieties developed by the Institute is increasing significantly in the sub tropical India. The Institute also conducts basic, strategic and applied research on various aspects of sugarcane varietal improvement and crop production and crop protection technologies. The Sugarcane Germplasm maintained by the Institute is the largest in the world and the only collection that has been characterised and documented. The Institute has a strong interface with the sugar industry and the sugarcane development departments for the transfer of technologies developed by the Institute.

The Institute has one regional centre at Karnal, Haryana to take care of the varietal needs of the sub tropical India. The Research Centre at Kannur, Kerala, houses the World Collection of Sugarcane Germplasm while the Agali Research Centre serves as the National Distant Hybridisation Facility and the national off season nursery for the mandated crops.

Mandate of the Institute

- Breeding of superior sugarcane varieties / genotypes having high sugar productivity as well as sustainability and to assist state sugarcane breeding programmes.

- To conduct basic and strategic researches on crop improvement, production and protection aspects of sugarcane cultivation.
- Collection, maintenance, evaluation, documentation and conservation of sugarcane/*Saccharum* species genetic resources.
- Effecting technology transfer, consultancy and human resource development in the areas of sugarcane agricultural research.

Status of Technology Development

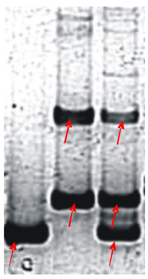
Co 86032 - Most Popular Variety in the Country

SBI had developed over 2900 sugarcane varieties since its inception, many of which had become popular varieties in different parts of the country. The first interspecific hybrid produced in India in 1912 between the cultivated sugarcane *(S.officinarum)* and the wild species *(S.spontaneum)* was the earliest demonstration of the use of wild species in crop improvement. Some of the landmark varieties developed by the Institute are Co 205, Co 312, Co 313, Co419, Co 527, Co 740, Co 997, Co 62175, Co 6304, Co 6907, Co 1148, Co 1158, Co 7805, Co 7717, Co 8903 and Co 86032. These varieties played a significant role in sustaining the growth and expansion of the sugar industry during different periods. Besides, the Institute also supported the breeding programmes of over 20 State Sugarcane Research Stations by extending the National Hybridisation facility. Several outstanding varieties like CoC 671, CoJ 64, CoS 767, CoS 8436, CoJ 83, CoPant 84211, CoSe 92423, CoSe 95422, CoS 88230 etc. were developed from this collaborative effort between SBI and the State Research Stations.

sugarcane germplasm in the world, comprising of nearly 4500 accessions. The collection had been characterised for morphological and agronomic traits, disease and pest resistance and tolerance to abiotic factors. Institute had been organising explorations in the distributional areas of *Saccharum* in the country since 1912 and the activity is still continued. Extensive research on the cytogenetics of *Saccharum* species and interspecific and intergeneric hybrids had been carried out at the Institute. Interspecific and intergeneric hybrids involving the different species of *Saccharum* and the related genera of *Erianthus, Narenga* and *Sclerostachya* were developed and cytologically characterised. Institute also developed unique hybrids of sugarcane with *Imperata*, Maize and Sorghum.

SBI was one of the first to develop sugarcane tissue culture protocols in India. Several somaclones with modified phenotypes were developed through tissue culture. Co 94012 released in Maharashtra and Karnataka, which has recorded highest sugar recovery ever, is a somaclone of the popular variety CoC 671. Micropropagation protocol for rapid multiplication of the released varieties was developed and the technology was transferred to sugar Industry and commercial tissue culture labs. Institute also developed a protocol for medium term *in vitro* storage of germplasm.

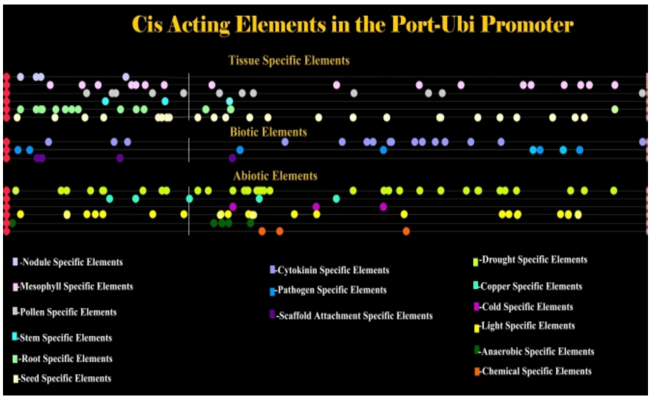
Molecular studies on sugarcane was initiated in the country for the first time at SBI in 1990s and the genetic diversity and phylogeny of Saccharum complex was elucidated using an array of marker systems. Breeding programmes were restructured based on molecular diversity of the parents. Fingerprinting of important varieties has been done. DBT has accredited the Institute for virus indexing and genetic fidelity testing of tissue culture plants. Genus and species-specific markers were developed and used for the precise characterisation of interspecific and intergeneric hybrids, which facilitated the



Lane 1. IND-90-776 (Erianthus)
Lane 2. PIO-96-435 (S. Officinarum)
Lane 1. 04(28) EO-2 (Hybrid)

Characterisation of *Saccharum x Erianthus* hybrids using Microsatellite Markers

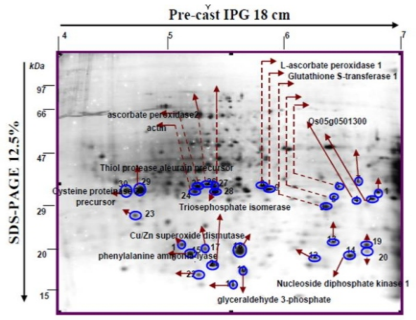
monitoring of the wild genome during the introgression with sugarcane. Trait specific markers for red rot resistance, top borer resistance and drought resistance and candidate genes for drought resistance had been identified. Expression profiling for genes involved in sucrose synthesis is in progress.



A ubiquitin gene promoter was isolated from *Porteresia* species and characterised. This promoter was found to express both in monocots and dicots.

The Institute was the first to develop sugarcane transgenics in the country. Protocols for biolistic and *Agrobacterium* mediated transformation in sugarcane had been developed. Transgenics with chitinase, 1,3 β glucanase, aprotinin and cry1Ab were developed. Transgenics with aprotinin showed resistance to top borer while transgenics with cry1Ab showed resistance to shoot borer. The first confined field trial of sugarcane transgenics in the country was laid out during January 2011 following the approval by GEAC.

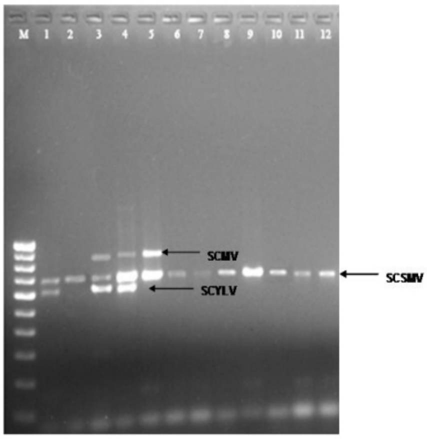
The Institute had developed appropriate technologies for the effective management of the crop under normal and stress situations. Wide row planting was conceived and evaluated to facilitate mechanical operations and the technique is now widely adapted. Effectiveness of biofertilisers in reducing the N & P requirement to the extent of 25% was demonstrated. New efficient strains of *Gluconacetobacter* and *Phosphobacteria* were isolated and characterised. A total package for weed management was developed and demonstrated that the period between 30-45 days after planting is the most critical period for crop-weed competition and if the weeds could be managed during this period the crop will remain weed free. Experiments on organic cultivation of sugarcane showed that by the third crop cycle organic cultivation becomes sustainable in terms of productivity and improves soil physical, chemical properties and rhizosphere microbial activities significantly. Studies on micro irrigation showed that over 40% saving in water and nearly 25% saving in N & K fertilisers could be achieved through drip fertigation. Digital soil map of 3 districts have been prepared for developing site specific management packages.



The management of red rot had been a major focus and the Institute had been largely responsible for the management of the disease in the country through the development of red rot resistant varieties. A Controlled Condition Testing (CCT) procedure was developed to facilitate screening of large number of genotypes for red rot resistance in a short time. The molecular basis of red rot resistance has been investigated and sixty differentially expressed proteins involved in red rot resistance have been characterised through 2D-GE and MALDI-TOF. The stalk proteome of sugarcane was established as a platform for the study of proteins involved in disease resistance. Three full length genes associated with red rot resistance were sequenced and characterised. Currently transcripts involved in red rot resistance are being identified using subtractive libraries. An elicitor molecule glycoprotein moiety was isolated from C.falcatum, which was found to induce systemic resistance in sugarcane against red rot. Molecular diagnostics have been established for fungal, bacterial and viral diseases.

A multiplex RT PCR was developed for detecting SCMV, SCSMV and SCYLV simultaneously in a single assay. Tissue blot was developed to detect RSD bacterium.

Detection of three major RNA viruses in sugarcane using multiplexreverse transcription polymerase chain reaction (M-RT-PCR)



Lanes M 100 pb DNA size marker, 1. Co6304, 2 CoC 671 (glass house), 3. CoV 94101, 4. Co 86010, 5. CoA 7701, 6. Co 86032, 7. Co 94008, 8. CoJ 65, 9. CP 52-68, 10. CoPant 84211, 11. Co 7218, 12. BO 54.

Considerable success had been achieved in the biocontrol of important pests. *Trichogramma chilonis* was found to be effective in managing internode borer. Efficacy of pheromones in the management of shoot and internode borer also had been demonstrated. The use of *Dipha aphidivora* and *Encarcia flavoscutellum* against sugarcane white woolly aphid was found to be very effective in managing the pest.

SUGARCANE BREEDING INSTITUTE 2030

SBI had a predominant role in the development of improved sugarcane varieties suited for the different agroclimatic conditions of the country. Apart from a large number of prominent varieties developed by the Institute which became popular in both tropical and sub tropical states, the Institute also contributed towards the development of a large number of location-specific varieties by the State Sugarcane Research Stations through the National Hybridisation Facility. The success of the sugarcane varietal development programmes in India is largely attributable to the effective collaboration between SBI and the State Sugarcane Research Stations.

SBI remains the hub of all sugarcane breeding activities in the country. The genetic variability required for the development of new varieties in the country is almost entirely derived from the crosses made at the National Hybridization Garden (NHG) of SBI. Hence strengthening, diversifying and rationalising the composition of the NHG is of utmost importance to ensure the continued development of superior, well adapted varieties. The strength of SBI lies in the diverse germplasm it holds which is the largest in the world. The characterisation of this large germplasm for important attributes and allele mining to identify alleles for various traits are of primary importance to optimise the utilisation of germplasm in breeding. The pre-breeding activities will be further strengthened to develop genetic stocks with a broad and diverse genetic base to augment the quality and composition of the NHG. New germplasm will be collected/ introduced to supplement the existing collections to support the emerging varietal needs. The breeding programmes will be strengthened taking advantage of the new developments in biotechnology, information technology and nanotechnology.

The sugarcane productivity in the country is showing signs of slowdown despite the availability of potentially high yielding and locally adapted varieties. The impact of climate change, decline in soil productivity and depletion of natural resources is apparently affecting the sugarcane productivity in the country. Apart from improved varieties, development of appropriate crop production and crop protection technologies also assumes importance in maximising productivity in this context. The quantum jump expected in sugarcane productivity to meet the sugar and energy requirements of 2030 is possible only through the proper integration of conventional, new and emerging technologies. SBI will continue to provide leadership in sugarcane varietal development and related research in the country and also position itself as the major centre for developing technologies for better crop management in relation to the emerging situations.

Vision

To make India the World Leader in sugarcane and sugar production through evolution of superior, stress tolerant varieties and cost effective, sustainable and input use efficient crop management technologies.

Mission

To meet the growing sugar and energy needs of the country, to provide stability in sugar production and to ensure livelihood security to the sugarcane farmers through the development of improved varieties and cost effective technologies.

Focus

- Breeding of superior sugarcane varieties having high sugar productivity as well as sustainability and to assist state sugarcane breeding programmes.
- To develop varieties and management technologies for energy needs.
- To develop improved crop production and crop protection technologies for making sugarcane cultivation profitable and sustainable.
- To conduct basic and strategic researches on crop improvement, production and protection aspects of sugarcane cultivation.
- Collection, evaluation, documentation and conservation of sugarcane genetic resources.
- To study the impact of climate change on sugarcane agriculture and evolve comprehensive strategies to mitigate the impacts of climate change.
- Management of natural resources to ensure long term sustainability of the crop.

  Effecting technology transfer and human resource development in the areas of sugarcane agriculture and research.

Harnessing Science

By 2030, the cane production in the country has to be increased by 50% from the same area to meet the domestic requirements, which implies that the increased production has to be achieved through a steep increase in productivity and sugar recovery. The research focus needs to be on improving productivity and sugar recovery taking into consideration the biotic and abiotic stresses, resource constraints, sustainability of the crop in terms of profitability and in competition with other crops, likely impacts of climate change, etc. The conventional breeding programmes have to be strengthened through the use of latest technologies. Computerised databases have to be created for the current breeding pool and germplasm on aspects like pedigree, progeny performance, genetic diversity, variability for agro-morphological traits, stress tolerance, flowering behaviour and floral biology to render the breeding programmes more focussed.

The pre-eminent strength of SBI is the highly diverse germplasm collection it holds, which also is the largest in the world. Allele mining of the germplasm to identify alleles for various traits of importance need to be undertaken to fully exploit the potential of this large germplasm. Characterisation of the germplasm for YLD resistance, borer resistance, drought and winter tolerance, climate resilience, fibre and sucrose characters is a priority considering the emerging needs. Pre-breeding through intraspecific, interspecific and intergeneric crosses will help in diversifying the genetic base of the existing breeding pools. *Saccharum* germplasm also holds promise as a rich source for high value products like anthocyanins, flavonoids, phenolic compounds, vitamins and various other antioxidant compounds. Proper characterisation of the germplasm for antioxidant compounds using appropriate biochemical technologies like mass spectroscopy, IR spectroscopy and NMR will help in identifying potential clones to be used as a source for these products. While improved sugar production remains the primary objective of sugarcane breeding programmes, redefining breeding objectives is warranted in view of the current interest in alcohol and fibre. Utilisation of new genetic stocks with high biomass, total sugars and fibre content in breeding programs are to be considered for the development of special varieties for cogeneration and alcohol industries.

The technology landscape in biological sciences has been changing over the years and advancements made in this field have made genetic manipulations for crop improvement far more tangible. Many of the practical problems in plant breeding like fingerprinting of varieties and germplasm, genetic fidelity testing, diversity analysis, monitoring of the allied genome during introgression, identifying QTLs etc. has been resolved through the routine use of molecular markers. The marker technology will be developed to characterise and manage the vast genetic resources available with the Institute. Candidate genes for specific traits will be identified from the available EST and genomic databases and through association mapping to develop trait specific markers for MAS. Molecular markers will be useful in effectively monitoring the introgression of wild genomes of *S.spontaneum, S.robustum, Erianthus* and *Miscanthus.*

Genome sequencing combined with bioinformatics will facilitate identification of genes, promoters and transcription factors associated with important traits like drought, salinity, cold/winter tolerance, disease and pest resistance. Expression profiling for important traits like sucrose accumulation at different stages of development will provide a proper understanding of the metabolic pathways of sucrose accumulation. Through the integration of transcriptomics and proteomics tools it will be possible to identify the genes controlling important traits like sucrose accumulation, resistance to biotic and abiotic stresses and enhance their expression.

The application of bioinformatics will be vital to the genome sequence comparisons and for the comparison of proteomes and metabolomes across the *Saccharum* species. Bioinformatics will also be useful in understanding the metabolic pathways associated with important traits to enable pathway level modelling and predicting the molecular modifications that can bring about favourable phenotypic changes in sugarcane.

Transgenics will be one of the major strategic options for the future for sugarcane varietal development. Transformation of sugarcane for enhanced expression of traits utilizing suitable promoters is one of the possibilities for increased yield and sugar content. Recent report on the development of sugarcane clones with significantly high levels of stored sucrose through the introduction of a sucrose isomerase (SI) gene tailored for vacuolar compartmentation holds promise as a strategy for improving sucrose levels. Major focus will be on development of transgenics for weedicide resistance, red rot resistance, yellow leaf resistance, drought tolerance, cold tolerance and high sugar. Identifying new genes and tissue specific promoters will be the basic requirement for achieving these goals. SBI has already identified an ubiquitin gene promoter which was found to have a high level of expression in both monocots and dicots. For red rot, the effort will be on expressing the antifungal peptides in the stem.

Exploration for novel Bt strains against Coleopteran and Lepedopteran pests will be the appropriate strategy for identifying new genes for management of these pests. Development of wound inducible promoters will be a potential approach in developing transgenics resistant to borer pests.

The high biomass potential of sugarcane can be exploited as a biofactory to produce high value molecules like therapeutics, vaccines, vitamins, industrial enzymes etc. in large scale. This is possible by developing technologies for expressing the genes of interest in sugarcane and targeting their storage in the vacuoles which will facilitate easy extraction and purification of the products from the juice.

Production of cellulosic ethanol from sugarcane bagasse will be a key factor in meeting the biofuel requirement of the country. The present technologies are not economically viable and more efficient technologies have to be developed for the economic production of cellulosic ethanol. This will involve developing efficient microbial strains which will convert ligno-cellulosic biomass to fermentable forms. Alternatively cheaper production of cellulolytic enzymes also will bring down the cost of production of cellulosic ethanol. Australian scientists have succeeded in expressing the cellulolytic enzymes in sugarcane which will facilitate large scale production of these enzymes.

RNAi is gaining significance as an emerging strategy in plant disease management. Target genes for silencing viral RNA with respect to pathogens viz. SCYLV, SCMV will be identified for developing virus resistant sugarcane transgenics. Further, developing knock-out mutants and their functional analysis and phenotyping will open-up the avenues for identifying pathogenicity related genes against the red rot pathogen, which will be validated in other important pathogens of sugarcane. The RNAi strategy will be useful for manipulating other important traits including drought and winter tolerance by suppressing the negative regulators associated with these traits. This technology can also be utilised in managing the post harvest reduction of sucrose by reducing the invertase activity at the maturity stage by stage-specific silencing of invertase gene.

Diseases and pests cause considerable yield losses and their management will be a priority. Many of the highly productive varieties had to be replaced because of their susceptibility to diseases and pests inspite of their superior performance. In this context apart from the deployment of resistant varieties, alternate strategies for disease and pest management need to be explored so that highly productive susceptible varieties also can be grown. Research on Systemic Acquired Resistance (SAR) to identify biomolecules that can induce resistance in susceptible varieties will be strengthened both in the case of diseases and pests. Identification of new Kairomonal principles and development of new formulations of sex pheromones will be the primary approach for the control of major pests like borers. Efforts to identify new bio control agents against major pests will be continued.

Optimising the yield of new and existing varieties through innovative crop management techniques is essential to realise their full potential. Site specific nutrient management is very important for the overall improvement in productivity across the country. The varietal, nutrient, water and other input requirements are highly variable for the different agro climatic zones. Besides, the biotic and abiotoic stresses that prevail across the locations also vary considerably. A comprehensive documentation of the data on various aspects of crop requirements across the agroclimatic zones will be required to evolve a suitable Web enabled, interactive, multilingual Sugarcane Decision Support System that will serve as an effective platform for technology transfer. Use of geo spatial techniques to assess and forecast the nutrient requirements of the crop and carry out site- specific application will be important in maximising the sugarcane productivity. Remote sensing technique coupled with digital data processing will enable the precise estimation of the total cropped area and the likely sugarcane production to suitably programme the cane development activities. Besides it will also help in estimating nutrient deficiencies and the occurrence of diseases and pests and to effectively manage the affected areas in time. A UN survey has recognised Nanotechnology to have potential applications in enhancing crop productivity in developing countries. In sugarcane, nanotechnology will be useful in the controlled release of agro chemicals and growth promoters to optimise productivity, soil health monitoring through nano-sensors, characterisation of soil minerals, management of soil rhizosphere etc.

Studies conducted in India, South Africa, Mauritius and Trinidad have shown that there will be significant reduction in yield due to rise in temperature and consequent moisture stress in sugarcane. In this context, studies on the likely impact of climate change on sugarcane growth and development, soil physical, chemical and biological properties, carbon sequestration etc. through simulation models and experiments assumes importance. Such studies will enable the development and deployment of technologies to mitigate the negative impacts of climate change.

The extension activities have to be made IT enabled and scaled up to match the evolving needs of the sector. Innovative approaches to harness the potentialities of ICT such as voice messages in local languages and mobile telephony (SMS) can reduce transaction costs and bridge time and space barriers in information delivery. Local networking of development departments for community interface meetings, periodical field monitoring visits, cross learning workshops, thematic workshops, on-site capacity building sessions at the village level will make the transfer of technologies faster and effective.

Strategy and Framework

The strategies for meeting the targets set for 2030 have been framed to ensure sustainable and stable sugarcane production in the country, taking into consideration the likely demand for sugar and other products, the emerging crop scenario with respect to domestic and global markets, sustainability of the crop in terms of economic returns, growing concerns on depletion of natural resources, impacts of climate change, new opportunities likely to arise and the advancements in frontier areas of science.

1. Genetic resources conservation and utilisation

a. Collection of sugarcane genetic resources from the distributional areas in the country. Acquiring species-germplasm from other countries.

b. Conservation of the germplasm collection through field maintenance and *in vitro* storage.

c. Phenotypic characterisation and allele mining of the germplasm.

d. Production and characterisation of new interspecific and intergeneric hybrids.

2. Improving the profitability and sustainability of the sugarcane crop

a. Development of high yielding, high sugared varieties, tolerant to biotic and abiotic stresses and suited to different agro-climatic conditions of the country through conventional and biotechnological approaches.

b. Development of suitable crop production technologies to improve income generation from sugarcane farming integrating various aspects of crop management like planting geometry, cropping system, weed management, site specific nutrient management and mechanisation.

c. Seed production and nursery management

d. Management of sugarcane diseases and pests through the development of appropriate technologies

e. Management of post harvest losses.

3. Improving the resource use efficiency

a. Development of technologies for moderating the use of water and nutrients.

b. Residue recycling, improving carbon sequestration efficiency, improving soil physical and chemical properties, rhizosphere engineering, organic cultivation of sugarcane.

c. Precision farming based on site specific management on a geo spatial platform, use of nanotechnology for improving input use efficiency, use of biofertilisers to conserve the use of chemical fertilisers.

4. **Development of sugarcane varieties and production technologies for use in byproduct industry**

a. Development of fuel-canes through interspecific and intergeneric hybridisation.

b. Technological evaluation and characterisation of the fuel-canes for biomass, energy potential and fibre.

c. Developing suitable agronomy for fuel canes.

d. Identification/development of novel microbes that can convert cellulosic material into fermentable sugars.

e. Bioengineering of sugarcane for the production of high value products like vaccines, therapeutics, vitamins, bioplastics and industrial enzymes.

5. **Studies on impact of climate change and its impact**

a. Studying the impact of climate change with respect to soil moisture stress, altered rainfall, elevated atmospheric temperature and CO2 content.

b. Changes in pest and pathogen dynamics and likely impacts on sugarcane production system and anticipatory research to locate sources of resistance to new pests and diseases that are likely to emerge.

c. Identification of sources for climate resilience in the germplasm and use of biotechnological tools for developing climate resilient varieties.

d. Developing management strategies to mitigate impacts of climate change.

6. **Dissemination of technologies, assessment of technologies with respect to adoption and impact and identifying technology gaps**

a. Use of conventional and IT enabled extension methods - cyber extension for rapid and effective dissemination of technologies.

b. Assessment of technologies transferred for their adoption using quantitative methods and refinement.

c. Assessment of impact of technologies on socio-economic terms

d. Identifying gaps in technology generation

e. Survey, documentation, validation and use of ITKs.

f. Capacity building in sugarcane sector by imparting training to cane development personnel and farmers.

7. **Technology Management**

a. IPR protection of varieties and other technologies developed by the Institute and commercialisation of the technologies through appropriate channels.

b. Management and optimised use of the biological diversity available in the country for the overall benefit of the society.

Epilogue

SBI is in the forefront of sugarcane variety development since 1912 and over 90% of the varieties cultivated in the country today have been developed either by the Institute or by the State Sugarcane Research Stations with the support of the Institute. However the crop scenario is fast changing and sugarcane is making a rapid changeover from a sugar-crop to sugar and energy crop. This necessitates significant increases in sugarcane production which is a stiff challenge in the wake of limited land area, depletion of natural resources, escalating cost of cultivation and the impacts of climate change. New opportunities are also emerging for the use of sugarcane as a bio-factory taking advantage of its huge biomass potential to produce a host of high value products in large scale.

The sugarcane production at present can barely meet the current domestic requirements of sugar and sweeteners and scaling up the sugarcane production to meet the sugar and energy requirements of 2030 needs significant increase in productivity and sugar recovery. Development of superior varieties and improved crop management technologies are vital in increasing the productivity of the crop to the projected levels. The breeding programmes have to be restructured with special emphasis on harnessing the strength of the large germplasm available and the power of biotechnology. The potential of geospatial techniques and nanotechnology has to be exploited in the management of the crop for enhanced productivity. Other factors that are likely to affect the productivity related to climate, environment and natural resources need to be addressed to ensure stability and sustainability in production. SBI is committed to remain responsive to the needs of the sugarcane farmers, sugar industry and the energy sector to bring in the required technological advancements in sugarcane research to meet these goals.

Annexure - 1: Strategic framework

Goal	Approach	Performance measure
Management of Genetic Resources for crop improvement	Collection of the genetic resources from India, accessing new germplasm from other countries, agro-morphological characterisation of the accessions, characterisation for disease/ pest resistance, allele mining, pre breeding through interspecific and intergeneric crosses, introgression of wild genomes	Availability of a well conserved, well characterised germplasm for utilisation in breeding Availability of potential sources for various attributes of importance Availability of new genetic stocks with broad genetic base for use in breeding
Evolving high yielding, high sugar, disease and pest resistant varieties suited for different agro-climatic regions of the country	Improving breeding strategies- use of pedigree management system, use of genetically diverse parents in crosses, MAS Strengthening the National Hybridisation Garden with diverse parents and new genetic stocks. Development of sugarcane transgenics for important traits	New improved varieties will be available for cultivation in different agro climatic regions. Productivity and sugar recovery will be improved Varieties that can withstand biotic and abiotic stresses will become available.
Molecular analysis of sugarcane genome	Development of trait specific markers, identification of QTLs identification of candidate genes, identification of promoters and genes associated with important	Improved varieties will be available through MAS and transgenic approaches with desired characters

Goal	Approach	Performance measure
	traits, expression profiling for important traits, sequencing of the sugarcane genome and generate a monoploid genome sequence of sugarcane, Transcriptome, Proteome and Metabolome analysis in sugarcane and engineering the metabolic pathways.	Improvement in biomass and sugar yield through metabolic engineering.
Developing improved, cost effective crop production technologies	Refining precision farming technologies for assessing crop requirements in different agro climatic zones and development of site specific input management systems. Development of nano formulations for efficient delivery and use of agro chemicals Development of effective Decision Support Systems on a geospatial platform. Developing intercropping systems suited to different zones to augment farm income. Developing variety specific management practices. Identifying varieties and suitable agronomy for mechanised sugarcane farming Developing cultural and chemical interventions to	Improvement in productivity and sugar recovery. Improvement in the profitability and sustainability of sugarcane production system. Will make sugar production in the country competitive

Goal	Approach	Performance measure
	improve sugar recovery. Rhizosphere prospecting and manipulation for improved productivity.	
Management of natural resources	Development of nutrient and water conservation technologies under varied soil and climatic zones. Development of water use efficient varieties Developing technologies for organic recycling in sugarcane production systems. Developing more efficient biofertiliser strains Improving soil physical properties.	Conservation of natural resources for the sustained sugarcane production. Reduction in cost of production.
Management of diseases and pests	Identifying sources of resistance for important diseases and pests among the germplasm and breeding pool Developing precise screening methods for wilt and YLD. Use of remote sensing technology for disease forecasting and management. Developing molecular diagnostics for major diseases. Use of genomics and Proteomics to address disease and pest related problems, identification of genes and proteins involved in resistance,	Reduced crop losses due to pests and diseases.

Goal	Approach	Performance measure
	use of RNAi strategy for the management of viral and fungal diseases. Evaluation of new generation fungicides/ novel SAR inducers for red rot and smut. Surveillance and monitoring of sugarcane pests and diseases. Creation of a nation-wide database on sugarcane diseases and pests. Developing a sugarcane disease-map for the country. Identification of new biocontrol agents and pheromones for management of pests.	
Evolving varieties and technologies for the by product Industry	Development of energy canes with high biomass and energy potential. Development of suitable management technologies for energy canes. Identification/development of novel microbes that can convert cellulosic material into fermentable sugars. Bioengineering of sugarcane for the production of high value products like vaccines, therapeutics, vitamins, bioplastics, antioxidants and industrial enzymes.	Supplementing the energy needs of the country Reducing green house emissions. Economic production of high value biomolecules

Goal	Approach	Performance measure
Assessing and mitigating the climate change impacts	Analyzing and interpreting the weather parameters over the years in relation to crop productivity. Visualizing the possible climate change scenarios in different cane growing regions and their impact on growth and productivity through appropriate models Developing climate resilient varieties integrating conventional and molecular approaches and developing suitable crop management technologies to mitigate the effects of climate change Study of substrate dynamics under elevated stress levels of temperature, water and CO2 and developing appropriate strategies. Epidemiological studies on pests and diseases under climate change scenario to assess potential threats and evolve appropriate management strategies.	Mitigation of the impacts of climate change to sustain higher productivity.
Capacity building	Creating infrastructural facilities and trained man power in frontier areas like biotechnology, bioinformatics, remote sensing, geo-informatics and nanotechnology.	Improved capabilities for research

Goal	Approach	Performance measure
Technology assessment and transfer	Conducting location specific techno-economic feasibility studies and up scaling the improved technologies in target domain. Use of conventional and cyber extension methods for effective transfer of technologies. Local networking of development department's local communities for capacity building, effective transfer of technologies. Training of development personnel and field staff for skill upgradation Documentation and validation of ITKs	Faster and effective dissemination of technologies Improved farm income.
Impact assessment of technologies and economic assessment of the sugarcane production trends and market access	Survey, collection and analysis of field data on the adoption of technologies and their socio economic impact Assessment and prediction of demand, supply and market trend with respect to the commodities using business forecasting models.	Availability of primary data for developing research priorities and strategies.

100 Years of Sugarcane Research

2011