Sugarcane: Challenges & Future Strategies for Doubling Farmers' Income

Souvenir

National Workshop
November 14, 2019

सत्यमेव जयते

भाकृअनुप
ICAR

भारतीय गन्ना अनुसंधान संस्थान, लखनऊ

Organized by

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

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Directorate of Sugarcane Development, DAC&FW, Lucknow- 226 024

Sugarcane: Challenges & Future Strategies for Doubling Farmers' Income

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सुरेश राणा
मंत्री
गन्ना विकास एवं चीनी मिलें
उत्तर प्रदेश

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कक्ष संख्या : 65-66
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लखनऊ

दिनांक : 11th Nov. 2019

Message

Sugarcane is an important commercial crop of India as well as Uttar Pradesh. The sugar sector plays a vital role in the socio-economic development by mobilizing rural resources and generating employment opportunities. Uttar Pradesh has the distinction of being the largest sugarcane producing State of the country by producing about 225 million tonnes of sugarcane with average productivity of 80.5 tonnes/ha. The state has also emerged as the largest sugar producing state of the country by producing 11.82 million tonnes of sugar with average recovery of 11.26% and has helped India in surpassing the Brazilian sugar production and attaining the status of the largest sugar producing country with 31 million tonnes of production.

It is a matter of immense pleasure to know that ICAR-Indian Institute of Sugarcane Research (ICAR-IISR), Lucknow in collaboration with Directorate of Sugarcane Development, Department of Agriculture, Cooperation and Farmers' Welfare, Ministry of Agriculture and Farmers' Welfare, Govt. of India is organizing a National Workshop on "Sugarcane Challenges & Future Strategies for Doubling Farmers' Income" at ICAR-IISR, Lucknow on November 14, 2019 to deliberate upon various R & D issues related to technologies for enhancing productivity of sugarcane, sugar, green energy and value added products, development programme / policy imperatives in Sugarcane and sugar sector and potential of sugarcane and sugar sector for doubling the farmers' income.

I hope that the event will provide a good platform to all the stakeholders for discussions and recommendations emerging from the Workshop would help in preparing a roadmap for achieving higher profitability of sugarcane farmers and sustainable development of sugar and integrated industries.

I wish the Workshop a grand success.

(Suresh Rana)
Minister for Sugar Industries & Cane Development
Government of Uttar Pradesh

सत्यमेव जयते

त्रिलोचन महापात्र, पीएच.डी.
सचिव, एवं महानिदेशक

TRILOCHAN MOHAPATRA, Ph.D.
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001

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Message

I am pleased to learn that ICAR-Indian Institute of Sugarcane Research. Lucknow and Directorate of Sugarcane Development (Under Ministry of Agriculture and Farmers' Welfare, Govt. of India), Lucknow are jointly organizing a National Workshop on "Sugarcane: Challenges & Future Strategies for Doubling Farmers' Income" at ICAR-IISR, Lucknow on November 14, 2019. During this Workshop, R & D issues related to technologies for enhancing productivity of sugarcane, sugar, green energy and value added products, development programme/policy imperatives of the farmers will be discussed.

Sugarcane being world's number one crop in terms of harvested tonnage is cultivated on about 26 million hectares of land in more than 90 countries and provides 80% of the world's sugar and 40% pf ethanol as the primary sugar and biofuel feedstock crop. India has emerged as the largest sugar producing country of the world with increased production and productivity of sugarcane. Sugarcane as most important cash crop of the country has tremendous potential to contribute in big way to enhance or double the income of the farmers. I compliment the organizers for organizing the Workshop on such a relevant theme to discuss various issues involved in sugarcane and sugar sector of the country.

I am sure that the Workshop will provide a common platform to all the stakeholders in sugarcane and sugar sector to discuss in length the various issues involved in sugar production which need immediate redressal for sustainable growth of the sector and enhancing profitability of the farmers.

My best wishes for the entire endeavour.

(T. MOHAPATRA)

Dated the 4th November, 2019
New Delhi

Shubha Thakur
Joint Secretary

सत्यमेव जयते

भारत सरकार
कृषि एवं किसान कल्याण मंत्रालय
कृषि, सहकारिता एवं किसान कल्याण विभाग
Government of India
Ministry of Agriculture & Farmers Welfare
Department of Agriculture, Cooperation
& Farmers Welfare

Message

Sugarcane is the second most important Commercial Crop grown in India. It is grown in about 5 million hectares in both tropical and sub tropical regions covering 3% of total cultivated area of the country. Globally India occupied second largest Sugarcane producing country, next to Brazil. A wide range of products have been developed from Sugarcane viz., Sugar, Jaggery (Gur), Brown sugar (khandsari), various bio-products like bagasse (used as fuel, Compressed fiber board, Paper, plastics) & molasses (used in distilleries for manufacturing of ethyl alcohol, butyl alcohol, citric acid), press mud cake for soil amendment in saline & alkaline soils. About 8 million farmers of the country are engaged in cultivation of Sugarcane crop.

The present scenario of Sugarcane revealed that the production and productivity has been increased in recent past years mainly due to improved varieties and efforts of developmental organizations. Various programmes are also being implemented for promotion/development of Sugarcane including NFSM-Commercial crop (Sugarcane). Intercropping of Pulses with Sugarcane and also under RKVY. Many challenges still to be addressed such as drought/ moisture stress in central and southern states, floods in many states in recent years affects the area and production which warrants the need of suitable remedies.

Sugarcane crop will definitely play important role in doubling the income of farmers if cope-up with the other sector of agriculture. The National Workshop on "Sugarcane: Challenges & future strategies for doubling the farmers income" going to be held on 14th November, 2019 will prove a common platform for researchers, development officials and Sugar industry to develop effective strategies towards sustainable growth of this sector and for betterment of farming community.

I appreciate the efforts made by the Directorate of Sugarcane Development, Lucknow and Indian Institute of Sugarcane Research, Lucknow for organizing the workshop and bringing out the Souvenir. I wish them grand success in future endeavors.

Shubha Thakur

(Shubha Thakur)
Joint Secretary (Crops/Oilseeds)

New Delhi
Dated the 5th November, 2019

डा0 अश्विनी दत्त पाठक
निदेशक
Dr Ashwini Dutt Pathak
Director

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Message

The Indian Sugar Industry, a key driver of rural development, is an important agro-based industry which is witnessing exciting developments with the highest ever sugar production and diversification towards other bio-based products. The sustainability of the crop and the industry is being influenced by the number of challenges faced by the industry which need to be addressed through technological and other interventions for the sugar and integrated industry to remain more profitable and sustainable.

It gives me immense pleasure to be associated with the National Workshop on "Sugarcane: Challenges & Future Strategies for Doubling Farmers' Income" being organized at ICAR-Indian Institute of Sugarcane Research (IISR), Lucknow on November 14, 2019 in collaboration with Directorate of Sugarcane Development, Lucknow to discuss various facets of R & D involved in sugarcane and sugar production in an interactive manner to chalk out a road map for successfully overcoming the emerging challenges and increasing the farmers' income.

I am sure that the Workshop will provide a platform for all the stakeholders to deliberate on the various issues and challenges for a profitable and sustainable development of the Indian Sugar Industry along with increasing income of the sugarcane farmers which will ultimately be helpful in improving the standard of living of millions of farmers.

I wish the Workshop a grand success.

(A.D. Pathak)

November 11, 2019
Lucknow

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Dr A.K. Sah
Organizing Secretary
National Workshop-2019

भाकृअनुप–भारतीय गन्ना अनुसंधान संस्थान
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Message

It's my proud privilege to be associated with organization of National Workshop on "Sugarcane: Challenges & Future Strategies for Doubling Farmers' Income" being jointly organized by ICAR- Indian Institute of Sugarcane Research, Lucknow and Directorate of Sugarcane Development (DAC & FW), Lucknow on 14th November, 2019 at ICAR-IISR. As we know that sugarcane improvement programes and better management practices have contributed substantially in increasing sugarcane and sugar production in the country during last 2-3 years. This crop is a potential source of green energy production and transforming socio-economic condition of 6 million farm families involved in cane cultivation and about 0.6 million skilled workers employed in sugar industry.

The unparallel success achieved due to advent of green revolution has made the country not only self-sufficient in food, but also a net food exporting nation. Despite of this accomplished scenario, the income of majority of farmers remained low and rampant poverty prevailing in rural areas is manifestation of that. Realising the need to pay special attention to the plight of farmers, the Central Government in its 2016-17 budget, gave enough policy thrust on income security proposing to double the farmers' income by 2022-23 (*i.e.* 75th year of Independence).

In this ambitious target of doubling farmers' income, sugarcane sector can play vital role. This crop occupies a pre-eminent position in the Indian Agricultural scenario on account of its wider adoption in the agro-climatic conditions of the country. In India, sugarcane is one of the most important agro-industrial crop grown in about 5.0 million hectares area and occupying 3% of gross cropped area. The turnover of the sugarcane and sugar related economic activities is in the range of ₹ 800-850 thousand millions per annum, out of which around ₹ 550-600 thousand millions accrues to the sugarcane farmers of the country. The sugar industry in India has been instrumental in accelerating the socio-economic development in villages through mobilizing rural resources leading to generation of employment, increase in income and overall improvement in facilities for transport and communication.

The workshop will provide common platform to all the stakeholders in sugarcane and sugar sector to discuss in length the varying issues which need to be addressed for enhancing profitability of the farmers and industry.

On behalf of the Organizing Committee, I extend warm welcome to all the delegates and hope outcome of deliberations will be helpful in deciding future strategies.

(A.K. Sah)

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LEAD PAPERS

Sugarcane sector in sub-tropical India: Present status and way forward

A.D. Pathak
ICAR-Indian Institute of Sugarcane Research, Lucknow 226 002

Sugarcane is grown in about 26 million ha in the world with total production of nearly 1900 million tonnes *(FAOSTAT 2018).* Approximately, 75% of total sugar production comes from sugarcane and the rest from sugar beet. More than 115 countries cultivate sugarcane with total sugar production of 171 million tonnes. India has emerged as the largest sugar producing country followed by Brazil. Besides, sugar as major product, sugarcane is also used as raw material for value added products like feed, fibre and energy, especially bio-fuel and co-generation. The crop being one of the most efficient converter of biomass to energy and thereby an excellent source of bio-fuel production, there has been heightened focus on sugarcane cultivation, sugar trade and other related products at national as well as global level. Out of total global sugar output, developing nations contribute approximately 70-75% of the production. In majority of developing countries, sugar production is mostly consumed domestically except in Brazil where annual growth has enabled the country to turn its attention towards sugar export market.

Global sugarcane production was nearly 260 million tonnes from 6.3 million ha area, with average productivity of nearly 41 tonnes per ha during 1950's. In 1980's, world annual sugarcane production had reached up to 770 million tonnes with the average yield of 57 tonnes per ha. In another three and half decades time, world sugarcane production achieved the new height by more than two fold production increase to 1900 million tonnes from area of 26 million ha. In nutshell, global sugarcane production had enhanced nearly seven times during past seven decades. The sugarcane area and productivity also improved 4.0 and 1.85 times, respectively with average sustained CGR of nearly 1.1 per cent per annum during 1960-2017 (*FAOSTAT 2018*).

The perusal of world sugar estimates for the year 2017-18 revealed that world sugar production has been declining since 2013-14. Global sugar production which was 175.7 million tonnes during 2013-14 has been reduced to 174.3, 173.4, 170.9 and 147.0 million tonnes, respectively during 2014-15, 2015-16, 2016-17 and 2017-18, respectively. It was expected that sugar production will further decline to 138.0 million tonnes next year due to forecast of decline in sugarcane production due to reduced average yields after less rainfall than expected in major sugarcane growing countries. Brazil is the largest exporter of sugar followed by Thailand and Australia. China, European Union, Indonesia, USA and UAE are the major sugar importing countries in the world.

Although, India had emerged as 4^{th} largest sugar exporting nation since year 2015-16, with the share of 4.55% in total sugar export. The major export destinations for Indian sugar were Myanmar, Somalia, Sudan, Sri Lanka and UAE. Due to sustained higher sugar production in India, thus, negligible amount of sugar was imported from global market under quota system.

Indian sugar industry is quite vibrant, supports approximately 6.5- 7.5 million farmers through sugarcane cultivation and other related industries. This crop is cultivated on about 5 million ha i.e., 3.52% of net sown area and produces approximately 350-380 million tonnes sugarcane with average productivity of 70 tonne per ha. The area, production and productivity of sugarcane in India during 1950-51 to 2017-18 given in Table 1, clearly revealed the continuous upward trend. Although national average productivity has been hovering around 80 t/ha, tropical states recorded higher productivity ranging from 80 to 105 t/ha.

Table 1 : Area, production and productivity of sugarcane in India

Year	Area (000 ha)	Production (000 tonnes)	Productivity (t/ha)
1950-51	1707	69220	40.5
1960-61	2456	110544	45.0
1970-71	2615	126368	48.3
1980-81	2667	154248	57.8
1990-91	3686	241046	65.4
2000-01	4316	295956	68.6
2010-11	4885	342382	70.1
2017-18	5042	411000	81.5

The perusal of the data embodied in Table 2 on area, production and productivity of sugarcane in major sub-tropical states of India like Uttar Pradesh, Bihar, Punjab, Haryana and Madhya Pradesh revealed an upward trend during last decade. Only in Uttarakhand, area under sugarcane has been decreased during last decade but production and productivity of sugarcane has been enhanced during the same period.

Table 2 : Area, production and productivity of sugarcane in major sub-tropical states of India

Year	Area (000 ha)	Production (000 tonnes)	Productivity (t/ha)
Uttar Pradesh			
2008-09	2084	109480	52.3
2009-10	1977	117140	59.3
2010-11	2125	120545	56.7
2011-12	2162	128819	59.6
2012-13	2212	132427	59.9
2013-14	2228	134689	60.5
2014-15	2141	133061	62.1
2015-16	2169	145385	67.0
2016-17	2160	144783	67.0
2017-18	2198	159722	72.7
2018-19	2794	224920	80.5
Bihar			
2008-09	112	4960	44.3
2009-10	116	5033	43.4
2010-11	248	12764	51.5
2011-12	218	11289	51.8

2012-13	250	12741	51.0
2013-14	258	12882	49.9
2014-15	254	14034	55.3
2015-16	244	12649	51.8
2016-17	242	15416	63.7
2017-18	247	14269	57.8
Punjab			
2008-09	81	4670	57.7
2009-10	60	3700	61.7
2010-11	70	4170	59.6
2011-12	80	5653	70.7
2012-13	83	5919	71.3
2013-14	89	6675	75.0
2014-15	94	7039	74.9
2015-16	90	6607	73.4
2016-17	88	7252	82.4
2017-18	95	7721	81.3
Haryana			
2008-09	90	5130	57.0
2009-10	74	5335	72.1
2010-11	85	6042	71.1
2011-12	95	6959	73.3
2012-13	101	7437	73.6
2013-14	102	7499	73.5
2014-15	97	7169	73.9
2015-16	93	6692	72.0
2016-17	102	8640	84.7
2017-18	114	8729	76.6
Madhya Pradesh			
2008-09	71	2975	41.9
2009-10	62	2535	40.9
2010-11	65	2667	41.0
2011-12	69	2677	38.8
2012-13	59	2642	44.8
2013-14	73	3173	43.5
2014-15	111	4567	41.1
2015-16	103	5281	51.3
2016-17	92	4730	51.4
2017-18	83	3670	44.2
Uttarakhand			
2008-09	107	5590	52.2
2009-10	96	5842	60.9
2010-11	107	6498	60.7
2011-12	108	6311	58.4
2012-13	110	6785	61.7
2013-14	104	5940	57.1
2014-15	102	6165	60.4
2015-16	97	5886	60.7
2016-17	93	6477	69.6
2017-18	86	5981	69.5

The data on number of factories in operation, average actual capacity, total cane crushed and recovery of sugar depicted in Table 3 also revealed increasing trends. Sugar production has also been increasing continuously, touching a new height of 32.47 million tonnes during 2017-18 (Table 4). India's sugar production has increased in last 10 years at CAGR of 2.63 per cent. During the same period, India's sugarcane production has increased at CAGR of 2.40 per cent and area under cultivation at CAGR of 3.19 per cent. Molasses production in the country has also been recording upward trend. (Table 4).

Table 3 : Number of factories in operation, average annual capacity, total cane crushed, recovery of sugar and average duration of the mills in India

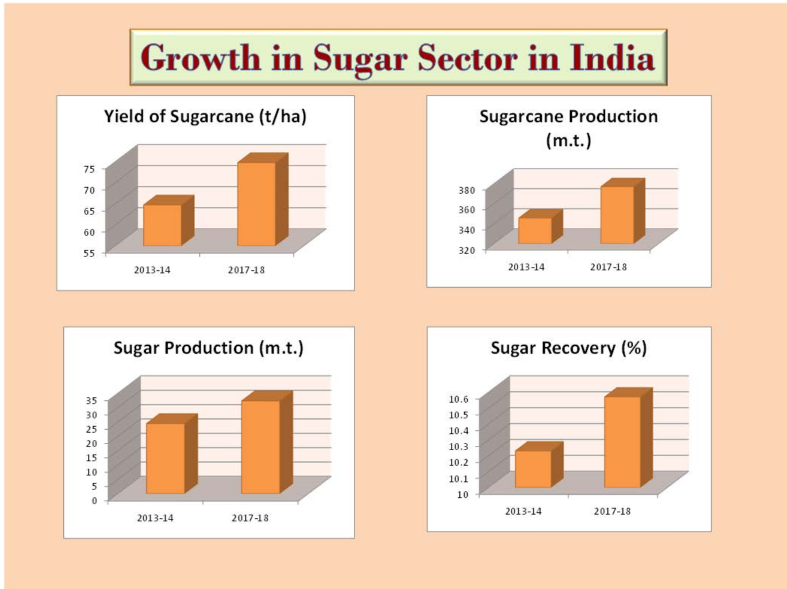
Year	Number of factories in operation	Average actual capacity (tonnes) per 24 hours	Total cane crushed (000 tonnes)	Recovery of sugar (% cane)	Average duration (days)
1950-51	138	859	10971	10.03	101
1960-61	173	1175	31109	9.74	167
1970-71	216	1408	38204	9.78	137
1980-81	314	1707	51598	9.98	105
1990-91	385	2088	122319	9.85	166
2000-01	436	3180	176651	10.48	139
2010-11	527	3650	239807	10.17	136
2017-18	525	4488	302427	10.74	140

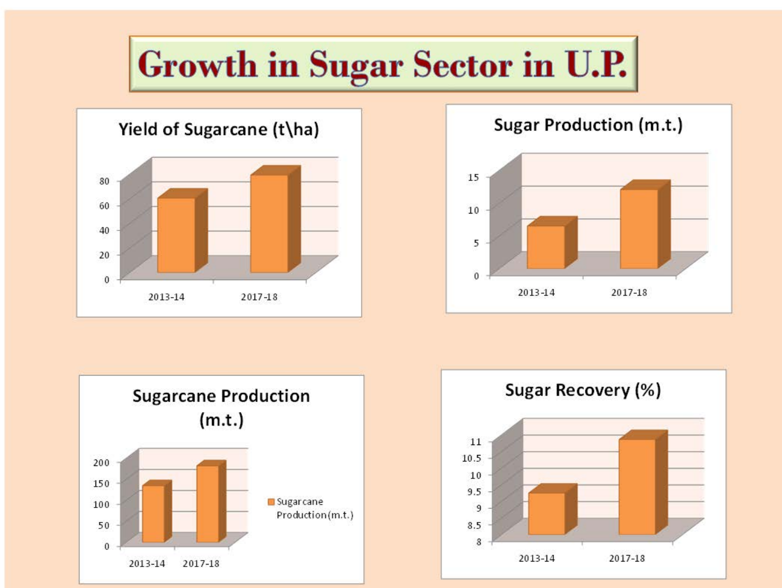
Table 4 : Sugar and molasses production in India

Year	Sugar production (000 tonnes)	Molasses production (000 tonnes)
1950-51	1101	402
1960-61	3028	1240
1970-71	3740	1620
1980-81	5147	2126
1990-91	12046	5444
2000-01	18519	7820
2010-11	24394	10970
2017-18	32479	14063

The year 2017-18 was good year for sugar production in India recording the highest ever sugar production of 324.79 lakh tonnes. Uttar Pradesh produced the highest ever 120.5 lakh tonnes of sugar during 2017-18 and the longest crushing period was recorded by sugar mill. Maharashtra produced 106.5 lakh tonnes of sugar. About 36.3 lakh tonnes of sugar was produced by Karnataka. Sugar production in Bihar, Punjab and Haryana reached record levels in their history at 7.10 lakh tonnes, 8.0 lakh tonnes and 7.25 lakh tonnes, respectively. Other states like Gujarat, Tamil Nadu, Andhra Pradesh and Telangana produced 10.90, 7.10 and 5.30 lakh tonnes of sugar, respectively.

Growth recorded in sugar sector in India and Uttar Pradesh during last five years (2013-14 to 2017-18) has been depicted in following bar diagrammes:





The sugar recovery is hovering around 10.5% for the past decade with maximum recovery of 12.4% in Maharashtra. There are two distinct sugarcane growing zones in India – the tropical zone (contributing 45% of total sugarcane area) and sub-tropical zone (contributing 55% of total area). The average sugarcane productivity in the sub-tropical zone was lower (nearly 72 t/ha) as compared to the tropical zone (approx. 85 t/ha). India is a major producer as well as consumer of sugar in the world with annual sugar production of 25-32 million tonnes. Indian sugar contributes nearly 15-

17% to global sugar production. 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.

It is estimated that India may require nearly 51 million tonnes of white sugar by 2050 for 1.65 billion population of the country at the rate of per capita consumption of 35 kg /year. 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% 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 million hectare. Sugar beet 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.

This year, the Govt. has also allowed ethanol production directly from sugarcane juice, to avoid surplus sugar production. This permission will pave the way for its blending with petrol and will be helpful in saving lot of precious foreign exchange on import of crude oil. For this, the sugar industry will require the varieties suitable for higher biomass.

Major challenges in sugarcane cultivation

With its present level of sugarcane and sugar production, we may be satisfied for the self sufficiency in meeting the internal demands of sugar and other sweeteners. In spite of that, there are a large number of challenges 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. The non-availability of favourable factors of growth, fast declining factor productivity in major cropping systems and rapidly shrinking resource base are the major challenges to meet the future demand of food, highlighting the need 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 management of water for the cane cultivation is the major area of concern. The irrigation efficiency estimated at around 30% needs to be raised to at least 50% which would be helpful in contributing immensely in enhancing 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 the farm sector. The aberrations like intra-seasonal variability of rainfall and extreme events and unseasonal rains cause heavy losses to sugarcane production every year and results in cyclic movements in sugar prices. This highlights the speeding up of 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*. There is hardly any possibility of bringing additional area 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 with the further assumption of availability of additional area from intercropping of other crops in a sugarcane based cropping system. Thus, the target of sugarcane production has to be met primarily by increasing the productivity and quality of the crop. The average productivity level needs tremendous boost by crossing 100 tonnes/ha mark. 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 liberalization in industrial sector has resulted in more number of sugar mills and consequently 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 water requirement of sugarcane crop is very high and it accounts for nearly 30 per cent of the 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

India is yet to tap the vast potential of it's rich diversity with respect to sugarcane germplasm to our advantage. Limited utilization of basic germplasm (at the species level) in India has 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 over the years. Tapping of the huge available genetic potential will be helpful in breaking both the barriers of sugar recovery and yield.

Varietal spectrum of sugarcane varies from state to state and from region to region depending on the location specific suitability of a particular variety. Large number of excellent varieties developed in the past has ruled the sugar industry, but were gradually phased out due to various factors like varietal decline, susceptibility to biotic and abiotic stresses *etc*. Quick replacement of the old and denotified varieties can help in sustaining sugar productivity at the existing level. Considerable time elapses before the variety covers sizeable area (even in case of availability of suitable replacement) due to slow rate of seed multiplication in sugarcane and lack of an organized quality seed production and replacement system in this crop.

Issue of sustainability

The issue of sustainability is of prime importance which is very closely linked with the maintenance of productivity potential and soil health. Sugarcane being a long duration crop with large canopy, 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 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. Fertilizers and irrigation like essential production inputs always remained the major bottlenecks 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 bottlenecks, 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 sub-tropics and therefore, sub-tropical cane varieties remained more climate resilient than the tropical cane varieties. Agronomic practices such as planting geometry, fertilizer application, irrigation scheduling, and cultural operations that sustain a higher shoot population might break the present yield barrier and may enhance 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

Biosecurity has a direct relevance to sustainability in agriculture and providing crop insurance to growers, as it 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 helpful in overcoming the adversities of nature. Moreover, crop diversification through intercropping of short duration crops in sugarcane can mitigate the monetary loss of growers. There is a need to develop minimum 4 to 5 varieties for a location or zone for avoiding the risks involved in monoculture of single variety. Development of bio-intensive measures will also be helpful in warding off the population of natural enemies of insect-pests.

Mechanization

Around 50% of the operational cost of sugarcane production is spent on manual labour who works right from preparatory cultivation to harvesting. Being a long-duration crop of 12 months and its planting spreading the period between October and May, sugarcane requires about 250 to 400 man-days labour per ha as most of the operations are carried out manually and mechanization is mostly limited to field preparation prior to planting. To address the issue of the labour scarcity and for ensuring timely farm operations along with the reduction in human drudgery, mechanization of cane agriculture from planting to harvesting and loading is necessary which will also improve the overall energy use efficiency of the sugarcane-based farming.

Intensive research efforts are required to enhance 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.

Way Forward

To achieve the desired growth in area, productivity and recovery of sugarcane in different agro-ecological zones of the country and to extent appropriate information and technologies to the end users, the issues of low levels of cane yield and sugar recovery, high cost of cane cultivation and decline in factor productivity need to be addressed vigorously. We should be 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. For achieving the targeted goals, we should focus ourselves on development of cost-effective, profitable and sustainable agro-techniques for improved plant and ratoon productivity, mechanization to suit location specific needs of small and marginal farmers, 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, conventional and non-conventional approaches to enhance cane yield, sucrose content, red rot resistance, tolerance to abiotic stresses and thermo-insensitivity, location-specific bio-intensive crop-protection strategies, climate change mitigation strategies including development of climate resilient varieties, crop production and diversification *vis-a-vis* value addition for enhanced profitability and sustainability, technology assessment, transfer and refinement, impact assessment of technologies and capacity building of scientists and other staff.

With the increase of domestic demand and consolidation of ethanol as sustainable and competitive alternative energy, investment in innovative technology is paramount to guarantee sustainability of Indian biofuel industry. About 625 million tonnes of agricultural residues (biomass) is produced each year in our country, of which about 150 million tonnes can be available for industrial use. Therefore, this constitutes a sustainable and "green" bio-source of organic raw materials, chemically; the lignocellulosic biomaterials to supplement petroleum based liquid biofuels. The future plans for sustainable technology for energy and bio-molecules production shall include development of energy cane for round the year supply of feedstock to distilleries for bio-ethanol production; reduction of the large technological gap between first-generation, land-intensive feedstocks and second-generation, capital-intensive biofuels; fostering R&D investments in agricultural technologies with financial supports for conducting pilot scale trials, including genetic improvement of sugar crops and new machinery/equipments dedicated to production of sugar crops and establishment of proper mechanism for production, collection, transportation and handling of biomass feedstock, allowing the country to become a player in second-generation biofuel production. It is also suggested to explore on site production of feedstocks and biofuels so as to aid farmers income without depending on industry, promoting sugar beet as intercrop in sugarcane cropping system in addition of small diffusion units in sugar factories having distilleries for sugar beet processing for ethanol production, building integrated plants to replace up to 35% raw material input with feedstock in current ethanol plants and cellulosic plants to focus on low-lignin agricultural waste feedstocks-corn stover, wheat straw, sugarcane bagasse, sugar beet for increasing 2G ethanol production along with setting up of commercial plants/biorefineries for scaling up biofuel and new by-products production with ready-to-go technologies is need of the hour. Facilitation of technology transfer requires strengthening for promoting cooperation and collaboration between domestic and foreign organizations, stimulatation of scientific studies and technological innovations for ensuring the long-term sustainability of second generation production, attracting investments for sustenance of ethanol recovery through development of sugar crops under intercropping systems; encouraging and providing flexibility for market players that operate biorefineries for targeting multiple markets that should include materials, feed, food, and energy - both domestically and internationally; incorporating lessons from sustainability criteria applied for first-generation biofuels into near and midterm sustainability provisions or labels for advanced biofuels; continuously promoting technical dialogue among different production regions of advanced fuels in order to ensure compatible standards for feedstock and promote trade in advanced biofuels and promoting sustainable utilization of sugarcane based ligno-cellulosic resource (sugarcane bagasse and trash) as “an inexpensive round the year available feed stock for production of ethanol” coupled with cost effective delivery at the plant site” and initiating Indo-Brazilian Agro Energy Plan for combining best Brazilian technologies with India for optimal sugar crops value chain focusing on biofuel, high efficiency electricity generation and carbon emission reduction targets will go a long way for the sustainability of Indian biofuel industry.

Sustainability of sugar industry in northern India - Sugar & beyond

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ABSTRACT

Amidst all challenges relating to demand-supply imbalances, cane price fixation mechanism, cost of production vis a vis revenue pot in sugarcane value chain, production of high-quality sugars to compete in the global and international market, changing dietary patterns and drift in the consumer preferences has indeed led the industry to think beyond sugar towards product innovation viz. cane juice preservation, special sugar production, smart packaging and branding of sugar, production of low GI, multivitamin sugars, fortified, flavoured and other special sugars, production of edible molasses etc., thereby achieving a good nutritional status. Production of other innovative value added products from sugar factory resources i.e. bagasse, filter cake and molasses is essential for a economically stable, self-sustained industry. Advances in research and development of novel technologies are required for economic and sustainable conversion of the industry's resources into energy and value-added products which ultimately support the development of agro-based industrial sector with a more profitable, sustainable and environmentally responsible sugar system.

Keywords: Urbanization, Nutritional status, Fortification, Sustainable

Introduction

Indian sugar industry as a whole faces critical economic sustainability issues on & off and. Till couple of years back, the sugar factories in northern India used to feel the heat to a greater extent owing to lower recovery of sugar and higher sugarcane prices. There are several internal and external factors governing the prices of the sugar in the market resulting in sugar prices which are not lucrative all the time. Relatively lower and wavering profits for sugar and at times the losses, issues relating to disposal of surplus sugar, recent trends to produce renewable bio-based products in replacement of those derived from petroleum sources thereby reducing stress on environment and increasing consumer demands for 'green products' are putting immense pressure on the sugar industry to diversify its strategies for economically and environmentally sustainable future. There are immense possibilities and challenges for sustainable innovations in times to come whose potentials are yet to be harnessed to the maximum possible extent. Industrialists, technocrats and engineers play a vital role in bringing a radical change towards a smarter and profitable society with improved 'quality of life' for all stakeholders involved.

It is evident that there is a greater urge to produce sugar in a sustainable way keeping in view the quality requirements for both national and international market is mounting on all parts of the value chain, from producers through to consumers. In regard to this, there is a need for the sugar industry to shift from the conventional routes of producing only sugar of a particular quality into having assorted products of superior quality that would not only prove befitting to the industry but also would satisfy the wants of the consumers at the same time keeping pace with the competition in the anticipated market. It is to be kept in mind that out of the total sugar production in the country, about 60% is consumed by the bulk consumers and about 40% is meant for direct consumption.

India now accounts for being the largest sugar producing geography with production of around 33 MMT. Sugar is highly fungible with comparatively small portion of production being amenable to special sugar market. Currently, Indian sugar industry is in the phase of excess sugar production to the extent of 6.5-7.0 MMT, carrying sugar surplus of about 14.2 MT at the end of season 2018-19 after due considerations for sugar exports of about 3.5 MT. Policy interventions for facilitating sugar export, fixation of 'Minimum Selling Price' of sugar, differential pricing policy for ethanol by the government has helped the sugar industry but there is a long way to go for achieving economic stability & sustainability in times to come. The need of the hour is for better allocation of the present resources in making assorted product line that provides the industry as a cushion for its better survival.

Change is a part of life therefore, up-gradation of the existing technologies for cleaner, greener processing, plant and process expansion for greater deal of value-added products is the right call the sugar industry technocrats must take without any second thought, with a holistic approach to achieve cleaner, greener, natural and nutritive product, process and policy. Innovations like sugarcane juice preservation, fortified sugars, multi-vitamin sugars, low GI sugars, use of filter cake for the production of Bio-CNG, cane wax, trade of molasses as edible molasses, molasses/ethanol-based chemicals, use of bagasse for particle board manufacturing, as dietary fiber, surfactants, eco-friendly cutlery in addition to co-generation, production of bio-plastics etc. would not only be beneficial for the industry but will also act as a win-win situation for both the consumers who happen to be the main driving force for revenue generation and also these innovations would have no harmful impact on the environment.

In light of the above-mentioned scenario, the paper provides a review of the possibilities and innovative approaches and solutions that the future holds for the sugar industry in the northern India in times to come so as to remain economically viable, self-reliant and self-contended.

Beyond Sugar - Sustainable approaches towards value-addition

In line with the shared vision of moving forward, the sugar sector has a number of transformational opportunities which have remained largely untapped. The industry has the potential to cater to the large and growing domestic sugar market as per its requirement and emerge as a self-sustained industry by providing better products and creating value addition. Some of such innovative approaches are discussed herewith:

Sugarcane Juice Preservation

The complex attitude of consumers towards food commodities often linking food to health has caused a tremendous shift in the market. A study conducted by grand view research in 2018 indicates that the Indian soft drink industry since past two years has seen growth (CAGR) @ 11% and 5% in terms of value and volume respectively with around 5.9 billion liters of soft drinks being consumed in a year. Studies also report that non-alcoholic beverage market has a value of about USD 3,266 million in 2018 and is further expected to grow at a CAGR of 17.6% till 2020 [1].

With the increasing rates of obesity, on the behest of World Health Organization (WHO) many countries have imposed sugar tax on drinks containing sugar. For instance, introduction of 10.0% tax on sugary beverages in Mexico led to 6.0% average reduction in its purchase during 2014 [1]. It is obvious that it would affect the consumption rates of carbonated drinks over the subsequent years. Likewise, with the changing lifestyle and eating habits of the consumers, it has been observed that there has been a switch towards fresh juice drinking habit, and the market has seen a decrease in sales of carbonated drinks in various countries [2]. While the market for energy drinks is expanding and is expected to grow further, the drink manufacturers have a challenge of supplying drinks that consumers feel are safe to consume as there has been a lot of discussion on ill effects of such drinks and health risks associated with them. As per the report published by Ministry of Food Processing Industry in 2017, natural health drinks are considered to be one of the fastest growing sectors in FMCG market with annual growth of about 22% [3].

Sugarcane juice is considered as a traditional natural health drink which has a potential and assured market looking to its benefits and liking amongst the consumers. Out of the envisaged routes, bottling of natural sugarcane juice or cane juice fortified with ginger and lemon etc. is considered as a very promising approach for sustainable market in present times. Being rich in iron, calcium, potassium, proteins and carbohydrates, sugarcane juice has several benefits such as – it acts as a diuretic and helps maintaining proper functioning of the kidney. Sugarcane juice is also reported to help strengthening liver and thus it is used as a remedy for jaundice. Further, being rich in minerals, sugarcane juice helps in preventing tooth decay [4].

Sugarcane juice gives instant kick of energy and also suppresses thirst and hence is a very popular drink in summers. Despite being rich in sugar content, sugarcane juice is good for diabetic patients, reason being that it contains natural sugars that have a lower glycemic index thereby preventing sudden rise in blood glucose level. Therefore, sugarcane juice may act as a substitute of aerated drinks for diabetic patients. However, type-2 diabetic patients must consult with the doctor before consumption and should keep the intake to a minimum. Sugarcane juice is also very essential when it comes to the skin health. Glycolic acid present in sugarcane juice helps prevent ageing, keeps the skin hydrated reduces blemishes and acne. While there are several advantages of sugarcane juice, it is important to ensure that the extraction of the juice is done in a hygienic manner. Therefore, the industry may focus on processing and packaging of sugarcane juice keeping the shelf life and conscious consumers in mind [5,6].

Speciality Sugars

Sugar is used as an additive in various food applications. Demand for ‘green labelled’, ‘natural ingredients rich’ food products is gaining favor in national and international market and with strong healthier and natural food consumer base, the demand is expected to grow in the anticipated market. With sugar industry having surplus sugar in hand, diversion of this excess lot towards production of speciality sugars may be one of the favourable approaches towards value-addition.

Industrial sugar has a huge market for industries like bakery, dairy, confectionery, beverages, canned & frozen foods etc. Amongst them, confectionery is said to be the largest and the most fast growing sector because of its variety of application and broad spectrum of products such as marmalade, chewing gum, sweets, candied nuts, chocolates, and chewing gum. Increase in confectionery industries, rapid inclusion of specialty sugars in various cuisines and availability of hundreds of varieties are boosting the market of specialty sugars at a healthy CAGR. Technological advancements and growing population significantly contribute towards the growth of the specialty sugar market in global perspective.

With the modern concept of value-addition, speciality sugars are emerging as a swing and also acting as a brand value for the companies. Specialty sugars are high quality high premium sugars with increasing domestic (approximately 250000 MT per annum) and worldwide demands. Various kinds of special sugars such as breakfast sugar, caster, icing sugar, cube sugar, natural cane sugar, various kinds of brown sugar, pharma sugars may give rise to an incredible opportunity for companies to substantially drive their profits [7]. Production of various kinds of flavoured sugars like orange, ginger, lemon, butterscotch, cinnamon etc. has immense potential due to their wide range of application such as use in bakery recipes, candy making and many more. It can also be used in coffee bars, dessert toppings, sugar bulk bars, baking, salads, cocktails, mocktails and coating of various products. To further add to the shelf, value-addition to sugar, considering the nutritional aspect of the consumers, sugars such as low-GI sugar or multivitamin sugar can also boost up the market of specialty sugar [8]. Innovations in food science & technology that not only addresses the escalating demand for food but also come up with new products, processes, and packaging developments in the food business and balance taste with nutrition is the need of the hour. Keeping this in view, one such possible innovation could be co-crystallization of sugar with nutrients. Such approach offers flexible, simple and economic means of value addition. This encapsulation technique provides a practical means to enhance the properties of the original material and therefore enhance the product line of the industry.

Jaggery

The never ending demand for food has been greatly influenced and steered up by emergent trends in food processing sector, particularly with the growing focus on health and wellness of the consumers. Modernization in food technology that not only cater to the substantial increase in the demand for nutritious food but also that brings in novelty products, processes and packaging to the existing culture of manufacturing in the industry is the need of the hour. Approaches like these would give a tremendous boost to the sugar industry towards a significant drive to their profits. With trends such as elimination of synthetic and artificial ingredients, replacing them with organic, naturally occurring ingredients have pave way for the companies to offer more transparency in the nutritional aspect of their product and also elaborating their product line using prevalent food habits thereby making themselves competitively more strong than the other players in the anticipated market, also capturing huge health conscious consumer base.

Considering this, one such product ‘jaggery’ has immense growth potential both in national and international market due to its high nutritional and medicinal values. Jaggery is used for direct consumption or as a sweetening agent for preparation of various dishes [9]. Jaggery is said to be the unrefined natural non-centrifuged sugar which is processed with the use of natural clarificants of vegetable origin. However, at present, it is being produced in the country by un-organized sector in small units using unwanted chemicals and processing it in rather unhygienic conditions. Jaggery is also referred to as "medicinal sugar" finding its application in ayurvedic medicines for curing infections. Since nearly 70% of global production is being done in India, jaggery industry supports a huge rural economic system providing employment to millions of people. Amongst various value-added products from the sugar industry, jaggery processing and packaging in sustainable, hygienic and environment friendly way would help the sugar industry to strengthen its revenue base and also its status in the market [10,11].

A study conducted by Agricultural & Processed Food Products Export Development Authority (APEDA) threw light on the importance of jaggery and reveals that while refined sugar mainly consists of glucose and fructose, jaggery contains glucose and sucrose and is a rich source of minerals and vitamins which lacks in the refined sugar [12]. The mineral content of jaggery includes calcium, phosphorus, magnesium, potassium and iron and traces of zinc and copper. The vitamin content includes folic acid and B-complex vitamins. Thus, other than being a good source of energy, it also prevents rheumatic afflictions; prevents disorders of bile; helps in relieving fatigue, relaxation of muscles, nerves and blood vessels; maintains blood pressure and reduces water retention; increases hemoglobin level and prevents anemia. It is also pertinent to mention that being the major jaggery producer; India has been recognized as one of the leading traders and exporters of jaggery to the world. Reports indicate that around 3, 13,826.00 MT of jaggery worth Rs. 1,606.08 crores/ 230.03 Millions USD has been exported by India in the year 2018-19. The major bottleneck faced by the jaggery manufacturing sector in India is lack of proper infrastructure and manufacturing facilities for jaggery processing and packaging, limited resources for product innovation, insufficient price dissemination and a sense of responsibility amongst manufacturers. Traditionally jaggery is made by processing the sugarcane juice in open pans into jaggery moulds of different sizes. Other than jaggery moulds, various other forms viz. solid, liquid, powdered, granular form of jaggery can also be made to elaborate the product line. Also for value-addition, vitamin C infused jaggery, flavoured and other various types of jaggery can also be made available to the consumers. Such innovations will indeed add more value to the present system in times to come and would definitely prove to be beneficial for both the farm and the folk and last but not the least would give added revenue to the sugar industry as well. However, the processing shall require to be carried out under hygienic conditions carrying out higher level of filtration and setting up mini jaggery plants using steam as heating media [13].

Innovative usage of by-products from sugar industry

The most important environmental challenge faced by the world is management of the waste which is generated from various agro processing industries. Now-a day's emphasis is given on minimization of waste and increasing revenue generation through by-product value addition, thus to convert "waste to resource" or generating "wealth from waste". Some such usage of various by-products are discussed here:

Sugarcane bagasse

Fibrous bagasse is one of the most important by-product from the sugar industry in terms of volume (28-32% on cane). Primarily sugarcane bagasse is used as a fuel for steam and subsequent electricity generation which is utilized by the sugar factories itself and is also exported to grid. With the advent of time apart from using it as a fuel for boilers, bagasse had its application in making of paper and pulp and numerous other value-added products. This is considered of paramount importance as bagasse based co-generation and export of power is losing its charm as a result of reduced power tariffs due to competition with tariffs offered by power generated through non-conventional energy resources [14].

This by-product being widely available, cheap and also being environment friendly can be a potential source to a huge number of products and therefore its potential is to be fully harnessed by the industry in order to add benefits to the present system. Several literatures have reported the use of this lignocellulosic biomass fraction for manufacture of number of products of high market potential, viz., production of bio-ethanol, furfurals, dietary fiber, mushroom, surfactants, cosmetic ingredients and graphine oxide etc. With increasing concerns on environment and ecological wellbeing and increasing use of conventional non-biodegradable, non-renewable sources of energy, there has emerged a need for technologies and approaches for sustainable and environment friendly products and processes [15]. To throw light on the above thought, studies have been reported about the use of bagasse in manufacture of new bio-degradable plastics. This search for biodegradable plastics evolved as a result of the emerging environment concerns and also for the purpose of replacing petroleum based products from the ecosystem. Studies report that the only constrain in manufacture of such high quality plastics is the cost of production i.e. the cost associated with the carbon source for the production of the bio-polymer. A recent research published describes production of bio-polypropylene (bio-PP) by utilizing various biomasses, mainly crop residue, to produce iso-propanol (IPA) which further undergoes dehydration to form polypropylene monomer [16]. This novel bio-PP has wide range of application such as food packaging products, spanning automobiles parts to medical care products, etc. Several literatures suggested the efficient use of agro-residue such as sugarcane bagasse for production of poly hydroxyalkaonates (PHA) [17]. Since more that 50% of the cost of production is accounted by the carbon source, the effective use of these agricultural waste would help in its excessive management and also would help the industry to balance their situations.

It is also pertinent to mention that with the growing wood panel industry as a result of rising demands from the furniture sector, search for new raw materials has increased tremendously. Several literatures have reported the use of sugarcane bagasse in the production of particle board panels and when the quality of the above mentioned panels was compared with that of the conventional panels made using other materials, it showed promising results [18,19]. In a nutshell, along with adding value to the system, production of particle board using sugarcane bagasse would help in reducing the dependency on timber and eventually would help in reducing cutting of forest thus preserving the ecosystem.

Filter cake

Amongst the by-products of the sugar industry, filter cake, in particular, is the second main solid waste generated from the sugar industry with annual production of around 9-10.5 million metric ton [20]. Proper disposal of this by-product is of great concern for the industry. Its management, handling, storage and transportation becomes difficult due to high water content of filter cake and also its peculiar smell which causes insect and pest infestation. Filter cake is largely being utilized as bio-fertilizers and is used as compost in sugarcane fields. Since direct use of filter cake pose risk and several limitations, it is used with other fertilizers to improve the fertility of the soil, pH balance in soil, improve drainage and also to promote growth of healthy microflora to enhance soil quality for better crop management [21].

Several literatures have reported the use of filter cake as fuel along with bagasse in the sugar factories thereby adding economic value to the present state of the filter cake. Studies reported the potential use of filter cake as fuel. According to the literature, the lower heating value (LHW) of filter cake on wet basis is said to be around 8.8 MJ/kg while that of bagasse is around 9.95 MJ/kg, which means, about 1.2 ton of filter cake in energetic term is equivalent to one ton of bagasse. The studies concluded that the blend of filter cake/bagasse as boiler fuel for sugar factories is promising as it reduces the disposal, storage and management cost of filter cake. Environment impact of filter cake is also reduced as burning of filter cake results in release of CO_2 which has 20-21 times lower impact on environment towards global warming as compared to an anaerobic decomposition [22].

Another aspect which talks high on further exploring the potential of filter cake could be in manufacturing of cane wax. Waxes have been used in various applications such as for making candles, as coating materials, in textile processing, rubber and adhesive industries etc. The waxes in present times are manufactured either from minerals, plant or animal derived materials, or by different synthetic means. According to studies reported by P. Manohar Rao, filter cake may present a good source for extraction of sugarcane wax as during the clarification of cane juice most of the wax and fats are precipitated and come along in the filter cake itself. However, there are certain constraints in the processing of sugarcane wax with respect to its properties as compared with carnauba wax which most of the carbon paper, polish, fabrics manufacturers use. Properties such as hardness of cane wax needs improvement and also oil retention and wetting property are required to be improved and worked upon. If such constrains could be worked upon, it may open a new area of economic value for the filter cake [23].

With the depleting natural resource and increasing demand for green and clean energy, there is indeed a need to look for positive alternatives that maintain the ecosystem balance and also cater to the need of the humans without affecting the natural resources. One such rational approach towards sustainability is adoption of bio-energy systems with a vision to save fossil energy [20].

One of the advantages of using bio-energy system is their low greenhouse gas (GHG) emissions compared to fossil-energy ones. There are various alternatives that can be adopted for alternative fuels but among them, bio-gas seems to be one of the most promising and best alternatives to the present fossil fuels. There are number of countries that have different bio-gas plant set-up in their vicinity and are in the process of installing more, for instance Italy has doubled the bio-gas plants in 2013 and is expected to increase further [24]. Considering filter cake % cane been about 3.5 and limited option available for its commercial exploitation, this by-product having substantial amount of organic material can be used for production of bio-gas, compressed biogas/ bio-CNG. With proper investment and planning, this untapped potential can be harnessed which will also help in value addition for the sugar factories. Although a thorough study relating to the cost of production and the quality of the raw material is to be carried out.

Molasses

Molasses is one of the most valued by-products of the sugar industry. In present times molasses is used primarily by the distillation industry. Although due to the recent pricing policy announced by the government of India, production of ethanol has gained momentum, but a part of the molasses can still be used for converting it to a value added product earning higher revenues as compared to those with ethanol production. Wide range of molasses as obtained from different sources exists in the market such as cane molasses, beet molasses and refinery molasses. Various MNC's are branding and selling edible molasses @ Rs. 1000/kg or so which is much higher than the normal price of molasses sold by the sugar factories. This edible molasses has wide application ranging from bakery product to enhancing flavouring properties in meat, herbs, chocolate, spices etc. also help in fortifying sweets, savoury or spice flavours. Many innovative technologies and ideas can be explored to make this product more nutritious and more easily available in the market which therefore opens a new field for the sugar industry to prosper.

It is also pertinent to mention that many more value-added products like organic acids, enzymes etc. can be produced by utilizing molasses in a better and efficient way. For instance, literatures have shown potential use of sugarcane/sugar beet molasses in production of enzymes such as xylanases, invertases etc. that have numerous applications in the various industries. On one hand xylanases is widely used in several industrial and biotechnological application such as; it is used for wood pulp bio-bleaching, paper making, for making supplements in animal feed and for production of xylitol. It is also used in manufacture of various food and beverages and also for bio-ethanol production.

Studies have reported that xylanase enhance the bleachability of the bagasse soda pulp and also reduce the use of chlorine dioxide by 33%. On the other hand, invertase enzyme also play vital role in food industry for production of various artificial sweeteners, production of invert sugar. Invertase is also used in making honey, biosensors for sucrose detection etc [25]. Studies report use of sugarcane molasses as substrate for invertase production. Studies concluded that using by-product of the sugar industry i.e. molasses for invertase production by *A. niger* GH1 is attractive as it lowers the cost of production and also gives good yield of the enzyme [26].

Organic acids and their derivatives are used in various applications in food, beverage, feed production etc. Organic acids such as itaconic acids, citric acids, lactic acids etc. are widely used in resins, rubber, plastic, surfactant, solvent, food, detergent, cosmetic, pharma and chemical industries. They also find their application as anti-oxidising, flavouring, preserving as well as buffering agent in food, beverage, cosmetic industries. Several attempts have been made to find replacement of the expensive carbon source used for the production of such acids. Cheap alternative substrates such as sugarcane and sugar beet molasses seem promising. Lunelli et.al reported the use of sugarcane molasses as carbohydrate source for production of lactic acid with good yield of lactic acid of around 0.83 g/g [27].

Conclusion

Various sustainability initiatives as discussed in the paper with a focus on production processes, environment and nutritional status should be taken up by the sugar industry in northern India to meet growing demands from health conscious consumers, food and beverage companies and also from international markets which will also render them economically sustainable and viable. It is essential for the industry to expand their product line with innovative solution that keeps balance with the current market scenario. An integrated approach towards value-addition and utilization of by-products in an innovative manner as discussed appears to be a promising approach for economic feasibility and sustainability of the sugar industry.

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Sugarcane varietal spectrum for maximizing profit of farmers and sugar industry in sub-tropical India

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ABSTRACT

The sugarcane production primarily depends on variety, availability and efficient use of farm input and selection of healthy planting material. The varietal spectrum of sugarcane determines the sugar recovery and total sugar production of the particular region as the varieties play a major role, not only in increasing cane productivity but also sugar recovery. One of the major strategies to enhance sugarcane and sugar productivity in sub-tropics is to select elite sugarcane varieties having high sucrose content, till longer duration, for commercial cultivation. Although, judicious varietal balance of improved high sugar early and midlate maturing varieties have played an important role in increasing sugar recovery in many sugar factories during last couple of years but, there is still a good scope for maintaining the proper balance of these varieties and completely discarding the area under rejected varieties. In northern India, a number of early and mid-late varieties like CoS 13231, CoS 08272, CoSe 08452, Co 0238, Co 0118, CoS 08279, CoLk 94184, U.P. 05125 and CoSe 01434 *etc* are showing promising results regarding higher sugar recovery and productivity throughout the crushing season. During 2018-19 crushing season, of the total cane acreage, approximately 85.86%, 12.34% and 1.80% area was occupied with early maturing, mid-late maturing, and rejected varieties, respectively in the sub-tropical region. Among which due to the liking of farmers, sugar mills and other cane development agencies, a single variety alone had occupied almost 70 percent of area and which increased more than 80 percent in the current crushing season (2019-20) in U.P. This imbalance of varietal spectrum led to severe epidemic of red rot in some major part of the cane growing areas of sub-tropical region. However for increasing productivity of sugarcane and production of sugar, besides use of scientific package of practices, varietal planning helps cane growers and cane managers in determining the allocation of land to different varieties, their plant and ratoon crops and in planning the harvesting and crushing schedule. Nevertheless, instead of relying on one variety in case of epidemics, there is a good scope for maintaining the proper balance of the above mentioned varieties in this region. It is assumed that the three components of the benefit formula are the cost of production, yield and price obtained for the commodity. If the appropriate sugarcane varieties can be grown to their economic cane yield level in the given climatic conditions fetching better price equivalent to their sucrose content, the profit equation will favour both the growers and millers.

Introduction

In sub-tropical part of India, sugar industry is one of the largest agro based industry providing employment to 7-10% of rural population. Around 45% of sugarcane production of country is contributed from Uttar Pradesh state alone. The crushing starts during October/November which lasts till March/April in this region. Sugarcane is considered to be mature and ready for harvesting if it attains over 16% sucrose and 85% purity of cane juice. The varieties, which attain such level at 10 and 12 months age, if planted in January/February are broadly classified as early and mid-late maturing types (Hagos *et al.*, 2014). Of the total cane acreage, approximately 94.48%, 5.01% and 0.5 % area is occupied with early, mid-late, and rejected varieties, respectively in this region (2019-20). Seeing the present scenario of early and mid-late maturing varietal spectrum, there is an ardent need to emphasize a balance under improved early and mid-late maturing varieties having high sugar, fibre and high biomass content. Studies carried out by Singh *et al.,* (2011), Singh and Rao (2009) also emphasized that proper balance of early and mid-late sugarcane varieties is very important for better cane productivity, longer crushing period and sugar recovery. To achieve the maximum sugar recovery, it has been found that balanced proportion of area under early and mid-late maturing varieties should be kept to ensure proper supply of cane of desired quality and maturity throughout the crushing period (Table 1). Required varietal proportion which is lacking in this part of country,will not only increase the total sugar recovery but will also maintain it throughout the crushing season. Right varietal balance of early and mid-late maturing varieties will increase the sugar recovery *vis-à-vis* sugarcane yield in the North India.

Table 1. Harvesting schedule: Maturity based harvesting schedule leads to 10-25 % more yield and 0.5-1.5% increased sugar recovery

October/November	December	January	February	March	April onwards
Autumn/Spring Ratoon- Early maturing varieties	Autumn Plant-Early/ Ratoon-Mid-late maturing varieties	Ratoon- Mid-late /Spring plant-Early maturing varieties	Spring Ratoon/ Plant-Mid-late maturing varieties	Spring Plant-Mid-late maturing varieties	Late maturing plant cane

Proper balance of early and mid-late maturing varieties

There is a need to assess the value of balance of area grown under improved early and mid-late maturing varieties possessing high sugar contents. Studies carried out earlier also emphasized that a proper balance of early and mid-late maturing sugarcane varieties is very important for longer crushing periods with higher sugar recovery (Singh *et al.,* 2016). The cost of production of sugar and profitability of the sugar industry besides many other factors depends primarily on the availability of sufficient quantity of good quality sugarcane during the crushing season. For increasing productivity of sugarcane and production of sugar besides use of scientific package of practices, varietal scheduling helps cane growers and cane managers in determining the allocation of land to different varieties, their plant and ratoon crops and in planning the harvesting (Table 1) and crushing schedule during the peak ripening curve of varieties covering the possible crushing period to provide economic return to both the growers and millers.

A suitable variety is one that provides the most productive yield with maximum stability under the given environment. The start of harvest is determined by the sugar content of the canes, so the variation range in the percentage of CCS based on the maturing patterns of varieties (differences for rising curves of sucrose) becomes the critical point to facilitate harvesting. Other minimum crushing period during peak maturity of a particular variety definitely has an advantage in increasing recovery but this period can only be extended to both sides until recovery is desirable. Therefore, proper varietal balance and harvesting schedule will help to a great extent to maintain sugar production (Table 1 & 2).

Table 2. Cane yield and pol in cane in different months in plant crop of some promising sugar rich improved varieties

Variety	Month						
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**
Early maturing							
Co 0238	11.40	11.80	12.40	12.90	13.20	13.70	13.90
Co 0118	12.10	12.60	13.00	13.60	13.80	14.20	14.40
CoLk 94184	10.86	11.35	12.28	12.92	13.20	13.72	14.61
CoS 08272	10.50	11.70	12.20	12.70	13.30	13.80	14.10
CoSe 98231	11.00	11.80	12.30	12.80	13.00	13.70	13.90
CoJ 64	11.28	11.99	12.63	13.19	13.82	14.02	14.65
Co 98014	11.30	12.33	12.72	12.79	13.41	13.91	14.49
Mid-late maturing							
CoS 767	10.60	11.00	11.70	12.40	12.70	13.20	13.30
CoSe 11453	8.90	10.52	11.81	12.50	12.63	13.00	14.00
CoS 12232	10.90	12.12	12.51	12.56	12.73	13.07	13.67
CoS 97261	10.30	11.20	11.50	12.30	12.50	12.70	12.90
CoS 08279	10.40	11.40	11.60	12.10	12.70	13.20	13.30
CoS 08276	10.98	11.19	12.00	12.39	12.87	13.46	13.99
CoSe 01434	10.30	11.40	11.70	12.50	12.70	13.10	13.30
Least significant difference ($P<0.05$) = 0.258							

Recently, several improved early and mid-late maturing varieties have been developed through varietal improvement programme by different research institutes in the country. The pol% in cane of these elite early and mid-late maturing varieties has been found to increase across the crushing season (Table 2). Although the area under such early maturing varieties has increased in 2015-16, which resulted in the enhanced sugar recovery in the state, however, there is still a good scope for adopting the proper balance of these early and mid-late maturing varieties and completely discarding the area under rejected varieties. Judicious combination of early and mid-late maturing varieties and ratoons, staggered planting and planned harvesting will ensure the supply of mature and fresh quality cane for crushing. Increasing the area of early and mid-late sugar rich varieties of sugarcane in a ratio of about 50:50 (Singh *et al.*, 2017) may help to a great extent in sustaining the enhanced sugarcane and sugar production. This ratio is very important and it will provide insurance against epidemic of pest or disease which may otherwise threaten to completely wipe out the particular variety. It was found that the sugar recovery was increased by almost two units ie; 100 tons sugar/ day (5,000 TCD) in few mills of sub-tropical India that implemented this scheme and increased the ratio of high sugared varieties (Table 3).

Table 3 . Impact of sugar rich improved early and mid-late maturing varieties on recovery of some selected sugar factories of Uttar Pradesh

S.No.	Year	Total cane area (hectare)	Area of early maturing varieties (%)	Area of mid-late maturing varieties (%)	Area of rejected varieties (%)	Total processing (lakh quintal)	Average sugar recovery (%)
A. The Saksaria Biswan Sugar Factory Ltd., Sitapur							
1	2011-12	30881	17.47	72.09	10.41	103.25	09.78
2	2012-13	31504	25.33	71.12	03.55	96.23	09.78
3	2013-14	27732	35.11	63.21	01.68	85.32	10.17
4	2014-15	26827	49.78	37.66	12.56	108.42	10.38
5	2015-16	33162	68.38	13.86	17.76	85.68	12.40
B. Dalmiya Chini Mill, Nigohi							
1	2011-12	21064	08	84	08	89.01	09.31
2	2012-13	22423	21	60	19	90.05	09.34
3	2013-14	22790	39	47	14	69.44	10.30
4	2014-15	19579	54	41	05	76.73	10.53
5	2015-16	20161	76	22	02	71.77	11.94
C. Dwarikesh Sugar Dwarikeshnagar							
1	2011-12	26351	14.25	81.54	04.21	76.63	10.16
2	2012-13	27761	19.26	70.35	10.40	77.30	10.32
3	2013-14	26496	32.39	62.82	04.80	67.54	10.47
4	2014-15	26073	49.21	48.39	02.39	82.89	11.11
5	2015-16	26432	72.98	26.24	00.77	78.21	12.12

Need of sugar rich improved varieties

Apart from disease resistance and improved yielding capacity, an important requirement for the sugar industry is of improved early and mid-late maturing varieties having high sugar content. Many sugarcane varieties do not attain their optimum sweetness until mid season. It is, therefore, obvious that any such variety milled before this period contains less than its optimum percentage of sugar and causes a loss to sugar factory. If early maturing high sugared varieties are available with optimum sugar content during the first and second months of crushing, each tonne of cane crushed is worth for more sugar and money to factory (Table 1). In the northern India, a number of early and mid-late varieties (Table 2) are showing promising results regarding higher sugar recovery and productivity throughout the crushing season. By increasing the area of such varieties there will be a significant improvement in recovery in the state. The proper varietal planning of early and mid-late maturing varieties and by adopting scientific harvesting schedule together for the target area may help to a great extent in sustaining the higher sugar production and also helping the farmers to attain higher sugarcane yield and income as well. It may be worth mentioning that with sustained efforts the sugarcane yield has increased from about 66 t/ha (2015-16) to about 79 t/ha (2018-19) recorded during the current sugar season.

Varietal planning reduce the cost of production due to increased recovery. Table 4 shows approximate percentage of area under different maturing varieties and its impact on sugar recovery. Table 5 extends some information about the approximate area required under different maturity groups for producing canes to feed 5,000 tonnes of sugarcane per day for nearly 180 days.

Table 4. Effect of varietal spectrum on sugar recovery during the year 2012-13 to 2018-19

Varieties (%)	2015-16	2016-17	2017-18	2018-19	2019-20*
Early Maturing	34.47	52.83	70.46	85.86	94.48
Mid-late Maturing	40.14	37.44	24.40	12.34	05.01
Rejected	25.39	09.72	05.14	01.80	00.51
Recovery %	10.62	10.61	10.85	11.48	-

Source: U.P. Cane Development Department * Tentative

Table 5. Varietal planning for a factory of 5,000 TCD

S.N.	Particulars	Drawl @ 50%	Existing in factory zone
1.	Crushing period	November to April (180 days)	
2.	Total cane required (t)	180×5000= 9,00,000	1,800,000
3.	Area required @ 70 t/ha cane yield	12,857 ha	25,714 ha
(i)	Ratoon cane	50% (6428 ha)	12,857 ha
(ii)	Plant cane	50% (6428 ha)	12,857 ha
a	Early plant 50%	6428.5 ha Autumn 20% (1285.7 ha) Spring 80% (5142.8 ha)	-
b	Mid-late plant 50%	6428.5 ha Autumn 20% (1285.7 ha) Spring 80% (5142.8 ha)	-

Major considerations for varietal planning

Several improved varieties have been developed through varietal improvement programmes for the subtropics of India by the ICAR-Sugarcane Breeding Institute, Coimbatore; ICAR-Indian Institute of Sugarcane Research, Lucknow; U.P. Council of Sugarcane Research, Shahjahanpur & Seorahi; *etc*. The major considerations while development of sugarcane varieties is given in Table 6. Exposure to new threats or new races of an existing disease such as red rot makes diversification of the variety the best management against major economic losses. When planting large percentages of the land to the most profitable variety, the growers must retain small acres of other varieties in the event that their big varieties suffer devastating losses from pests.

Table 6. Major considerations for varietal planning

1	Cane requirement	Tonnes of cane per day
2	Area under cane	Plant and ratoon (command area) production & supply
3	Tested variety	Early/ Mid-late maturing (with ripening pattern)
4	Environment	Location
		Plant/ratoon crop
		Autumn/spring/late planted
		Low input/recommended input
		Normal/Stress condition (abiotic / biotic)
5	Cropping system/Planting period	Intercropping, Crop rotation, Autumn, Spring and Late planting
6	Seed cane program	Varietal balance
		Assured availabllity of quality seed
7	Duration of crushing	Estimated production
		Varietal spectrum
		Plant ratoon ratio
		Production to crushing ratio
		Economic recovery

Advantages of varietal planning

Indeed, developing a variety that encompasses all the desired attributes is extremely difficult. The breeder must, therefore, have a compromise for the most essential and possible attributes. Essentially, varietal planning deals with complementing the characteristics of the various varieties tested suitable for the given area. The goal is to increase the remuneration of the crop for both the grower and the miller (Fig. 1).

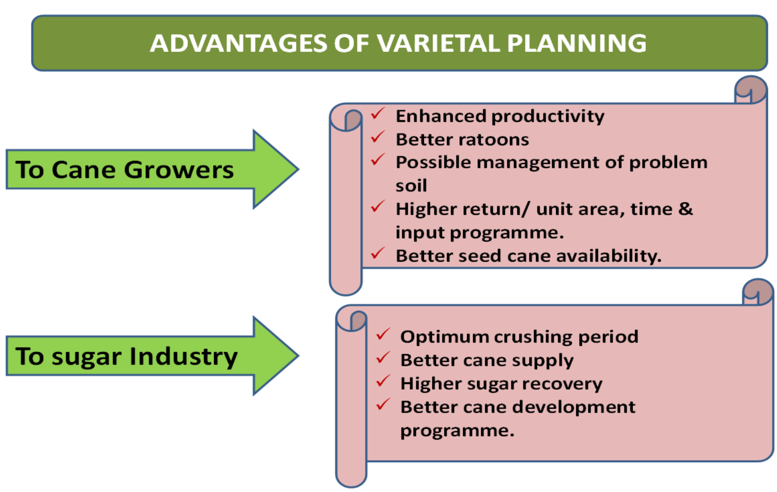

Fig. 1. Advantages of varietal planning to farmers and sugar industry

Table 7. Important sugarcane varieties recommended for cultivation in different zones of Uttar Pradesh for obtaining higher recovery

S.N.	Zones	Varieties	
		Early maturing	Mid-late maturing
1.	**All Zones**	CoS 8436, CoS 88230, CoS 95255, CoS 96268, CoSe 03234, UP 05125, CoSe 98231, CoS 08272, CoSe 95422, Co 0238, Co 0118, Co 98014, CoS 13231, CoS 13235.	CoS 767, CoS 8432, CoS 97264, CoS 96275, CoS 97261, CoS 98259, CoS 99259, CoSe 01434,UP 0097, CoS 08279, CoS 08276, CoS 12232, CoSe 11453, Co 05011, CoS 09232, CoSe 13452
2.	**Eastern**	CoSe 01235, Co 87263, Co 87268, Co 89029, CoLk 94184, Co 0232, CoSe 01421, UP 09453, CoLk 12207 including varieties recommended for all the zones	CoSe 96436, Co 0233, CoSe 08452, CoLk 12209 including varieties recommended for all the zones
3.	**Central**	CoJ 64, CoSe 01235, CoLk 9709, Co 0237, Co 0239, Co 05009, CoPk 05191, CoLk 11203 including varieties recommended for all the zones	CoS 94257, CoS 96269, UP 39, CoPant 84212, CoH 119, CoPant 97222, CoJ 20193, Co 0124, CoH 128, CoLk 09204, CoLk 11206, Co 09022, Co 12029 including varieties recommended for all the zones
4.	**Western**	CoJ 64, CoS 0325, 1CoLk 9709, Co 0237, Co 0239, Co 05009, CoPk 05191, CoLk 11203 including varieties recommended for all the zones	CoS 94257, CoS 96269, UP 39, CoPant 84212, CoS 07250, CoH 119, CoPant 97222, CoJ 20193, Co 0124, CoH 128, CoLk 09204, CoLk 11206, Co 09022, Co 12029 including varieties recommended for all the zones.
5.	**Water logged area**	-	UP 9530, CoSe 96436, CoS 10239 (saline area)

Source: UPCSR,Shahjahanpur

Other factors which need to be considered for varietal planning

Ratooning ability

Ratoon crops giving favourable annualized average value of net returns form the basis of a cultivar's merit. Variety by environment interactions for both plant and ratoon crops are high, thus the optimal choice of variety may vary according to environment. The trend of decline has generally been found to be less between plant-cane and first ratoon than between the first and the second ratoon. However, differences exist among varieties in yield potential of the plant crop and the rate at which the yield decline in successive ratoon crops. Variety which produces high ratoon crop yield or many economically rewarding ratoon crops should be preferred (Srivastava and Kapur, 1997). However, while harvesting the thumb rule to remember is that a variety's ratoon crop matures earlier than its crop.

Post- harvest quality deterioration

The post-harvest quality losses in sugarcane significantly affect the farmers and industrial processing and is a serious problem concerning the sugar industry worldwide. In India (especially the sub-tropical region), processing starts during October/November (low temperature) and continues till April/May (high temperature). The cane grower harvests the crop 10-12 days prior to the supply, in order to plant the succeeding crop, like wheat, as soon as possible. A number of cane cultivars are being evolved for higher cane productivity and with high sugar content for cane growers and sugar mills. There is enormous scope for elevating sugar productivity by the existing cultivars merely controlling cut to crush losses. As the post harvest deterioration is a genetic trait, the newly evolved cane cultivars should also be screened for their sugar sustainability end longevity under various temperature and environmental conditions (Table 8 & 9).

Table 8. Loss in moisture per cent (weight) at different hours of cane harvest during low and high temperature

Month	Hours after harvest	Variety									
		CoSe 08452		CoS 08276		CoS 08279		CoS 08272		Co 0238	
		T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
Nov	0	-	-	-	-	-	-	-	-	-	-
	48	0.68	0.40	0.60	0.35	0.58	0.45	0.80	0.45	0.70	0.41
	144	3.00	2.80	2.50	2.40	3.50	3.20	3.80	3.10	3.39	3.00
	240	6.00	5.00	4.80	4.70	6.90	5.10	7.10	5.20	5.90	4.50
Dec	0	-	-	-	-	-		-	-	-	
	48	0.55	0.20	0.50	0.30	0.50	0.35	0.77	0.40	0.69	0.30
	144	2.90	2.05	2.40	2.20	3.44	2.50	3.65	2.30	3.21	2.65
	240	5.70	3.40	4.90	3.30	6.80	4.70	7.00	4.80	5.80	4.30
Jan	0	-	-	-	-	-	-	-	-	-	-
	48	0.71	0.26	0.68	0.57	0.62	0.42	1.97	0.76	0.96	0.33
	144	6.08	2.36	3.70	2.40	5.64	3.73	5.81	4.13	3.21	2.43
	240	6.87	6.69	5.30	4.60	8.69	6.07	6.74	6.15	5.25	4.77
Feb	0	-	-	-	-	-	-	-	-	-	-
	48	1.03	0.36	0.55	0.37	1.42	0.77	2.63	2.06	1.32	1.00
	144	7.53	6.44	5.45	3.00	5.37	3.86	9.78	9.59	5.88	3.79
	240	13.69	9.31	9.37	7.55	10.20	7.57	16.53	13.49	12.50	7.60
Mar	0	-	-	-	-	-	-	-	-	-	-
	48	4.00	3.00	4.50	3.7	3.81	3.6	5.17	4.76	3.94	2.46
	144	13.0	8.99	15.0	13.0	11.34	10.0	13.41	12.0	12.24	10.59
	240	24.0	17.34	20.6	17.61	22.60	16.90	22.97	19.33	20.0	16.62
Apr	0	-	-	-	-	-	-	-	-	-	-
	48	4.50	3.50	5.10	4.90	4.00	3.70	5.25	5.10	4.10	3.20
	144	14.00	9.50	17.0	14.00	13.20	11.00	15.10	13.50	14.00	11.80
	240	25.00	18.00	21.5	18.00	23.20	17.50	24.00	20.00	21.30	17.50

Where T1 = uncovered cane after harvest, T2= canes covered with trash after harvest
Source: Singh *et al*, 2019

Table 9. Unit loss in sucrose at different hours of cane harvest during low and high temperatures

Month	Hours after harvest	Variety									
		CoSe 08452		CoS 08276		CoS 08279		CoS 08272		Co 0238	
		T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
Nov	0	14.94	14.94	15.93	15.93	16.22	16.22	14.80	14.80	17.04	17.04
	48	14.64	14.67	15.70	15.74	15.92	15.97	14.52	14.57	16.82	16.84
	144	14.39	14.48	15.45	15.50	15.66	15.68	14.18	14.30	16.50	16.60
	240	13.95	14.00	14.95	15.11	15.45	15.50	13.40	13.50	16.23	16.30
Dec	0	16.22	16.22	15.94	15.94	16.36	16.36	15.12	15.12	16.82	16.82
	48	16.04	16.05	15.79	15.81	16.18	16.23	14.92	14.94	16.70	16.95
	144	15.78	15.90	15.36	15.38	15.95	15.98	14.64	14.65	15.70	16.66
	240	15.39	15.66	14.85	14.95	15.42	15.69	14.23	14.32	15.25	16.23
Jan	0	17.66	17.66	17.98	17.98	16.97	16.97	15.9	15.9	19.05	19.05
	48	17.21	17.53	17.87	17.88	16.84	16.85	15.76	15.78	18.93	18.94
	144	16.89	17.34	17.30	17.35	16.30	16.35	15.16	15.19	18.73	18.75
	240	16.27	16.95	16.60	16.75	15.05	15.11	13.89	13.92	18.32	18.35
Feb	0	19.14	19.14	18.50	18.50	18.67	18.67	17.14	17.14	19.34	19.34
	48	18.91	18.94	18.30	18.31	18.43	18.45	16.87	16.89	19.14	19.16
	144	18.68	18.72	17.61	17.70	17.57	17.60	16.15	16.17	18.80	18.85
	240	18.33	18.35	16.83	16.91	15.53	15.59	14.75	14.78	18.20	18.24
Mar	0	17.96	17.96	18.23	18.23	17.99	17.99	19.33	19.33	19.32	19.32
	48	17.71	17.73	18.00	18.05	17.75	17.82	19.08	19.10	19.10	19.12
	144	17.35	17.53	17.60	17.75	17.35	17.60	18.60	18.80	18.59	18.81
	240	16.65	16.82	16.80	16.98	15.00	15.35	17.10	17.44	17.17	17.50
Apr	0	17.67	17.67	17.68	17.68	17.52	17.52	18.87	18.87	19.20	19.20
	48	16.98	17.45	17.40	17.50	17.21	17.30	18.55	18.60	18.90	18.95
	144	16.20	17.00	17.00	17.05	16.10	16.15	17.80	17.90	18.38	18.20
	240	15.40	16.00	16.15	16.30	14.50	14.60	16.65	16.80	17.58	17.15

Where T1 = uncovered cane after harvest, T2= canes covered with trash after harvest
Source: Singh *et al,* 2019

Varietal screening for jaggery production

In India, *jaggery* and *khandsari* consumption is 40 lakh tonnes (2015-16). In India, studies reported that there are around 45,000 jaggery making units producing about 6-8 million tonnes of jaggery (Sharma *et al*, 2014). The average capacity of jaggery unit is 8-10 TCD. Peak months of operations are October-February and average days of operations are 100-120 days. However, per capita consumption of sweetener is 22.7 kg. As urban people becoming more health conscious demand for jaggery will certainly increase in coming days. Sugarcane varieties play a major role in quality jaggery production . The major factor that governs the consumer preference and marketing of jaggery is its external appearance *i.e.*, colour, texture and storability, which in turn depends on quality of matured sugarcane. Quality jaggery comprises of high sucrose and purity with less invert sugars and low colloids. It has been found that there is a wide variation in quality of jaggery depending on varieties used for its preparation. On the basis of the results of varietal studies, the under mentioned varieties were found suitable for the purpose of quantity as well as quality for jaggery production at commercial scale. These varieties yielded maximum jaggery recovery (% cane as well as % juice basis) and minimum invert sugars and the colour, thus could be used for large scale production of quality organic jaggery (Table 10).

Table 10. Comparative performance of different varieties of sugarcane for yield and quality of quality jaggery production

S.N.	Variety	Cane yield (t/ha)	Jaggery yield (t/ha)	Jaggery % cane	Jaggery % juice	Pol % jaggery	Invert sugar %	Colour reading
1	CoS 08276	97.06	11.80	12.16	21.43	85.4	3.27	104
2	Co 0238	96.91	12.00	12.39	21.33	92.2	4.68	127
3	UP 05125	89.96	10.36	11.52	21.53	71.8	3.46	121
4	CoSe 01434	89.04	9.33	10.48	19.63	82.2	3.74	127
5	CoS 08279	95.83	10.53	10.99	20.51	84.2	3.34	116
6	Co 0118	91.20	11.23	12.31	21.87	85.2	3.79	110
7	CoS 07250	92.59	11.01	11.90	21.57	77.4	3.66	107
8	CoS 08272	90.27	11.03	12.22	21.68	85.6	3.77	112
9	CoSe 03234	75.77	8.67	11.45	21.37	83.6	3.70	113
10	CoS 767	84.10	9.63	11.45	21.15	83.2	3.88	123

Source: Singh *et al,*2018

Conclusion

The target of increasing sugarcane farmers' income and sustainable sugar industry lies majorly in proper varietal spectrum of varieties, by adopting cost effective technologies, transferring them from laboratory to land, educating the farmers and creating a linkage between all stakeholders. Although, the early varieties must be given precedence over mid-late varieties for cultivation in this part of the country for sustainable increase in cane productivity and sugar recovery but, the ratio of 50 (early): 50 (mid-late) may be good for most of the sugar factories in safeguarding the interest of both millers and growers.

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Green technologies for improving cane yield and sustaining soil fertility in sugarcane based cropping system

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ABSTRACT

Sugarcane is a long duration and huge biomass accumulating crop. It requires number of operations from planting to harvesting of crop. It is also a wonder crop where after harvesting of main crop, subsequent ratoon crop is generated through established root system. Adoption of green technologies are viable options to improve sugarcane productivity and sustainability. Tuning the green technologies, different methods/techniques of crop production, planting methods (cane node technologies and planting through Cutter Planter), nutrient management strategies (intercropping, green manuring, pressmud, bio-fertilizers *etc.*) insect-pest and disease management options (cultural and physical methods, use of bio-agents, bio-pesticides, botanicals *etc.*) and management of adverse climatic conditions (drought and flood) and or crop residue recycling and trash management technologies may not only improve soil health and cane productivity but also eco-friendly and environmentally safe. These green technological interventions are being applied in sugarcane and sugarcane-based production system in the country. Improvement in the crop productivity *vis –a-vis* sustaining natural resources are key components to be addressed through these technologies. Thus reduction in cost of production, improvement in soil health, increased crop productivity and overall improvement in crop productivity and farmers' income would be possible through adoption of green technologies. Adoption of green technologies in sugarcane cultivation will certainly improve sugarcane yield and sugar recovery besides enhancing farmer's income and sustainability. In the present paper, the various aspects of increasing sugarcane and sugar yields, reducing cost of production and increasing farmers income through adoption of green technologies are being discussed. Adoption of these technologies by sugarcane growers will certainly safeguard environment (soil, water and air) and improve sustainability.

Introduction

During past hundred years, average temperature of earth has increased by 0.89°C. Temperature rose due to burning of fossil fuels and anthropogenic activities as well as gases generated in agricultural fields. Increased temperature may adversely affect temperature and rainfall of equatorial belt which covers tropical and sub-tropical regions of the world. Sugarcane is a C_4 plant and can tolerate certain limits of changing climatic conditions compared to C_3 plants. However, cane yield and productivity of C_4 plant also gets adversely affected by changing climatic conditions worldwide. Lower temperature can affect sprouting in sugarcane while prolonged water scarcity affects cane growth and development. Besides this, variable climatic conditions will also affect juice quality parameters and sugar recovery.

The sugarcane cultivation and sugar industry plays a vital role towards socio-economic development in the rural areas by mobilizing rural resources and generating higher income and employment opportunities. It requires more nutrients and water because of production of higher biomass and nutrient removal. Sugarcane crop is attacked by large number of insect-pests and diseases. The application of chemical fertilizers for supplying nutrients and pesticide to control insect–pest in sugarcane is increasing day by day to harvest higher yields. The prolonged and over usage of chemicals has, however, resulted in human and soil health hazards along with environmental pollution. Adoption of green technologies in sugarcane cultivation will certainly improve sugarcane yield and sugar recovery besides enhancing farmer’s income and sustainability. In the present paper, the various aspects of increasing sugarcane and sugar yields, reducing cost of production and increasing farmers’ income through adoption of green technologies are being discussed.

Improved Sugarcane Varieties

In India, state agricultural universities and state research organizations, two ICAR institutes *viz.*, ICAR- Indian Institute of Sugarcane Research, Lucknow and ICAR –Sugarcane Breeding Institute, Coimbatore are contributing research activities for development of high yielding and high sugar varieties as well as breeding for resistance to biotic and abiotic stresses. Besides, a private institution like VSI, Pune is also going on the same way particularly for Maharashtra state. All India Coordinated Research Project (AICRP) on Sugarcane is coordinating sugarcane research at the national level. AICRP on Sugarcane has 22 regular and 15 voluntary centres in 16 sugarcane growing states of the country. So far, one hundred twenty four sugarcane varieties have been identified for sugarcane producing zones in India and out of these sixty three have been released and notified by the Central Varietal Release Committee. The sugarcane varieties have also been developed for tolerance to drought and flood conditions under AICRP on Sugarcane. These are performing well and can tolerate abiotic stresses up to critical stage.

Sugarcane varieties have been widely adopted and occupied larger share in sugarcane area viz., (Co 86032 (70%) in Pennisular zone, Co 0238 (>60%) in North Western Zone and Central Zone, and CoLk 94184 (28%), BO 91 (20%), Co 6907 (20%) and Co Bln 9104 (18%) in Eastern Zone of the country. Impact analysis of Co 86032 done at ICAR-SBI, Coimbatore by Ram *et al,* 2017 indicated that the cane yield level could be maintained around 100 t/ha throughout growing period except during severe drought years. The variety spread in almost all the states of Tropical India (Tamil Nadu, Karnataka, Maharashtra, Gujarat, unified Andhra Pradesh and Kerala). The variety covered 11.96 m ha area and approximately generated ₹ 20,354 crore as additional monetary benefits. Similarly, monitory benefits accrued to the farmers/millers by adoption of variety Co 0238 in sub-tropical India during 2013-14 to 2016-17. Because of this, additional income generated to the farmers about ₹ 34,196/ha and to sugar mills ₹ 12,499 on hectare basis.

Organics in sugarcane

Organic matter is considered a major binding agent that stabilizes soil aggregates. Aggregate stability depends on the binding mechanisms of clay and organic matter, such as chemical bonding of organic compounds and physical binding of particles by fungal hyphae and plant roots. Manure amendment is a management practice that can improve the nutrient status of the soil and increase soil organic carbon (SOC) levels. Nutrient concentrations in FYM are usually small and vary greatly depending upon source, conditions, and duration of storage. The N, P and K contents of fresh FYM range widely from 0.01 to 1.9 percent on dry weight basis due to variable nature of manure production and storage (Inoko, 1984). Several researchers all over the world have shown various benefits of the application of FYM on soil properties and productivity of crops (Prabhakar *et al.* 2010). Application of organic sources encouraged the growth and activity of mycorrhizae and other beneficial organisms in the soil and is also helpful in alleviating the increasing incidence or deficiency of secondary and micronutrients and is capable of sustaining high crop productivity and soil health (Nambiar *et al.* 1992). Application of well decomposed FYM/compost @ 10-15 t/ha or composted press mud @ 5 t/ha is recommended (Srivastava *et al.* 2005). Sharma *et al*. (1999) reported that organic fertility amendments enhanced beneficial soil microorganisms, reduced pathogen population, total carbon, and cation exchange capacity, and lowered down bulk density, thus improved soil quality (Singh *et al*. 2002). Application of 20 t/ha FYM/ compost along with inorganic fertilizers applied on the basis of soil test crop response for targeted yield or on the basis of general recommendation for the region has shown positive effect on sugarcane growth and yield both in plant and ratoon crops. Response of sugarcane to bio-fertilizers (*Azotobacter/ Acetobacter/ Azospirillum*/ PSB) was more pronounced in Peninsular Zone in India. Use of organic sources of nutrients in plant-ratoon system brought forth substantial enhancement of soil health parameters in most of the sugarcane growing soils. Bagasse is produced from local sugarcane crusher and sugar miller. It has nutrients which can be used for mass multiplication of bio-fertilizers (Rocha *et al*. 2011). After crushing hundred tonnes of sugarcane about three tonnes of press mud is produced (Gupta *et al*. 2011). It contains 50–70% moisture which is most favourable for soil micro-organisms, especially earthworms (Dominguez 1997). Pressmud also contains significant amounts of iron, manganese, calcium, magnesium, silicon, and phosphorus, and enhances the suitability of sulphitation pressmud (SPM) as a source of plant nutrients (Yadav and Solomon 2006).

Response of sugarcane to green manuring varies greatly depending upon the environments. Before chemical fertilizers came in use in sugarcane farming, green manuring was considered as an indispensable practice. The principal leguminous crops used for green manuring include sannhemp (*Crotolaria juncea*), dhaincha (*Sesbania aculeata*), senji (*Melilotus alba*) *etc*. Green manuring of *Sesbania*, green gram and cow pea increased soil microbial biomass carbon and soil microbial biomass nitrogen after decomposition indicating the key role in sustaining soil fertility and crop productivity (Bhander *et al.* 1998). Green manure legumes preceding sugarcane gave a benefit of 27-43 per cent increase in spring sugarcane yield and contributed 41-71 kg N ha^{-1} through biological nitrogen fixation (Mishra, 1971).

Green approaches are also applied for weed management through botanical/herbicides prepared at farm from local plants and animal origin products. Cultural operations are also adopted for management of insect–pest and diseases. Mono-culturing of sugarcane and continuous ratooning should be avoided for sugarcane smut management (Mansoor *et al.* 2016). Ratoon stunting disease can be controlled by planting healthy seed cane and sterilising cane knives and harvester blades. Use of disease free seed or stock and resistant varieties are the best preventive practice in pest management. Maintenance of biodiversity, effective crop rotation, multiple cropping, habitat manipulation and use of trap crops are also effective practices which can keep the population of insect-pest below economical threshold limit (ETL). Removal of affected plants and plant parts, collection & destruction of egg masses and larvae, installation of bird perches, light traps, sticky colour plates and pheromone traps are most effective mechanical methods of pest control.

Planting materials, growth regulators and planting methods

Cane node technology of sugarcane planting was developed and found useful in reducing seed cane quantity in sugarcane cultivation in addition to rapid germination of cane buds. The highest germination of 77.87% was recorded under single node cane segments as against 40.52% under 3 bud setts at 40 days after planting. The cane yield obtained under single node technology was higher to the tune of 11.14% than that of 3 bud setts planted crop. Rapid

multiplication of newly released varieties of sugarcane is possible because of low seed requirement (17-18 qtl/ha against 60-80 q/ha under conventional method of planting). In India where soil moisture does not deplete rapidly mainly in Peninsular zone, planting of primed cane node are generally recommended while in North West Zone, conventional planting of 3-bud setts is recommended. Seed cane primed with ethrel (100 ppm for overnight soaking) showed early and higher germination (55%) than control (25%). Primed cane and phasic application of GA_3 improved cane yield to the tune of 300 t/ha cane yield in autumn planted sugarcane variety CoLk 94184 at the ICAR-IISR, Lucknow.

Planting of sugarcane 2 or 3 bud setts in field trenches at a depth of 30 cm and spacing at 120/150 cm is recommended to get higher yields and good ratooning. It avoids crop lodging in light soils and increased input use efficiencies. Wider row spacing of 150 cm is recommended for tropical region of the country to facilitate mechanical harvesting as well as sustaining higher cane yields (Shukla *et al.* 2017). However, in sub-tropical region, increasing row spacing beyond 120 cm reduced cane yield. Development and adoption of thick varieties (Co 0238, Co 0118, CoS 8272, CoLk 11203 and CoLk 11206) particularly for subtropical region has great scope to improve the crop productivity through trench planting.

Trench method of planting in sugarcane is usually recommended in coastal areas which is prone to climatic conditions. But now it is being recommended and adopted in sub -tropical India also. Due to strong winds during rainy season, sugarcane crop may lodge. To save the crop from the strong winds, trenches are dug at a distance of 90-120 cm, with the help of ridger mounted tractor. The trenches should be about 30 cm deep. Setts in trenches are planted end to end method. Trenches are filled up with loose soil after planting. Besides this, Paired Row Trench Planting (30:150 cm) is modified version and is being adopted in various parts of the subtropical India. About 12-15 tonnes / ha seed cane is required through planting of 3 bud setts in paired row planting in trenches. However, the sugarcane yields >100 t/ha could be easily obtained through adoption of this planting method in subtropical India. However, in Maharashtra and other tropical regions because of higher individual cane weight, spacing may be increased up to 150 cm in single row planting. Trench planting avoids lodging of cane in both plant and ratoon crops. Paired row planting is the best practice for surface / subsurface drip irrigation system and involving maximum resource use efficiency and higher cane productivity. In sub tropical India, 25-30% cane yield could be increased. Besides 55–60% water saving has been reported through adoption of drip irrigation system in trenches. At ICAR-IISR, Lucknow, machine for trench planting and laying of drippers / laterals under sub surface drip have been developed. Planting through paired trench planter can increase multiple ratooning in the sugarcane system. Farmers can take 3-4 ratoon crops easily through adoption of trench method of planting and subsurface drip system. The adoption of this technology improved the sugarcane productivity and farmers income as well. The results of adoption of trench method of planting in Uttar Pradesh are being summarized below.

Furrow Irrigated Raised Bed technology (FIRB) of sugarcane planting has been developed at ICAR-IISR, Lucknow. The technology is recommended for subtropical region of the country. FIRB technique is an advanced technique of sugarcane planting after wheat sowing. In this technique, 3 rows of wheat are sown in the month of November on raised beds and sugarcane planting is done in the month of February in the furrow irrigated raised beds at distance of 80-85 cm. The technology is also promoted for cultivation of different vegetable crops in West Bengal, Maharashtra, Karnataka and Tamil Nadu. Sugarcane gives about 30% higher cane yield as compared to wheat-sugarcane sequential system without reduction in wheat yield. In this system, irrigation is applied only in furrows which requires less volume of water (20% water saving). The intercropping with autumn sugarcane crop is becoming key component in doubling farmers' income. Irrigation water and wheat seed up to 25% each could be saved. Farmers can apply N and irrigation water at grain filling stage to improve protein content without inducing lodging (Singh *et al.* 2005). Reduced lodging can have a significant positive effect on crop yield as many farmers do not irrigate after heading precisely to avoid lodging. Weeds between the beds can be controlled mechanically early in the crop cycle. Herbicide dependence is reduced. Hand weeding and hoeing between rows are easier. Compaction of soil is limited only to the furrows used as tramlines (tractor tracks). FIRB technique is the way of food security and economic growth of the farmers (Singh *et al.* 2002). Similarly, Ridge and Furrow method and Broad bed and furrow (BBF) system have also advantages including *in-situ* conservation of rainwater in furrows, better drainage of excess water and proper aeration in the seedbed and root zone.

Intercropping/Crop diversification

In sub-tropical India, autumn cane intercropped with mustard / potato / rajma (French bean) is profitable. Intercropping of pulses especially green gram and black gram, and vegetables (onion) with spring sugarcane are recommended to provide opportunity to cane growers to earn extra income per ha. In tropical India, usefulness of vegetables like onion, knol khol and cabbage in pre-seasonal planting are profitable. Simultaneous planting of wheat and sugarcane in the month of December particularly in western U.P. also increases the sugarcane productivity. In the areas where sugarcane planting is delayed and may leads up to May, technology provides ample scope of increasing crop productivity and farmers income. Sugarcane and wheat planting in FIRBS (Furrow Raised Bed System) is another option of increasing wheat and sugarcane crop yields. Besides, planting of gladiolus, marigold and other high value crops with sugarcane are becoming profitable. The selection of component crop may also depend upon the location and market demand. Selection of short duration crops / varieties and compatible with sugarcane are key components. The cost of production of the crop may be reduced due to common irrigation and field management practices in component crop and sugarcane (main crop). In general crop to the time of component crop in the field, the management revolves around component crop. After harvesting of the component crop, sugarcane management practices and input application are adopted.

Integrated Weed Management

Sugarcane crop is affected by several weeds during the growing season. So for the economic management of weeds in sugarcane, three manual hoeings during tillering stage at 45, 90 and 120 days of the planting are recommended. However, under limitations of manpower-availability and labour cost etc., pre emergence application of either of atrazine @ 2.0 kg a.i./ha or metribuzin @ 1.0 kg a.i./ha (800- 1000 litres water/ha). In sugarcane ratoon, manual hoeings at 30, 60 & 90 days after ratooning can be successfully practiced. Further, trash mulching in between sugarcane rows also controls the weed growth. Application of trash and use of 2, 4 D @ 1kg ai /ha at 30 days after planting for control of broad leaved weeds improved the growth and yield of ratoon crop.

Irrigation management

In present scenario, it has been observed that mean annual rainfall is decreasing in most of the sugarcane growing zones. Although, sugarcane is irrigated crop but cultivated under moisture stress environment in most of the states. Maharashtra, Karnataka, Andhra Pradesh. Tamil Nadu and western Uttar Pradesh are water stress states for growing sugarcane. The annual irrigation water requirement of sugarcane in subtropical India is about 1600–2300 mm. However, it ranges from 2000-3500 mm in tropical India. Thus sugarcane requires 6-8 irrigations in northern part and 30-40 irrigations in southern part of the country.

Keeping the scarcity and importance of water, drip irrigation method is being recommended to the sugarcane growers in water deficit areas. In drip irrigation, water is supplied directly to the root zone using a network of tubes and rippers/emitters nozzles placed along the water-delivery line. This involves precise control and manipulation of soil moisture temporally and spatially, which improves water economy, growth and ultimately crop yield. The uniformity of water application in drip irrigation would be as high as 95%, if the system is properly planned, designed and operated. In another customised irrigation system, sub-surface irrigation method is also recommended for sugarcane growers. This system needs proper care and monitoring of infrastructure developed. It reduces wastage of irrigation water and crop achieves better growth and development. About 50-60% irrigation water could be saved through adoption of drip method. It also saves fertilizers and improves nutrients use efficiency. The cost of drip system in sugarcane on per ha basis is Rs. 1.25 to 1.5 lakhs. However, in surface drip system laterals can be removed and inter-culture operations can be done easily. In subsurface system, drip system leads for one plant crop and minimum three ratoons without removal of dippers and laterals. Drip system of irrigation is encouraged by the Govt. and 80-90% subsidy is offered by the Govt. to minimize the burden on installation cost, effective resource use and increase farmer’s income.

The experiments conducted under AICRP(S) also resulted in surface and sub-surface drip irrigation in sugarcane effectively saved water (up to 40%) and increased crop productivity to the tune of 20%. Fertigation with drip resulted in 25% saving of nitrogen compared with surface irrigation. Drip irrigation system once installed could be effectively used for 5 years (up to fourth ratoon crop). Under skip-furrow/alternate furrow irrigation, a practical and effective approach of saving irrigation water by 30–40% water without reduction in cane yield has been considered effective in which one row is skipped and irrigation is applied in each furrow. In alternate furrow method, alternating furrows for irrigation each time has also economized water use and the method is recommended under limited water availability conditions.

Insect - pest & Disease Management

Sugarcane is an annual crop and attacked by number of insect-pests and diseases. In changing climatic conditions, some minor diseases and insect – pests may cause economic damage to the crop. The management will be very important to improve the cane yield and productivity. The management of insect-pests and diseases of sugarcane crop requires strategic and effective management technologies to improve the benefit cost ratio. The management strategies include from selection of seed cane, sett treatment, monitoring of crop fields and need based application of cultural operations and protection technologies. Bio-control agents, botanicals and bio-fertilizers *cum* bio-agents are being widely advocated to manage adverse situation while safeguarding our environment. Although sugarcane varieties through All India Coordinated Programme are identified on the basis of red rot, wilt and smut tolerance. Despite, after continuous use of seed of single variety, red rot symptoms may appear in selected pockets. Thus varietal diversification is important to control these diseases. Management of borer pests is also possible through natural enemies. Many plants are known to have pesticidal properties and the extract of such plants or their refined forms can be used in the management of pests. Among various plants identified for the purpose, neem has been found to be most effective. It is very effective botanical against variegated grasshoppers, green rice leaf hopper and cotton jassids (Chaudhary *et al.* 2017). Neem is also fairly good in managing beetles, aphids and white flies, mealy bug, scale insects, adult bugs, fruit maggots and spider mites (Gajalakshmi *et al.* 2004).

Beneficial microbes like fungi and bacteria have great potential in management of pathogenic microbes of the crop. *Trichoderma* spp. is among the most commonly isolated soil fungi. Due to their ability to protect plants and contain pathogen population under different soil conditions, these fungi have been widely studied and commercially marketed as bio-pesticides and growth regulators. *Trichoderma* spp. also produces numerous biologically active compounds, including cell wall degrading enzymes, and secondary metabolites (Yadav *et al.*; 2009). Efficacy of *Trichoderma* spp., to manage the red rot disease was also observed along with moist hot air treatment (MHAT) and other treatments with an aim of modulating host resistance for red rot. The lower incidence was recorded in highly susceptible sugarcane variety. Use of pest predators and pathogens has also proved to be effective method of keeping pest problem below ETL. *Trichoderma viride* or *T. harazianum* or *Pseudomonas fluorescence* formulations @ 4 g/kg seed either alone or in combination to manage most of the seed borne diseases. Mass multiplication of *Dipha aphidivora*, the predator of sugarcane woolly aphid is recommended for sugarcane woolly aphid susceptible variety (Balikai *et al*. 2003).

Crop residue recycling

Sugarcane is huge biomass generating crop. About 10–12 t/ha crop residue is generated through a sugarcane crop yielding about 80-100 t/ha. Trash is lignocellusic biomass which principally contains cellulose, hemi-cellulose and lignin. Its management is very important for sustainable sugarcane based cropping. It is good source for plant nutrients and conserves soil moisture, controls weeds and creates favourable rhizo-microbiome environment for optimizing nutrients availability and crop growth. Trash mulching (8-10 cm thick) in between rows of sugarcane ratoon has been recommended. Trash mulching conserves soil moisture, controls weed growth, and improves soil organic carbon (SOC) and availability of nutrients in ratoon crop (Yadav *et al.* 2009).

Mechanization in sugarcane cultivation

Advancement in sugarcane cultivation comes with adoption of farm machinery. Sugarcane is annual crop and takes 10 to 12 months for maturity. The crop growth and productivity is directly linked with soil tilth. So in preparing good tilth for sugarcane cultivation, role of farm machinery is important. The farm machines (from simple to advanced labour saving devices) are developed by the Government and private organizations. A number of machines have been designed and developed at the Indian Institute of Sugarcane Research, Lucknow keeping in view the soil and agro-climatic conditions and prevailing agronomic practices. Sugarcane cutter planter, ratoon management device, planter for inter crops, trench planter and residue shredder are few of these machines recommended for profitable cultivation. Farmers may use these machines on their own fields. Sugarcane cutter planter has been developed by ICAR-IISR, Lucknow. Ridger type sugarcane cutter- planter, PTO driven is being widely used and performs major operations during cane planting at an adjustable row spacing. It has also effective capacity of planting one ha in 4-5 hours and saves approximately 60% cost of planting operation. The planting operations *viz.*, opening of furrows, planting the setts, placing the fertilizers and pesticides and covering the setts have been combined in single pass. Planting through sugarcane cutter planter conserves soil moisture and improves germination. This is very much favourable under hot and drier conditions in subtropical India particularly in the month of April – May. The machines may be purchased on custom hiring basis through collaborations of sugar mills / cooperative societies.

Ratoon management

Ratooning is a common practice of growing sugarcane crop from sprouts of underground stubble left in the field after harvest of the main crop. It is an important crop because ratooning saves the cost of seedbed preparation, seed, and planting operations. Ratoon crop matures earlier than the main crop. However, most often, cane yields of ratoon crop are lower than the main crop due to many factors including soil compaction (Verma 2002), decreased soil fertility (Hunsigi 2001) and inefficient use of applied fertilisers (Sundara and Tripathi 1989). In sugarcane plant – ratoon system, at initiation dismantling of ridges, stubble shaving and off-barring is recommended for good ratoon yields. Gap filling with slip setts / pre-germinated setts / poly bag raised settlings is a must if gaps exceed 10-15% of normal crop stand. More than 60 cm distance between subsequent clumps is considered as gap in ratoon crop. At IISR Lucknow, paired row system of planting (120:30) reduced gaps and optimized plant population in subsequent ratoon. Low stubble population due to gaps and poor bud sprouting in winter season were found to be major bottlenecks in increasing ratoon productivity. ICAR-Indian Institute of Sugarcane Research has developed tractor operated ratoon management device (RMD). RMD performs dismantling of ridges, interculturing between rows, placing organic manures, fertilizers and mild earthing up in single pass at the time of initiation. Besides, trash chopper has also been developed for *in-situ* trash mulching. It creates favourable soil environment for better bud sprouting and further growth of ratoon crop.

Ratoon crop matures in 10 months and gives an advantage of early maturing variety. Harvesting of plant crop close to the ground level is recommended to improve the stubble bud spouting. However, if the harvesting of crop close to the ground level could not be done, stubble shaving is recommended. The ridges should be dismantled after harvesting of plant crop. In order to improve the soil physical condition and also to prune the stubble roots, the inter-row spacing must receive deep cultivation (off-barring) followed by irrigation. Three splitting of fertilizer nitrogen may be done at the time of initiation, 45 days and 75 days of ratoon initiation. Twenty five percent higher N is recommended in ratoon crop as compared to the plant crop. The ratoon crop should be fertilized with K at the rate of 80 kg K_2O/ha to avoid the lodging and improve sugar recovery. The requirement of K_2O and phosphorus could be ascertained by soil testing. Earthing–up in the month of July-August and wraping/propping should be done to check the growth of excessive tillers and avoid lodging in crop.

Conclusion

Sugarcane is vegetative propagated crop and requires 10 to 12 months for maturity. The changes in atmospheric conditions can affect plant biomass, cane & juice quality and sugar recovery. Adoption of green technologies from seed selection to harvesting are very important to improve the productivity and sustainability. Sugarcane crop encounters all seasons and faces extremes of climatic conditions and also attacked by several insect-pests, diseases and weeds. It becomes very difficult to sugarcane cultivators to grow crop in adverse climatic conditions and achieve maximum cane productivity and sugar recovery under limited application of inputs. So to minimise the adverse effect of climate, high yielding and high sugar varieties have been developed under AICRP(S) in addition to advanced crop production and protection technologies.

The small interventions of green technologies will certainly provide benefits to the farmers. Comprehensive approaches including micro-irrigation techniques, use of biofertilisers and crop residue recycling to minimise the use of chemical fertilisers and improving soil health is required. Nutrient management, water management, weed management, ratoon management, integrated pest management (IPM) and integrated disease management (IDM) technologies have been developed and these technologies are being adopted on farmer’s fields.

Sugarcane crop is not exhaustive rather than soil fertility restorer, if the crop products/ by products are being managed well in soil-sugarcane– sugar production system. In this scenario, trash, press mud cake, vinasse, composted bagasse, rhizodepositions of stubble plays great role in sustaining soil fertility and increasing crop productivity. Intercropped green manuring through dual purpose legume crops such as cow pea, green gram & black gram are the viable options. Integrated weed management in ratoon through trash mulching, one hoeing and single application of atrazin

@ 2 kg ai/ha during ratoon initiation minimizes crop weed competition during tillering phase. Adoption of skip furrow/alternate furrow techniques effected water saving up to 35-40% without yield reduction. Planting in FIRB method particularly in sugarcane–wheat system improves the sugarcane yield besides improving water use efficiency (WUE) and nutrient use efficiency (NUE). Adoption of IPM reduces burden of chemicals on the soil and crop besides increasing population of beneficial insects. Use of organics, biofertilizers reduces the amount of chemical fertilizers and improves the NUE and response of the crop to nutrients. Besides increased water holding capacity and nutrients availability provides sustainability to sugarcane based system. Sugarcane productivity in India has increased to >79 t/ha. However, keeping in view the achievable potential of the crop, we have still scope to double the productivity and farmers income while safeguarding environment (soil, water and air).

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Intercropping in autumn and spring planted sugarcane for sustainable development of the farmers

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The accelerating population and urbanization coupled with the high growth rate of industrial and housing sectors put a lot of pressure on the land. Under these situations focus on enhancing the vertical land productivity is an important avenue for sustainable development of the farmers. In view of changing market scenario, consumers' preferences and global competitions, new income generating opportunities need to be created through crop diversification in sugarcane 'Produce to Product Chain'. This would help in increasing the land utilization efficiency, reducing the production cost, economizing the use of market purchased costly inputs and making plant-ratoon system sustainable. This in turn raises the socio-economic status of small and marginal resource constrained farmers and generates employment especially for rural women and youths. Intercropping, an integral component of crop production refers to growing of two or more generally dissimilar crops simultaneously on the same piece of land, base crop necessarily in distinct row arrangement. The recommended optimum plant population of base crop is suitably combined with an appropriate additional plant density of the associated crop and there is crop intensification in both space and time dimensions.

The researches on intercropping have confirmed that small farmers in developing countries have been doing it for centuries and it makes efficient use of resources and generally provide yield advantage as compared to sole cropping. The crops and their combinations in intercropping systems are largely determined climatically. Inter-regional differences in the extent of intercropping depend on factors such as irrigation facilities, type of crops and soil management.

Growth pattern

The initial growth of sugarcane is very slow. It takes about 30-35 days to germinate in spring (February – March) and even more in autumn (November). Thereafter, further 100 days are taken to develop full canopy to cover entire inter-row spaces. In these 130-135 days, another crop of short duration like short duration pulses, oilseeds, spices, vegetable, cereals could easily be grown in this space without affecting the main crop.

Prospects and opportunities

Intercropping permits more intensive cropping in a crop like sugarcane, which is traditionally grown in 'Single Cropping System'. As sugarcane plants have large lateral spread when fully grown, their optimum row spacing is usually 90 cm or more. Weeds can quickly cover the vacant space in between the rows, which when allowed to grow might eventually offer severe competition to the main crop. Instead of such a waste of available spaces, intercropping would offer opportunity for profitable utilization of such space while cutting down on the direct cost of cultivation of the main crop by reducing the expenditure on weed control.

The practice of intercropping would require raising a short duration, quick growing crop in space left in between rows of sugarcane. The companion crop should require, only that much space which is unoccupied by the sugarcane crop. Such a situation only could theoretically give an associated growth with zero added competition.

Sugarcane characteristically widely spaced, initially slow growing, long duration and one time income generating crop, lends ample scope for intercropping with short duration, high value and mid-season income generating crops for nutrition and economic security especially of small and marginal cane growers.

Sugarcane based cropping system has a distinct advantage as it leaves large crop residues like trash, roots, stubble etc. and is also heavily fertilized. Intercropping in sugarcane is a small farmer technology, whereby the farmer gets additional income. Attempts have been made to change the geometry of planting in favour of growing intercrops. The intercropping in sugarcane is an additive series and not a replacement series. Sugarcane is always a dominant species.

Advantages of production system diversification

- Mid-season income generation from intercrops for better management of sugarcane, *per se*.
- Regular on -farm employment especially for women and children.
- Provides high yielding environment to pulses and oilseeds which otherwise are grown under low producing environments.
- Crop residue recycling *vis-a-vis* maintenance of soil health.

There is tremendous scope of increasing area under pulses, oilseed, spices, vegetables and cereals through intercropping in sugarcane under Indian tropics and subtropics (Table 1).

Intercropping with autumn planted sugarcane

Sugarcane in autumn is planted at wider spacing of 90 cm or more, the bud sprouting is late

Table 1. Crops suitable for intercrops in sugarcane

(A) Tropical belt	
Green gram (*Vigna radiata*)	Groundnut (*Arachis hypogea*))
Blackgram (*Vigna mungo*)	Sesame (*Sesamum indicum*)
Cowpea (*Vigna unguiculata*)	Sunflower (*Helianthus annuus*)
Maize (*Zea mays*)	
Finger millet (*Eleusine coracana*)	Soybean (*Glycine max)*
Radish (*Raphanus sativus*)	Coriander (*Coriandrum sativam*)
Onion (*Allium cepa)*	
Okra (*Abelmoschus esculentus*)	
(B) Subtropics (Autumn planting)	
Potato (*Solanum tuberosum*)	Onion (*Allium cepa)*
Radish (*Raphanus sativus)*	Garlic *(Allium salivum*)

Mustard (*Brassica campestris.*)	Coriander *(Coriandrum sativam)*
Carrot (Daucus carota)	Sugarbeet (*Beta vulgaris*)
Lentil (*Lens esculentus*)	Wheat (*Triticum aestivum*)
Linseed (*Linum usitatissimum*)	
French bean (*Phaseolus vulgaris*)	Peas (*Pisum sativum*)
Maize (*Zea mays)*	Turnip (*Brassica rapa)*
Toria (*Brassica spp.)*	Grain amaranth (*Amaranthus* spp.)
(C) Subtropics (Spring planting)	Tomato(*Lycopersicum esculentum*)
Green gram (*Vigna radiata*)	
Blackgram (*Vigna mungo)*	
Cowpea (*Vigna unguiculata*)	Brinjal (*Solanum melongena*)
Dhaincha (*Sesbania sesban*)	
(D) Subtropics (Ratoon cane)	
Berseem-Egyptian clover *(Trifolium alexandrium*)	
Shaftal- Persian clover (*Trifolium resupinatum*)	
Senji –Indian clover (*Melilotus parviflora*)	
Lucerne (*Medicago sativa*)	
Menthi- Fenugreek (*Trigonella fonum graecum*)	
Oats (*Avena sativa*)	

Source: Verma *et al.* (1984); Menhi Lal and Singh (2004)

and initial growth rate of crop is slow. Autumn planted sugarcane provides 15-20 per cent higher cane yield and 0.5 units more sugar recovery than spring planted cane but the area remains limited. However, companion cropping of winter pulses may promote autumn planting of sugarcane on account of higher returns and better resource use efficiency. Experiments conducted at SRI, Pusa in autumn sugarcane and their results discussed below:

Sugarcane + potato

For intercropping of potato with sugarcane, it is necessary to plant sugarcane in the first week of October at 90 cm row spacing with 100% seed rate as sole crop (50-60 q/ha). Potato is planted between two rows of sugarcane using paired row planting method. In this method seed rate of potato is kept almost same as sole crop (20-25 q/ha).The suitable varieties of potato under intercropping are Kufri Sinduri, Kufri Chandramukhi and Rajendra Allu-2. The distance between sugarcane row to potato row and potato to potato row should be 35 cm and 20cm, respectively.

Under sugarcane + potato intercropping system, the manure and fertilizer requirement of sugarcane is equal to the sole crop of sugarcane however, an extra dose of fertilizer (45 kg N, 5 kg P_2O_5 and 60 kg K_2O/ha) should be placed below the potato seed (tuber) in furrows. Remaining 40 kg N per hectare of potato should be top dressed at the time of earthing up. The potato crop will be ready for harvest in the month of January. Under this system potato produced yield of 25.0 t/ha, which is almost equal to the yield obtained from pure stand of potato with cane yield of 98.0 t/ha. This system recorded highest B: C ratio (2.29) for autumn planted sugarcane**.**

Sugarcane + wheat

In autumn season, sugarcane generally takes about 50 to 60 days for its complete germination. Irrigate the crop in the second week of November and do hoeing at field condition. Before hoeing, placed nitrogen at the rate of 25 kg per hectare in wheat rows. Two rows of timely sown irrigated wheat varieties PBW-343 or HD-2733 or K-9107 may be sown at 20 cm apart in the centre of two rows of sugarcane leaving 35 cm distance from cane rows are sown with a seed rate of 40-50 kg/ha.

Remaining 25 kg N for wheat should be applied in two equal splits i.e. one after first irrigation (20-25 DAS) and another at second irrigation (40-45 DAS). Third and subsequent irrigation should be given as and when required by wheat crop. The entire dose of phosphorus and potassium of sugarcane should be placed in furrows at the time of sugarcane planting. However, half of N for sugarcane should be applied in sugarcane rows only and the remaining half as per recommended schedule. In sugarcane + wheat intercropping system, sugarcane and wheat yielded 85.0 t/ha and 2.5 t/ha respectively with B: C ratio of 1.82.

Sugarcane + lentil

In this system sugarcane is planted in the first week of October. Two lines of lentil varieties PL 406 or PL 77-12 or any other short duration varieties of lentil with a seed rate of 15-20 kg/ha may be sown 30 cm apart in the centre of sugarcane rows. Since lentil is a leguminous crop, hence only 15 kg N/ha as a starter dose should he applied below the lentil rows at the time of sowing. Similarly basal dose of nitrogen for sugarcane should be placed below the setts in furrows. However, full dose of phosphate (85 kg/ha) and potash (60 kg/ha) of sugarcane should be applied as basal. The results indicated that (Table-2) this system produce 1.2 t of lentil per hectare with no adverse effect on cane yield (90 t/ha) with B: C ratio of 1.88.

Sugarcane + rajmash

Under sugarcane + rajmash intercropping system sugarcane may be planted up to last week of October. Two lines of rajmash (cv. PDR-14) can be sown 30 cm apart in the centre of two rows of sugarcane. The distance between cane and rajmash should be maintained at 30 cm with 60-65 kg/ha seed rate of rajmash.

An additional dose of 30 kg N for rajmash should be applied at the time of sowing in the rows of rajmash and 30 kg N after first irrigation for proper growth and development of crop. The recommended dose of P and K for sugarcane should be applied as basal. The results revealed that rajmash produces yield of 1.2 t/ha and cane yield of 88.5 t/ha with B: C ratio of 1.88.

Sugarcane + garlic

Garlic intercropped with sugarcane produce more yield than any other combination of intercropping probably due to its role in minimizing the nematode population in soil. Moreover, garlic acts as insect repellent in some extent due to its specific odour. Two lines of garlic Yamuna Safed, *Lahsun Badsah* or local varieties with a seed rate of 100-125 kg per hectare is sown in the centre of cane just after planting of sugarcane at 15 centimeter apart. An extra dose of 15 kg nitrogen per hectare is applied to garlic at the time of dibbling and 10 kg N at the time of earthing up.

Intercropping of garlic with sugarcane is very much remunerative and recorded highest B: C ratio (2.46) among intercropping during autumn planted sugarcane. The system produces cane yield of 98.2 t/ha and 4.0 t /ha garlic as intercrop.

Sugarcane + coriander

Two lines of coriander may be sown 30 cm apart in the middle of October planted sugarcane rows. The distance between coriander and sugarcane rows should be maintained at 30 cm with 12-15 kg/ha seed rate of coriander. Recommended dose of nitrogen for coriander is 40 kg per hectare. Half of N should be applied at the time of sowing and remaining half after first irrigation. Under this system sugarcane produced yield of 88.7 t/ha and yield of coriander is about 1.2 t/ha with B: C ratio of 2.36.

Table-2: Yield and economics of sugarcane and intercrops under sugarcane based cropping system

Cropping system	Yield (t/ha)		B:C ratio
	Sugarcane	Intercrops	
Autumn cane	98.5	-	1.75
Sugarcane + potato	98.0	2.5	2.29
Sugarcane + wheat	85.0	2.5	1.82
Sugarcane + lentil	90.0	1.2	1.88
Sugarcane + rajmash	88.5	1.2	1.88
Sugarcane + garlic	98.2	4.0	2.46
Sugarcane + coriander	88.7	1.2	2.36
Spring cane	87.0	-	1.58
Sugarcane + green gram	83.0	0.8	1.74
Sugarcane + black gram	83.5	0.5	1.65
Sugarcane + lady's finger	82.0	6.0	2.05

Source: Navnit Kumar (2015)

Intercropping with spring planted sugarcane

It is estimated that about one million hectare additional area can be brought under pulses by intercropping green gram and black gram in spring planted sugarcane especially in UP, North Bihar, Punjab and Haryana. Experiments conducted at Lucknow revealed that out of 5 genotypes of green gram minimum loss of cane yield is due to genotype PDM-11 and PDM-84-139 (4-5%). Among dual purpose legumes, the higher monetary returns may be taken through intercropping of sugarcane + green gram (K- 851 for grains) and sugarcane + cowpea (*Pusa Komal* for green pods). After picking green pods for vegetable and/or mature pods for grains, the legume plants with longer leaf area duration are incorporated in the soil between the inter-row spaces of sugarcane as green manure. These systems effect nitrogen economy in sugarcane to the extent of 35-40 kg/ha besides producing bonus yield of pulses. The compatibility of intercrops varies with the row arrangements and genotypes selected as intercrop in the system.

Sugarcane based intercropping system involving *Sesbania sesban* at high density in spring planted cane effectively controls weed population and its *in situ* turning exhibits allelopathic effects on germination of *Cyperus rotundus* nuts, besides correcting nutritional imbalances. In spring season, green gram, black gram and lady's finger are the best intercrops for sugarcane. Inclusion of pulses as an intercrops can increase the area of pulses in Bihar. Experiments conducted at SRI, Pusa in spring sugarcane and their results are discussed below:

Sugarcane + green gram

In this system, sugarcane is planted in the month of February with 90 cm row spacing. Two rows of short duration varieties of green gram like, PS-16 and Sons at 30 cm apart of the middle of sugarcane rows leaving 30 cm distance between cane and green gram are sown. A seed rate of 12-16 kg per hectare is sufficient for sowing green gram as an intercrops in sugarcane.

Only 10 kg nitrogen per hectare will he required as a starter dose for green gram at the time of sowing. The recommended dose of 85 kg P_2O_5 and 60 kg K_2O/ha for sugarcane should be applied as basal at the time of planting. This system produced cane yield of 83.0 t/ha and 0.8 t/ha of green gram with B: C ratio of 1.74.

Sugarcane + black gram

In this system, sugarcane is planted in the month of February with 90 cm row spacing. Two rows of black gram (cv.T_9) in between the two lines of sugarcane may be sown at 30 cm apart. The distance between cane and black gram rows area should also kept about 30 cm. Under this system, 12-16 kg seed of black gram is enough to sow one hectare of area. An additional dose of 10 kg N is applied for black gram at the time of sowing.

This system produced cane yield of 83.5 t/ha and 0.5 t/ha of black gram with B: C ratio of 1.65.

Sugarcane + ladies finger

Intercropping of lady's linger along with sugarcane has been found to be most remunerative in spring season. One row of Pusa Sawni or Prabhani kranti variety of lady's finger was sown in the centre of two rows of sugarcane with seed rate 8 kg per hectare.

The recommended dose of nitrogen for lady's finger is 60 kg per hectare. Out of which, 20 kg N per hectare applied at the time of sowing and remaining 40 kg N per hectare should be applied in two equal splits at first and second irrigation. From this set of intercropping the sugarcane produced yield of 82.0 t/ha along with 0.6 t/ha yield of lady's finger. This system having highest B: C ratio (2.05) for spring planted sugarcane.

Water management

Under sub-tropical conditions, autumn cane requires on average 5-6 irrigations; while spring planted cane may be irrigated 4-5 times. Under intercropping system, irrigation given as per the need of intercrops. First irrigation should be applied after germination of sugarcane.

Weed management

High crop density under intercropping system creates severe competition to weeds and thus, reduces the weed growth to some extent. Inclusion of green gram or black gram as intercrops in spring sugarcane effectively reduces the weed population, there by decreases cost of cultivation. Under intercropping system, generally weed management is done manually by doing inter culturing operation but, in case of unavailability of labourers recommended herbicides for different intercrops may be used.

Harvesting and yield

Under sugarcane based intercropping system, all of the intercrops are harvested earlier to sugarcane formative phase hence, there is no chance of adverse effect on sugarcane yield it shows yield potential as sole crop. However, yield of intercrops depends upon its plant population and proportionate area occupied by them in the intercropping system.

Tips for successful intercropping in sugarcane

- Crop selected for intercropping in sugarcane should be of short duration, short stature, high value, mid-season income generating and eco- friendly
- Selection of the crop varieties should be on the basis of the recommendations for the region/areas.
- There should be sufficient moisture in the upper layer of the soil at sowing time of intercrops. If required, light irrigation should be given before sowing of intercrops.
- Irrigations in intercropping system should be as per the requirement of the intercrop.
- Before selecting an intercrop, scope of marketing the produce should be explored.

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Impact of plant growth regulators on sugarcane: crop establishment, productivity and expression of genes associated with sucrose synthesis and accumulation

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Generally sugarcane experience slow and reduced sprouting/germination which not only hampers early crop establishment also lead to low productivity in sub-tropical part of India. Sett priming with ethrel and application of GA_3 (Gibberellic acid) were taken up to visualize their impact on two sugarcane varieties (CoLk 94184 and CoPK 05191) on cane and sugar yield. As sucrose gets accumulated in sink tissue *i.e.* stalk, supplied by the source *i.e.* leaf, the expression analysis of pivotal genes associated with sucrose in these tissues were performed to better manipulate sucrose level in sink tissues. Precise signal transduction between source-sink tissues regulate sucrose level in sink and negative feedback from it restrains further uploading of sucrose in stalk and therefore, any perturbation possibly would help in to improve sucrose content in cane. Results indicated seed priming with 100ppm ethrel, 100% increase in germination was observed in CoLk 94184 variety. Though germination was as such high in CoPK 05191, sett priming further increased it by 25%. GA_3 improved sink strength by redistribution of the photoassimilates as prominent increase in invertase activity was observed especially at early stage of the application to provide hexoses which in turn helped increase the internodal length and cane capacity for additional accumulation of sucrose. At maturity, sucrose % juice and Brix was found higher in GA_3 applied canes. Increased expression of cell wall invertase (CWI) as observed in GA_3 exposed samples at elongation stage indicated its role in phloem unloading of sucrose in sink tissues. Expression of both sucrose synthase (SuSy) and sucrose phosphate synthase (SPS) though involved in regulation of sucrose accumulation was found variable. Thus, through application of plant growth regulators, along with early and higher germination, redistribution of photo-assimilate is possible to improve sucrose content in sink tissues possibly by influencing source-sink dynamics in sugarcane.

Keywords : Ethrel, Gibberellic acid, Gene expression, Seed priming, Source-sink dynamics, Sugarcane

Sugarcane (*Saccharum* spp. hybrids) is primarily known for sugar in its stalk. It is an important cash crop cultivated on ~26 million hectares of land in >90 countries and provides 80% of the world's sugar (Zhang *et al.* 2018). Besides sucrose, sugarcane is also an important source of fiber, molasses, press mud, spent wash (stillage) and biofuel. Bio-physiological capability of the sugarcane stem indicated that the potential for storing sucrose in its stalk is ~30% (Fresh weight) (Bull and Glasziou 1963). This parameter has recently been challenged and shown that sugarcane stem is able to retain even higher sugar (Wu and Birch 2007). This recommends existence of some complex mechanism for both sucrose accumulation and its control in the stalk (Chandra *et al.* 2015). World's average cane productivity hovers around 70 t/ha, whereas in many parts of India cane productivity is still below 60 t/ha. In recent years due to good variety and agronomical practices, improved cane productivity is realized. Nevertheless, it is still far below than those estimated theoretically (340 t/ha). Slow and reduced germination is one reason which not only delays early crop establishment, hampers cane and sugar yield due to late emergence of tillers and their survival causing less number of millable canes (NMC), which is in-fact major component of cane yield. Yadav *et al.* (1997) demonstrated slow and late germination primarily restrict crop growth to 220 days and this further suppresses physiological growth of plants causing reduced dry matter and sucrose accumulation in sugarcane (Lingle 1999). Source-sink dynamics regulate sucrose accumulation in sink and negative feedback from sink restrains further sucrose accumulation. Possibly, perturbation of this negative feedback may help to improve sugar. Plant growth regulators namely ethrel and GA_3 have been contemplated to study/visualize their influence on crop establishments (early and higher germination) *vis-a-vis* tracking expressing of some pivotal genes associated with sucrose accumulation under control and source-sink perturbed conditions created by the application of GA_3 (Roopendra *et al.* 2018; Verma et al. 2017). Rai *et al.* (2017) demonstrated enhanced physiological growth of late planted sugarcane by exogenous applications of ethrel and GA_3.

In general higher concentration of ethrel (ethephon) is used to promote maturity in many crops including horticultural and forestry crops around the world (Li and Solomon 2003). Also, it is widely used to stimulate the maturation of sugarcane as it contains ethylene, which is released to the plant on spraying. Not much information is available when cane setts are exposed to low dose of ethrel especially before planting. Li *et al.* (2003) demonstrated effect of foliar spray of ethephon on some enzyme activities in stem cells of sugarcane. GA_3 (Gibberellic acid) in general influences seed germination, leaf expansion, stem elongation, flower/trichome initiation, flower and fruit development (Yamaguchi 2008). Khan *et al.* (2007) reported an increase of source potential and redistribution of photosynthate to enhance the sink strength by GA_3. Probably this will eventually improve the competitive ability of an organ to attract more assimilate (Farrar 1993). Impact of GA_3 on the expression of genes associated with sucrose synthesis and accumulation, is limited in sugarcane, nevertheless, it has impacted bud sprouting, culm growth, sugar production, ripening, water relations, and weed control (Moore and Buren 1978; Botha *et al.* 2013). GA_3 has been utilized commercially to promote the sugarcane growth in Hawaii where some varieties were found more responsive than others (Moore 1977; Moore and Buren 1978). Verma *et al.* (2017) and Roopendra *et al.* (2018) demonstrated role of GA_3 in perturbation of source-sink dynamics influencing intermodal length and expression behaviour of genes associated with sucrose accumulation in sugarcane. Nevertheless, information is lacking wherein role of seed priming and application of GA_3 during early crop growth stages of sugarcane is contemplated to visualize cane and sugar yield. The aim of the present study was to visualize impact and varietal response of ethrel and GA_3 on crop establishment and expression of genes associated with sucrose accumulation in sugarcane stalk primarily regulated through source-sink feedback mechanism.

Experiments was conducted at ICAR-Indian Institute of Sugarcane Research farm (26.78°N, 80.99°E, 111msl) Lucknow, India using two sugarcane variety namely CoLk94184 and CoPK05191 in October 2016 (Autumn planting). Three bud setts were used as seed to prime by soaking them overnight in 100 ppm ethrel. Before planting the setts in furrows they were rinsed with 0.2% Bavastine. Row to row distance maintained was 75cm. GA_3 (35 ppm) were applied exogenously twice at 90 and 120 days of planting (DAP) using uniform controlled dispensing mechanical sprayer. The crops were raised with standard agronomic cultivation practices and recommended doses of N, P, K (150:80:80 Kg /ha). Germination was recorded at 50 DAP.

Following the procedure of Meade and Chen (1977), cane juice quality was analysed from 12 randomly selected mature stalks (360 DAP). Brix, sucrose percent juice and juice purity were determined after cane crushing in the month of October 2017. For sucrose % juice, the fresh cane juice was clarified by adding lead acetate and filtered through Whatman filter paper No 1. Automatic Saccharimeter (Rudolph Autopol) was used to measure the sucrose % juice. Handheld digital refractometer (PAL-1, Atago, Tokyo) was used to measure the cane stalk Brix. Other biochemical parameters were estimated as described earlier (Verma *et al.* 2017). Samples for enzyme analysis comprising a total of 12 randomly selected stalks per plot (2 adjacent stalks/row) were taken at 50 DAS (days after spraying) and further at 30 days' interval, up to 200 DAS (50, 80, 110, 140, 170, 200 DAS).

Total RNA was isolated by using the TRIzol (Invitrogen, USA) reagent from source (LTM leaf) and sink tissues (internodes). The quantity and integrity of the isolated RNA was checked on 1.0% agarose gels. cDNA synthesis and qRT-PCR was performed using one-step reverse transcriptase PCR kit (Qiagen, USA) following the procedure described earlier (Roopendra et al. 2018). The purified RNA was stored at -20^0C until further use. RNA concentration in all the samples was first normalized on agarose gel and on the nano drop (Quawell UV-visible spectrophotometer). End point PCR was performed using Surecycler 8800 Agilent Technologies. Amplified products were separated on 1.6% agarose gel and visualized using gel documentation system (Alpha Innotech, San Leandro, CA, USA). Statistical analysis was done on data derived from three independent experiments on three biological replicates of control and treated canes. Results were depicted as mean ±SE. The significance of the difference between control and treated samples was statistically evaluated with two-sided student t-test using Microsoft Excel 2007 software Data Analysis tool pack.

Sett priming with ethrel induced early and high germination over control. In case of CoLk 94184 germination recorded at 50 DAP was 60.5% (treated setts) whereas only 29.9% was recorded with control setts (Fig. 1). In case of CoPK 05191, germination in control samples was 68.8% which further improved significantly when setts were primed with 100ppm ethrel (85.5%) (Fig. 1). A significant varietal difference was also visualized. In general setts of CoPK 05191 were thicker than those of CoLk 94184 and accordingly the auxillary buds attached at each node were more conducive for germination as they stored more carbohydrates to provide energy during germination.

Increased germination provided additional time for crop establishment/growth. Two sprays of GA_3 at 90 and 120 DAP further promoted rapid elongation and division of cells supported with increased invertase activity providing sufficient hexoses to elongating tissues. In our earlier study with CoJ64 variety this interventions has induced ~42.3% enlargement in cell size, ~39.3% increase

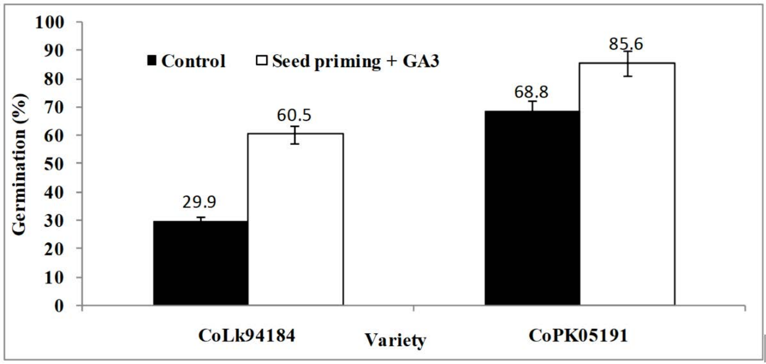
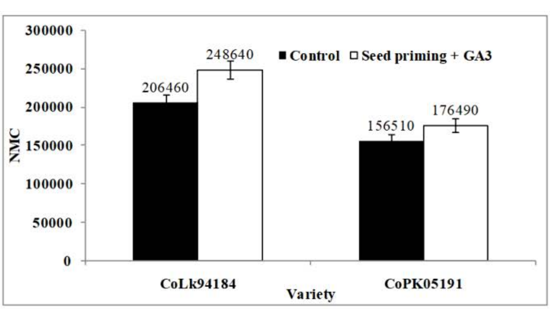
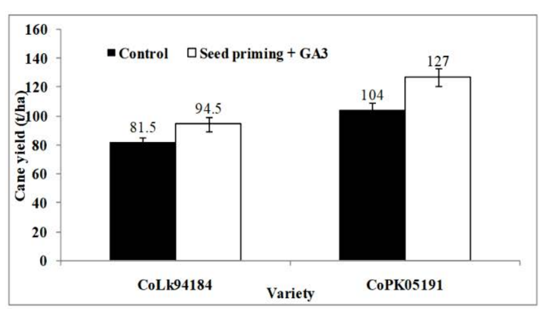


Fig. 1. Germination recorded at 50 DAP in control and ethrel primed setts seed

in internodal length (sink capacity), 177% escalation in reducing sugar (sink strength) and amplified expression of sucrose metabolizing enzymes (sink demand) (Roopendra *et al.* 2018). Increased growth of some sugarcane cultivars under Hawaiian winter conditions have been reported by the application of GA_3 (Moore and Buren 1978). Number of millable canes (NMC) as observed with both varieties was significantly higher in ethrel primed and GA_3 exposed samples than those of their respective controls (Fig. 2a). In case of CoLk 94184, NMC increased was about 40,000/ha whereas in CoPK 05191 this increase was ~20,000/ha. Increased shoot numbers has been also reported in late planted cane when sett was soaked with ethrel and exposed to GA_3 (Rai *et al.* 2017). Authors further summarized that this has happened due to decreased shoot mortality and robust development of root system (Rai *et al.* 2017). In the present study, tiller mortality was just double in CoPK05191than those of CoLk 94184 (data not shown). Though increase in NMC was much higher in CoLk94184 than those of CoPK 05191, cane yield was not increased in that proportion. Increase in cane yield was 13 t/ha in CoLk 94184 and 23 t/ha in CoPK 05191 (Fig. 2b). Though NMC is a prime contributing factor for cane yield, possibly cane weight has played important role in increasing cane yield. In general CoPK 05191 variety is thicker than those of CoLk 94184. Nevertheless, increased NMC is observed in CoLk 94184 due to seed priming and application of GA_3. Juice quality parameters as depicted in Fig. 3 did not change significantly in both varieties.



(a)

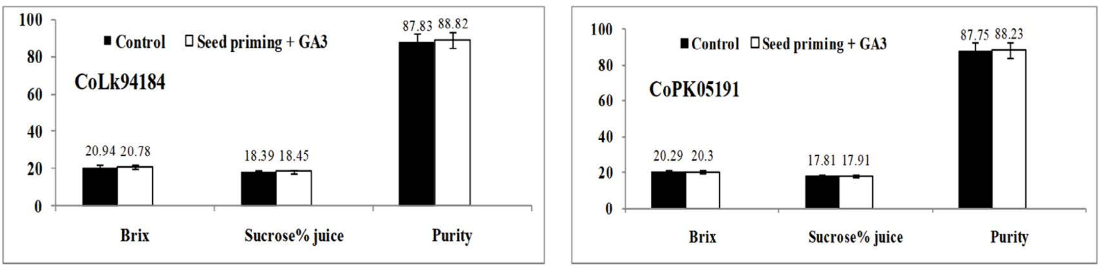


(b)

Fig. 2. Number of millable canes (a) and cane yield (b) as influenced by sett priming and GA_3 in two varieties (CoLk 94184 and CoPK 05191) of sugarcane

Range of increase in juice purity was 0.55 to 0.68% over control whereas sucrose % juice increased up to 0.56% in CoPK 05191 and 0.33% in CoLk 94184 (Fig. 3). Rai *et al.* (2017) also reported only 0.3% increase in purity of cane juice in ethrel-soaked setts with GA_3 applied cane over control.

At early stage (80 DAS), higher invertase activity was seen in all three top, middle and bottom portions of the cane, however at later stage only top portion sustained higher activity (data not shown). Possibly the initial increased invertase activity as observed in all three portions of treated cane triggers the elongation of internode due to the availability of higher concentration of hexoses



(a) (b)

Fig. 3. Cane quality parameters as influenced by sett priming and GA_3 in two varieties (CoLk 94184 and CoPK 05191) of sugarcane

to carry out required metabolic activities. Our result was in agreement to the earlier reports where increased invertase activity was observed at early stage of the cane exposed to GA_3 (Verma et al. 2017). Gene expression (qRT-PCR) analysis also supported the fact that higher expression of SAI in upper internodes eventually led to the availability of higher level of hexoses for stem elongation (Fig. 4).) Increased acid invertase transcript levels within 4 hrs after GA_3 treatment has been reported in pea (Wu *et al.* 1993). Expression of SPS, SuSy and CWI genes was observed variable in different internodes. However, expression was invariably higher in ethrel soaked and GA_3 exposed source and sink tissues over corresponding controls (Fig. 4).

Our findings indicated that sett priming with ethrel helped in achieving early and higher germination and improved cane yield. GA_3 application exhibited improved sink strength by increasing activity and expression of invertases which has finally triggered elongation of internodes via increased availability of hexoses. Though sugar level has not significantly changed, the expression patterns of some pivotal genes associated with sucrose accumulation as studied under normal and GA_3 perturbed conditions have provided a platform for better understanding of the source-

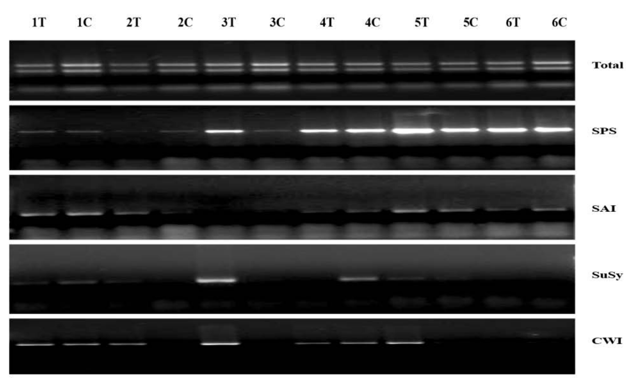


Fig. 4. Total RNA and qRT-PCR analysis with SPS, SAI, SuSy and CWI genes using tissues from source (LTM leaf, lane 1) and sink (lanes 2 to 6 starting from bottom to top internodes) of CoLk 94184 variety. C = control; T = ethrel soaked + GA_3 exposed

sink relationship and identification of signal transduction components that might improve sugar accumulation and sugar yield in sugarcane.

Compliance with Ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Mechanization of sugarcane agriculture for improving farm and industry income

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India is predominantly an agricultural economy with 60- 65% of its population living in villages and earn their livelihood through agriculture and allied activities. Rural population of India was 91% in 1901 and may reach to 50% by 2020. Rural people migrate to urban areas for employment and better amenities as such opportunities are not adequately available in rural areas. With the implementation of Mahatma Gandhi National Rural Employment Guarantee Scheme (previously known as NAREGA), there is further division of rural labour resulting into scarcity of labours for agricultural operations and increased labour wages. Indian agriculture is characterised by small and scattered holdings and sugarcane cultivation is no exception. Sugarcane crop remains in the field for almost a year. There is a heavy demand of labour and machinery throughout its crop cycle right from land preparation to harvesting of the crop and its timely supply to the mill. Sugarcane accounts for 60-70 % of the cost of sugar production and thus has a vital role to make sugar industry a commercially viable venture.

Agricultural mechanization is a crucial input to agricultural crop production. It is frequently very capital intensive, compared to other (usually annual) inputs and it has repercussions on the efficiency of all other inputs used in crop production, including seeds, fertilizer, water, and time/labour. Farm mechanization is a crucial input for improving agricultural production. Without farm power and the appropriate tools, implements and machinery farmers would struggle to emerge from subsistence farming. With increasing demand for food and agricultural products being exerted on the planet's natural capital base, the essential role for sustainable mechanization in production systems development becomes increasingly obvious.

The state of agricultural mechanization in the country is characterized by large variations in power availability which in 2001 varied from 0.6 kW/ha of agricultural land in some states to 3.5 kW/ha in Punjab. The average farm power available country-wide was about 1.91 kW/ha which comprised about 88 per cent from mechanical and electrical sources and 12 per cent from animal power and human labour. There is a strong linear relationship between the farm power available and agricultural output per ha. This underscores the emphasis on the growth and development of power machinery systems in Indian agriculture.

Mechanization aims at:

i) Timeliness of operation

ii) Reduced cost of unit operations

iii) Reduced human drudgery

iv) Increasing productivity of other critical inputs such as labour, fertilizer and insecticide *etc.*

Sugarcane (*Saccharum* sp. hybrid complex) is an important cash crop of India which is cultivated in an area of about 5 million hectares with an average production of about 350 million tonnes. Major proportion of sugarcane is processed in sugar mills for production of sugar. Livelihood of approximately 4.5 million populations depends on sugarcane production and processing. Sugarcane cultivation is energy, labour and cost intensive affair. Approximately 400 man-days are needed per hectare in sugarcane cultivation. Most of the cultural operations involved in sugarcane production are performed with traditional tools and equipments which result into high cost of cultivation and human drudgery. Mechanization will help in accomplishing cultural operations on time and precise application of critical inputs will ultimately lead to higher level of productivity at reduced cost per unit time, area and input besides removing the human drudgery.

ICAR-Indian Institute of Sugarcane Research, Lucknow popularly known as IISR, since its inception in 1952, is continuously making efforts for development of agricultural machines and equipments for mechanisation of sugarcane cultivation. As a result, number of useful, time and labour saving machinery were developed right from seedbed preparation to ratoon management operations. Being a deep rooted crop, sugarcane grows well in the field where deep tillage has been performed during seed bed preparation. Use of sub-soiler for breaking of hard pan, formed underneath the soil surface, has been found very useful in improving the sugarcane productivity. Sugarcane machineries *viz.*, ridger type and paired row sugarcane cutter planters, raised bed seeder, raised bed seeder-cum-sugarcane planter (RBS cane planter), sugarcane-cum-potato planter, sugarcane manager, ratoon management device *etc* have been developed at IISR. Recently, deep furrow sugarcane cutter planter, trench planter, and disc type sugarcane ratoon management device have also been developed and introduced at farmer's fields. Field testing and demonstration of most of these equipments at farmers field have proven their utility in terms of cost effectiveness, reduction in labour requirement, timely operations and reduction in human drudgery.

Seedbed preparation

Seed bed preparation machineries are mainly categorized as primary tillage such as mouldboard and disc plough and secondary tillage machinery like disc harrow and cultivator. One operation of primary tillage machinery and two operations of secondary tillage machinery is generally sufficient to achieve good soil-tilth for planting of sugarcane. Culti-harrow, a secondary combination tillage tool, has been developed at IISR for saving cost, energy and time. Use of subsoiler is also recommended once in four years for breaking the hard pan 35-40 cm underneath the soil surface.

Sugarcane planting

Several methods and techniques of planting sugarcane have received attention of researchers from time to time. These methods include flat method, trench method, furrow method, spaced transplanting technique (STP), cane node method *etc*. However, flat method of planting is prevalent among cane growers of India. Planting of sugarcane comprises of unit operations such as opening of furrows, cutting of cane into pieces known as seed setts, placement of setts, fertilizer and insecticide in the furrows and providing soil cover over the setts. Furrows are opened with the help of animal or tractor drawn ridgers. Forty to forty five man-days are required in one hectare to carry out other operations. Since arranging such a huge number of labour in a day is very difficult, the planting operation prolongs resulting into moisture loss of soil as well as seed setts. A lot of efforts have been made at ICAR- Indian Institute of Sugarcane Research, Lucknow to mechanize sugarcane planting operations. Brief description of few of the machinery is presented below:

Flat-bed sugarcane planter

Various models of sugarcane planters *viz.*, Animal or tractor drawn semi-automatic (billet) planters and later tractor operated sugarcane cutter planters suiting to different agro-climatic and soil conditions have been developed at IISR for mechanizing flat method of sugarcane planting. Different variants of tractor operated sugarcane cutter planters are either tractor PTO or ground wheel driven. Sett cutting is continuous and uninterrupted in PTO driven planters but proper sett metering is achieved at a particular combination of forward speed and PTO rpm. Sett metering remains same in ground wheel driven planters but precaution is required that ground wheels do not skid and remain in firm contact with soil. Tractor operated planters take four to five hours to cover one hectare. Four to five labourers are needed to operate the planter. There is saving of more than 50 per cent in the cost of planting operation by using sugarcane cutter planter as compared to traditional method.

Deep furrow sugarcane cutter planter

Recently, there is awareness of water shaving in sugarcane cultivation. In the North India, it is being recommended to plant the cane in furrow method to save irrigation water. Planting of sugarcane in furrow method needs machine for deep furrow opening. For this purpose, tractor operated deep furrower, deep furrower-cum-fertilizer applicator and deep furrow sugarcane cutter planter have been developed at IISR during last two years. Deep furrow sugarcane cutter planter is a multitasking machine, which performs all the unit operations involved in sugarcane planting including sett cutting, in single pass of the machine. It facilitates planting of sugarcane in deep furrow (20-25 cm) and maintains 5-7 cm loose soil bed underneath the planted seed setts. Planter has been field tested at IISR farm and on-farm trials are also going on at farmers field of western, central and eastern U.P. and Bihar.

Sugarcane trench planter

Planting of sugarcane in deep and wide trenches under wide spaced paired row geometry (30:120 cm) has shown promising results on cane yield, water saving, reduced lodging and better ratooning. In order to reap the benefit of trench method of planting, tractor operated trencher and trench planter were developed at IISR. While trencher performs opening of deep and wide furrow for paired row planting of sugarcane manually whereas, trench planter performs all the unit operations involved in cane planting including sett cutting, like earlier developed sugarcane cutter planters, in single pass of the machine.

Pit digger for mechanizing ring-pit method of sugarcane planting

The ring pit planting technique is very good from the point of view of increased cane productivity but digging of large number of pits over the entire field was found to be very cumbersome and labour intensive. Therefore, the technique could not be pushed up for large scale adoption by the farmers. Efforts were made at IISR to develop tractor drawn pit digger for mechanization of pit digging operation. The developed pit digger was able to dig one pit at a time. There was a problem of excessive vibrations and dynamic instability during the operation. Design refinements were made and modified prototypes of pit digger was developed. The equipment dig two pits simultaneously at a time. The developed equipment was tested and evaluated in sandy loam soil at IISR farm. With the help of the equipment, approximately 150 pits (75 cm diameter X 30 cm depth) at a spacing of 30 cm were dug per tractor-hour operation. Cost of pit digging operation was saved by 70 per cent by using the pit digger.

Planters for mechanizing planting of intercrops with sugarcane

Equipment for planting of inter crop like wheat or pulses with sugarcane has been developed at IISR. Two types of machineries have been developed for intercropping on the raised bed with sugarcane (i) raised bed seeder -cum-fertlizer applicator (RBS) and (ii) raised bed seeder-cum-sugarcane planter (RBS cane planter). The raised bed seeder is used for making three furrows and sowing of companion crop like wheat on the two raised beds. Sugarcane is planted in the furrows at a later stage manually. With the help of raised bed seeder-cum-sugarcane planter, planting of sugarcane in the furrows and sowing of companion crop like wheat on the raised beds are accomplished simultaneously in a single pass of the equipment. Recently, sugarcane-cum-automatic potato planter, deep furrow sugarcane cutter planter-cum-multicrop bed seeder, sugarcane trench planter-cum-multicrop bed seeder have also been developed for planting/sowing of intercrop simultaneously with sugarcane. These equipments are performing well during field trials at IISR and other locations.

Interculturing operations

About 4-5 interculture operations are quite common in sugarcane and each operation, if carried out manually, requires 25-30 man-days/ha. During early stage of crop growth (up to 50 cm of crop height), intercultural operations can easily be mechanized by using conventional 9-tyne cultivators, engine operated walking type rotary weeders and tractor operated rotary weeders. These equipments are commercially available. Performance of sweep shovels in place of reversible shovels has shown better results in terms of weeding efficiency. Sweep shovels completely cover the spacing and no weed is left in the covered space. A tractor operated interculturing equipment with sweep shovels for conventional as well as wide spaced paired row planted cane crops has been developed at IISR. It covers 0.50 ha/h. Of late, tractor operated sugarcane manager has also been developed which performs interculturing as well as band application of fertilizer near to root zone of cane crop. Effective field capacity of this machine is 0.40 ha/h.

Ratoon management

About more than 50 per cent of the total sugarcane area is occupied by ratoon crop in India. It is an integral part of sugarcane cultivation being a profitable proposition. Raising ratoon crop of sugarcane has economic benefits not only for cutting down the cost of land preparation, seed material and cost of planting, but also ensure an economically high recovery in the initial phase of the crushing season because of early maturity than the plant cane. In the tropical part 3-5 ratoon is quite common, but in sub-tropical India, farmers generally take only 1-2 ratoon crop. Keeping a good ratoon crop is always a problem and it is often less cared for. On an average yield of conventionally grown sugarcane, ratoon crop is lower than the sugarcane plant crop. Investigations reveal the fact that the productivity of sugarcane ratoon crop could be improved by applying crop inputs orderly in time and by executing cultural operations like i) shaving stubbles close to the ground surface, ii) off-barring or cutting old roots on either side of the stubbles, iii) interculturing, iv) applying fertilizer, insecticide or pesticides. These operations are not only difficult and arduous but also far too uneconomical to be carried over by using conventional tools like spades, cultivators, ridgers *etc*. Concerted efforts have been made at IISR and prototypes were developed to undertake most of the cultural operations simultaneously in a single pass.

Ratoon management device (RMD)

Equipment namely ratoon management device (RMD) was developed at IISR. The equipment performs all the recommended cultural operations *viz*., stubble shaving, off-barring & deep tilling, fertilizer, manure and chemical application, interculturing & soil-covering in its single pass. It consisted of units namely stubble shaving, off-barring including old root pruning, Manure, fertilizer, liquid chemical dispensing and earthing up unitsfor performing all recommended cultural operations independently or in a single pass of the tractor. It is a two row tractor mounted type equipment that requires a minimum of 35 hp to execute operations in field. The performance of the equipment was satisfactory and output of equipment was 0.25 ha/h.

Disc type ratoon management device (Disc RMD)

Disc type ratoon management device (Disc RMD) was developed at IISR for performing cultural operations in ratoon field even having surface trash. It was equipped with stubble shaving serrated blades mounted on a disc, two tillage discs for off-barring (pruning of old roots) on either side of the stubbles and application of fertiliser near to root zone. The effective field capacity of the equipment was 0.28 ha/h.

Sugarcane harvesting

Development of sugarcane harvester to mechanize the operation has also been made in India. Attempts have been made at IISR, Vasantdada Sugar Institute (VSI), Pune and to some extent at Tamil Nadu Agricultural University (TNAU), Coimbatore to develop tractor operated whole stalk harvester to partially mechanize the harvesting operation. The harvesters were intended to cut the cane stalks and windrow it. The other operations such as de-topping, removal of dry trash, bundle making and loading were to be performed manually. These harvesters are yet not available for commercial exploitation. Power operated detrasher was developed at IISR and Punjab Agricultural University (PAU) for de-topping and de-trashing of harvested sugarcane stalks. Few self propelled whole stalk harvesters were also imported by few sugar mills. These machines were capable of performing topping of green top in addition to cutting and windrowing. Removal of trash, making of bundles and its loading for transportation to be performed manually. These harvesters could not be popularized due to some constraints in their working.

Of late, commercially available self propelled billet harvesters have been introduced at few sugar mills of Tamil Nadu, Karnataka, Maharashtra, Andhra Pradesh, Madhya Pradesh for mechanizing sugarcane harvesting. These are cut and load type of harvesters and harvested cane is simultaneously loaded in transport vehicles for supply to sugar mill for its processing. Being a high cost machine, self propelled billet harvesters needed to be managed efficiently and effectively in order to achieve cost efficiency in sugarcane harvesting and transportation system.

Trash management

In the present scenario where manual harvesting is in vogue, handling of trash is another area requiring attention of the researchers. Research conducted has indicated that application of vinasse and filter cake to the residues, promotes decomposition of the dry matter so that resulting compost can be harrowed into the soil within 30 days. Nutrients derived from the trash may include 32 kg N/ha, 6 kg P_2O_5/ha and 30 kg K_2O/ha. Plant residue shredder has been developed at IISR for trash shredding in the field. The equipment is mounted with the tractor and is operated by PTO shaft. The system picks up trash, passes it on to the chopping unit where trash is chopped into small bits. Provision has also been made for applying chemical/ other substances for quick decomposition of trash. Proper management of trash helps in its effective use either as a mulch to conserve soil moisture and improving the soil health by adding organic content of the soil due to its decomposition.

Conclusion

Lot of efforts have been made in the country for mechanization of sugarcane cultivation. Efforts have been made to develop agricultural machinery suited to the agronomical practices of different regions. Efforts have also been made to commercialize the developed machinery through agricultural machinery manufacturers. There is need for concerted efforts by all the stakeholders for mechanizing the sugarcane cultivation for achieving overall system efficiency in sugarcane production system. Using cost effective machineries for accomplishing different cultural operations in sugarcane based cropping systems is an important tool to enhance profitability of farmers by saving the cost of operation, increasing the input use efficiency and overall productivity thereby sustaining the sugar industry by ensuring sufficient cane availability for the entire crushing season.

Emerging challenges in Insect Pest management of sugarcane

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Sugarcane is attacked by more than 125 insect pests but out of them, only about 2 dozen cause economic losses to cane yield (about 20%) and sugar recovery (about 1-2 units). All the insects of sugarcane and in general can be divided in four categories *viz.*, subterranean pests, borer pests, sucking pests and defoliating pests. Chemical, biological, mechanical and cultural methods of pest management are in vogue to save the avoidable losses to cane yield and juice quality.

Major factors affecting the insect pests scenario are indiscriminate use of selective synthetic insecticides, climate change and transportation of infested plant material from one place to other, monoculture and non adoption of proper crop cycle induces resurgence of minor pests as major ones and also invites new insect pests. In sugarcane, several insects become the pest either in the absence of competition with other insects and non availability of their bio-agents or in the influence of climate change. Naturally occurring bio-agents serve to decimate the pests during different stages of their life-cycles.

Table 1. Common insect pests of sugarcane and the part of cane plants attacked

Sr. No.	Common name of insect pest	Scientific Name	Part of the cane damaged
Subterranean pests			
1	Termite	*Odontotermes obesus* and other species	Setts, Roots and cane
2	White grubs	*Holotrichia consanguinea* and other species	Roots and leaves
Borers			
1	Shoot borer	*Chilo infuscatellus*	Shoots
2	Pink borer	*Sesamia inferens*	Shoots and water shoots
3	Root borer	*Polyocha (emmalocera) depressella*	Shoots and cane in root zone
4	Stalk borer	*Chilo auricilius*	Cane
5	Internode borer	*Chilo sacchhariphagus indicus*	Cane
6	Top borer	*Scirpophaga excerptalis*	Tops of cane
7	Gurdaspur borer	*Acigona steniellus*	Upper soft internodes
8	Plassey borer	*Chilo tumidicostelis*	Upper soft internodes
Sucking pests			
1	Scale insects	*Melanaspis glomerata* and other species	Upper half of cane and leaves
2	Mealy bugs	*Saccharicocus sacchari* and 5 other species	Cane and leaves
3	Plant hopper	*Pyrilla perpusilla*	Leaves and soft portion of cane
4	White flies	*Aleurolobus berodensis* and other 2 species	Leaves
5	Black bugs	*Cavelarious sweeti* and *Dimorphopterus gibbus*	Leaf whorl and leaf sheath
6	Woolly aphid	*Ceratovacuna lenigera*	Leaves
Defoliators			
1	Army worm	*Mythimna separata*	Leaves
2	Grass hoppers	*Hieroglyphus banian*	Leaves
3	Grey weevil	*Myllocerus* sp.	Leaves

Subterranean pests

Termites, *Odontotermes* spp.

Thirteen species of five Genuses of termites are known to attack sugarcane in India. Recently three new species of genus Odontotermes *viz., O. vaishno* Bose, *O. bellahunisensis* Holmgren and Holmgren and *O. horni* (Wasmann) have been recorded from ICAR-IISR, Lucknow infesting sugarcane.

Termites damage the crop just after planting continue before harvesting. At planting, termites enter through cut ends or buds of setts and feed on cane tissues fill the cavity in cane tissue with mud. Filling with mud is characteristic of termite damage. Germination affected adversely and results in gaps in sugarcane fields. Sometimes, termites enter the cane through root borer damage and cane tissue is eaten up leaving the rind intact with mud. The affected canes exhibit the yellowing of leaves. The activity of termites is enhanced under drought conditions and the fields have FYM and debris of previous crop.

During monsoon period, the swarming takes place in dusk hours of the day. The adults make pair and burrow into soil where they mate and give up new colony. The single queen may lay @ 20,000 to 80,000 eggs per day. Eggs are kidney shaped and yellowish in colour and hatch in about a week. These nymphs develop into workers and soldiers in about 6 months. In the summer months, the eggs may give rise to reproductive forms which attain maturity in 1-2 years.

White grubs, *Holotrichia consanguinea* Blanch. and *H. serrata* Fab.

This is a serious pest in Rajasthan and Gujarat. The grubs feed on roots of sugarcane but adult beetle feed on foliage of trees like *Ber*, *Neem, Sheeshum etc*. Plants wilt and gradually dry up due to feeding of grubs on roots. The canes in affected clumps fall down.

Borer pests

Root borer, *Polyocha depressella* Swinhoe

The larvae of the pest infest young plants but mature canes are also attacked. The damage is very peculiar because caterpillars enter at the stalk from soil surface by making one entry hole. The larvae do not move upward but remained coincide with the base. The 'dead hearts' are formed by root borer in germination or tiller phase and dead heart can be differentiated with other borer's deadhearts. The 'dead hearts' do not emit any offensive smell and pull easily as in the case of shoot borer. The female moth lays eggs during April/May on lower most part of plant (leaf and stem) singly or sometimes together on the underside of leaves. These eggs hatch within 3-4 days and larval period lasts for about 40 days. Pupal period lasts for about 10-12 days. The total life cycle is completed within 2 months.

Shoot borer, *Chilo infuscatellus* Snellen

The damage is caused by caterpillars by boring into cane stalk laterally by one or more holes. They move upwards and downwards and cutting off the central leaf spindle which dries up and forms 'dead heart'. The central unfurled leaf gets rotten. The dead heart is pulled out easily and sensed offensive smell.

Female moth lays creamy white eggs in clusters of 2/3 overlapping rows on the undersurface of the leaf. The eggs hatch in less than a week. The young larvae feed on inner surface of lowest leaf sheath from where they move to bore into plants. The larval period lasts for 3-4 weeks and pupal period for about a week. The larvae of shoot borer can be easily identified by the presence of 5 violet stripes on dorsal side and semicircular crochets present on the prolegs.

The over wintering caterpillars give rise to I brood during March, II brood in May III brood in June and IV brood during July-August. The infestation of shoot borer is high during premonsoon period from April to June. High temperature and low to moderate humidity is conducive for its development.

Top borer, *Scirpophaga excerptalis* Walker

In sub-tropical region, this is the most serious pest as it infests crop at all the stages of growth. The moths of this pest are silvery white in colour, female has crimson red anal tuft of hairs. One black spot is present on fore wings. Eggs are laid in masses on underside of the leaf and covered with crimson red/ brown hairs present in the form of anal tuft of the female moth. The larvae hatch within a week and take about 1 to $1^1/2$ months for full development. The pupa forms in the cane and moths hatch in 7-9 days. The newly hatched larvae enter the spindle through midrib of the leaves. The tunneling in mid rib causes white streak which turns reddish brown. The larva reaches central core of the spindle makes several cuts in unfurled leaves in spindle and the cuts become visible in the form of shot holes on open leaves. The larva feeds by boring into the narrow central core towards growing point, it also nibbles the inner half of the leaf surrounding the feeding zone. The damaged leaf dries up and forms ‘dead hearts’ when the mature larva cuts the growing point. The dead hearts thus formed can’t easily be pulled out. When central shoot has been damaged, side shoots develop and produce which is known as ‘Bunchy Top’. A bored tiller can be easily identified with a reddish brown, charred and sometimes curved dead- hearts besides leaves having shot holes and galleries in the midrib of leaves indicating downward movement of larva to the growing point.

The moths emerge out from over wintering larvae during February-March and commence first brood. The borer completes five generation in one year sometimes six generations. The detail of brood/generation is given below.

I Brood	-	February III week to April IVweek
II Brood	-	May I week to June II week
III Brood	-	June II week to August I week
IV Brood	-	August II week to October I week
V Brood	-	October II week to February III week (Over wintering of larvae)

It is the III brood which causes heavy loss to the crop. Hence, efforts are being made to manage III brood. There may be some changes in the appearance of broods due to changes in temperature and humidity. For effective management of top borer, insect control tools shuld be applied on the appearance of moth emerge from the eggs were laid by moths of II brood.

Stalk borer, *Chilo auricilius* Dudgeon

Stalk borer moths are of straw colour with golden spots on periphery cell of fore wings. Females are bigger than male. The creamy white eggs are laid on under surface of leaves in 2-3 rows, parallel to mid rib. The larvae soon after hatching wander for sometime on leaf surface and move downward to central whorl where they feed by scrapping the leaf sheath. Longitudinal orange yellow streaks are observed from tip to base on the both side of the midrib. The third instar larvae bore into shoots and internodes of the canes and feed on soft tissues, thus, reduces the quantity and quality of canes.

The eggs are laid in masses on the underside of leaves from which larva comes out within one week. There are five larval instars which take about 1-2 months. The pupal period lasts for about one week from which the moth emerges out. Borer completes three generations in U.P. but sometimes five to six generations.

Internode borer, *Chilo Sacchariphagus indicus* Kapur

The eggs are laid in masses in two rows in the manner that each egg over lap the ¼ part of the egg in same row and 1/8 part of adjacent two eggs of other row. Larvae hatch in about one week. There are five larval instars which take about 30-45 days. The pupal period lasts for about one week from which the moth emerges out.

The newly hatched larvae feed on leaf sheath by scrapping which are visible in the form of white streaks on leaf opening. Later the larvae bore into tender cane top. The borer feeds on inner tissues and frass is pushed out to exterior. The damaged nodes get hardened thus become hard to crush.

Gurdaspur borer, *Acigona steniellus* (Hampson)

The larvae pass through gregarious and solitary phases. In gregarious phase they crawl along the midrib to the cane on which they move for some time and later on segregate on first inter node from top. All the newly hatched larvae from one egg mass enter into one top internode through a common hole. The larvae feed gregariously for about a week afterwards they come out and migrate to canes individually in solitary phase .The entrance hole is always made on sheath-less inter node and is never below the third inter node from the top. In solitary phase, the larva suspends themselves from the leaves by silken threads and get disperse. Generally, one larva enters the cane but sometimes 2-3 may also enter the cane.

Sucking pests

Pyrilla, *Pyrilla perpusilla* Walker

Pyrilla perpusilla Walker is the most serious sucking pest of sugarcane. Nymph and adult are sucking the sap from the under surface of leaves near midrib resulting into yellowing of the crop. The hopper excretes a sweet fluid (honey dew) that falls on upper surface of lower leaves. Honey dew invites black sooty mould (*Capnodium* sp.) that results hindrance in photosynthesis. Female lays eggs in clusters on the underside of leaves near the midrib and covers with white cottony hairy filaments present as anal tuft of hairs on her abdomen. The nymph molts 5-6 times to become adult. The pest breeds in luxuriant crop. Long dry gaps with drought conditions during monsoon period favours fast multiplication of the pest.

Black bugs, *Cavelarius sweeti* Slater & Miyaomoto and *Dimorphopterus gibbus* Fab

It is a major pest of ratoon during pre-monsoon period. The nymphs and adults are found in the leaf whorls and under sheathing bases of leaves. Both nymphs and adults suck the sap from leaves which turn pale yellow with brown patches. The tips and margins of the leaves dry up gradually and sometime entire plant wither. The quality of juice is also affected. The damage of the pest is more pronounced in fields left with trash.

Scale Insects, *Melanspis glomerata* Green

The pest is prevalent in tropical belt of our country .The scales are grayish black in colour. They infest the cane in large numbers under the leaf sheath in nodal region. A thick encrustation gets deposited on the internodes, the canes shrivel up and growth is stunted.

White flies

There are three species of white flies, *Aleurolobus barodensis* Mask. *Neomaskellia bergii* Sign. and *N. andropogonis* Corbett among which *A. barodensis* becomes sometimes quite serious.

The leaves of affected plants turn yellowish and later on dry up. During heavy infestation black sooty mould develops on leaves causing hindrance in the photosynthesis. The damage caused by the pest results into retardation in plant growth besides reducing the sugar content in the canes.

Thrips

Stenchaetothrips saccharicidus (Ramk) is a pest of premonsoon period. The nymphs rasp the upper surface of leaves and suck the oozing sap as a result leave tips are rolled.

Besides above insects, some occasional pests *viz.*, leaf hoppers and aphids which cause minor loss to the crop.

Mealy Bugs, *Sacchari coccus sacchari* Cockerell Pseu*dococcus saccharifolli* Green

The pink mealy bug (*S.coccus sacchari*) is the most common pest of occurrence. The oval and flattened nymphs stick in wax over the nodal region.

Sugarcane aphids: Sugarcane is attacked by eight species of five genus of aphids viz., *Ceratovacuna graminum* Zehnt., *Hysteroneura setariae* Thomas, *Tetraneura cynodontis* Theo., *T. hirsute*., *T. kalingponensis*, *Rhapalosiphum maidis* Fitch. and *Melanaspis (Longiunguis) sacchari* Zehnt.

Defoliators

Sometimes grasshoppers (*Hieroglyphus* spp, *Atractomorpha* sp.,) Armyworm (*Mythimna separata* W.) do appear on the crop and cause minor to moderate damage.

Invasive pests

Fall army worm, *Spodoptera frugiperda*

It is the native to tropical and subtropical regions in America attacks a large number of Poaceae (Graminae) grasses including some field crops like maize, sorghum, *bajra*, paddy, sugarcane *etc*.

besides it has also been reported as pest of cotton and some vegetable crops. It has been repeatedly intercepted at quarantine in Europe and was reported from Africa in 2016 on maize and has great potential for further spread and economic damage because it has been reported different countries including India in 2018-19. First time reported in India in 2018 on maize. It is the most devastating polyphagous pest reported from Asia, Africa, North America, Central America and Caribean, South America, and Europe. In Asia, it is reported from India, Bangladesh, China *etc*. In India, its restricted distribution has been reported from Andhra Pradesh, Bihar, Chhattisgarh, Gujarat, Karnataka, Maharashtra, Odisha, Tamil Nadu and West Bengal. Newly hatched larvae feed on central whorl of the plant and enter the stalk. It's incidence in sugarcane (5-10%) has been reported from subtropical India (Anakapalle and Coimbatore).

Secondary pests

Sugarcane woolly aphidm, *Ceratovacuna lanigera* Zehntner

The pest appeared during 2002 in Maharashtra, later on the epidemics appeared during 2004 in Maharashtra, Karnataka and Andhra Pradesh. The pest has been reported from Bihar, Uttar Pradesh and Uttaranchal also.

The leaves of the infested plants look white due to white woolly coating of the insects. Both nymphs and adults suck the sap from the leaves which adversely affect the sugar recovery. The aphids also secrete honey dew on which sooty mould fungus develops which hinders the photosynthesis activity of the plant. The white molted skin of the aphids and white powdery secretions fall on the ground and lower leaves giving an appearance of white chalk powder coating on the ground and leaves.

Black beetle, *Heteronychus* sp.

It was observed gnawing the basal portion of young shoots that results in dying up of cane plants. Infestation of this black beetle was 5-10 per cent but spread was significantly good in Chilwaria (Bahraich) area. Beetles move inside the soil from one plant to other and sometimes they have seen on soil surface also.

Fig. 1. Heteronychus sp.

Delphacid plant hopper, *Eoeurysa flavocapitata* Muir

Eoeurysa flavocapitata Muir. has been noticed in two villages, Akheypur and Charkheda in District Muzaffarnagar of western Uttar Pradesh and Research Farm of Uttar Pradesh Council of Sugarcane Research (UPCSR) at Shahjahanpur. Crown portion of sugarcane plant was covered with translucent dense sticky substance along with the exuberant growth of black sooty mould on crown leaves of 'Co 0238'. The general appearance of newly hatched nymphs is pale green in colour with prominent red/maroon eyes (Fig.1). Abdomen is 10 segmented. Thoracic region has rudimentary wing pads.

With the maturity, nymphs turn blackish and eyes become dark brown. Head region is also smoky black. Abdomen is 10 segmented with dark brown shades on intersegmental tergites. Wing pads begin to develop (Fig.2). Adult hopper (2.7-2.8 mm in length) is shiny black. Fore wings are dark translucent with well developed veins. Hind wings are membranous. Head (vertex) and pronotum, except the lateral margins and pleura of abdomen are yellowish- white. Fore legs are smoky, while hind legs are light in colour (Fig. 3). Both stages (adult and nymphal) remain concealed in leaf whorl of the crown and de-sap the plant.

A translucent dense sticky substance was present on both the surfaces of new leaves of the

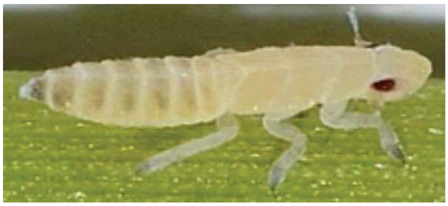

Fig. 1. Newly emerged nymph

Fig. 2. Nymph with wing pads

Fig. 3. Adult plant hopper

Fig. 4. Black sooty mould on leaf

crown. The old leaves were covered with the growth of black sooty mould (Fig. 4& 5). The black filmy growth of sooty mould on leaves impairs photosynthesis. The general appearance of the crop was dirty (Fig. 6). Affected green tops due to growth of the sooty mould were not fit to use as fodder. It has been observed by the farmers that their cattle have fallen ill after feeding such affected green tops.

Fig. 5. Affected crown

Fig. 6. Affected clump

Due to excess use of Chlorantraniliprole against borer pests of sugarcane other pests like sucking pests became the challenges to plant protection workers. Invasive pest like fall army worm, *Spodoptera frugiperda* has been introduced in India due to some lacking in plant protection and quarantine. Though the several spp. of *Spodoptera* are damaging a number of other crops in India. Recently, black beetle, white grubs, delphacid hopper, new species of termites, white fly, aphids *etc*. became the new challenges in sugarcane.

Technology of ethanol production from biomass-wastes

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Ethanol is alternative fuels derived from biomass-based recourses to meet our growing transportation energy needs. Ethanol has oxygen levels of 37%, while petroleum has virtually none, making the chemical properties of ethanol very different from those of petroleum (Prasad *et al.,* 2007). Currently, the commercialized ethanol is produced from sugar crops (sugarcane, sugar beet), and their by-products like molasses, food grain-starch (corn, potatoes). Sugar and grain starch is processed into ethanol by fermentation. Ethanol is the most widely used as an automobile's fuel (Attal *et al.*, 2014).

The reasons why Ethanol are appropriate for such a transition are as follows: (i) their simplicity; (ii) production via well-known agricultural technologies; (iii) potential for mitigation of global warming without complete restructuring of the current working energy system; (iv) the use of existing engines for their transportation; (v) potential to facilitate worldwide mobilization around a standard set of regulations;(vi) potential as a directly available energy source with good public acceptance; (vii) more uniform distribution than the distributions of fossil fuel and nuclear resources; and (viii) potential to create benefits for rural areas, including employment (Rothengatter, 2010).

Ethanol as a leading alternative to fossil fuel

Most of the energy requirements are currently satisfied by fossil fuels–coal and petroleum-based products and natural gas (MoPNG 2014). Globally, Ethanol has attracted much attention since it has become a leading alternative to fossil fuel, is produced domestically by many countries, requires only minimal changes to retail distribution and end-use technologies. According to FAO by 2022, global ethanol production is expected to increase by 70% compared to the average of 2010-12 and reach some 168 billion liters by 2022 (FAO 2013).

An advantage of Ethanol is their compatibility with the petrol-fuels to be used as blends in existing internal combustion engines (ICE). Ethanol is like petrol in terms of engine performance and refueling times (Prasad, 2018). The other side includes limits on the percentage of blends and the difficulty in its distribution using existing fuel pipelines. In the IPCC report, biofuels were identified as a "key mitigation strategy" (IPCC 2007). However, the debate surrounding biomass in the food versus fuel competition, and growing concerns about land use, water, replacement of forests, etc. has acted as incentives for the development and implementation of sustainability criteria and frameworks (SRREN, 2011; Das *et al.*, 2010). Furthermore, support for advanced bio-refinery and next-generation biofuel options are driving ethanol to be more sustainable (IPCC, 2014).

Recent years have witnessed a rapid expansion of ethanol production worldwide. In India, the Biofuel Policy, dealing with ethanol and biodiesel, aims to channelize biofuels into the energy and transport sector to address topics like energy security, climate change, and rural development (Rothengatter, 2010) Ethanol is one of the best alternatives as to the next-best substitute for petrol. India is endowed with significant potential for generating renewable energy. GOI is promoting the production of ethanol derived from sugarcane molasses and non-edible biowaste for blending with petrol (IPCC, 2014).

Though the biowaste/biomass-based ethanol industry in the country is still in developmental stages, ethanol is the most widely produced biofuel being produced from the abundantly available molasses. Currently, there are 140 distilleries in India, with the capacity to distill around 2 billion liters of conventional ethanol per annum (USDA GAIN Report, 2014) The broad range of technologies, and energy conversion pathways which are apt to match the widely differing environmental and socio-economic conditions (Das *et al.*, 2010) - ensuring energy and food to all sections of the society, while fulfilling international commitments towards climate change, provides an opportunity for the strengthening of the existing linkages between science and policy. Besides direct benefits as fuels, indirect benefits, such as employment generation, reduction of dependence on oil import, carbon sequestration, rural development, can be additionally gained (Das *et al.,* 2010).

Biofuel policies

The Government of India has initiated several policies to augment the production and use of ethanol during the past decade. There are several ministries associated with policymaking, regulation, promotion, and development of biofuels at the national level (MNRE, 2009). The expansion of a domestic biofuels market is anticipated to improve rural lives by creating more employment opportunities. The Ministry of Petroleum and Natural Gas issued a *notification* in September 2002 for the *mandatory* blending of *5* percent ethanol in nine major states and Union Territories. The government of India launched the National Policy on Biofuels on December 24, 2009 (MNRE, 2009). India's biofuel strategy continues to focus on the use of non-food resources, namely molasses to produce ethanol, and blending targets will be periodically reviewed and adjusted as needed. The policy proposes establishing a National Registry of feedstock availability to help monitor production potential and set blending targets (MNRE, 2009). National Biofuel Policy drafted by the MNRE assures that the biofuel program would not compete with food security, and the fertile farmlands would not be diverted to biofuel crops plantation. The policy also deals imporant issues like minimum support prices (MSPs) for biofuel crops, subsidies for growers of biofuel crops, marketing, grants and fiscal concessions for the biofuel industry, research and development, biofuel blending quality norms, testing, and certification of biofuels (Prasad and MS Dhanya, 2011).

Recently, the Government of India came out with the National Policy on Biofuels 2018 to reduce import dependency on petroleum and natural gas and to move towards renewable clean energy and mitigating climate change. As per the government's targets, biofuels would contribute 10 gigawatts (GW) of power by 2022. The policy seeks to achieve 20% ethanol blending with gasoline and 5% biodiesel blending with diesel by 2030. The policy increases the scope of raw material for ethanol production by allowing the use of sugarcane juice; sugar-containing feedstocks like sugar beet and sweet sorghum; starch-containing feedstocks like corn and cassava; damaged food grains like wheat, rice and rotten potatoes unfit for human consumption for ethanol production (PIB 2018). The new biofuel policy allows the use of surplus food grains for ethanol production for blending with petrol/gasoline with the approval of the National Biofuel Coordination Committee. With a thrust on advanced biofuels, the policy indicates a viability gap funding scheme for 2G (produced from cellulosic biomass waste) ethanol biorefineries of ₹ 5000 crores in 6 years in addition to additional tax incentives, a higher purchase price as compared to 1G biofuels (produced from sugar and grain). The policy supports setting up supply chain mechanisms for biodiesel making from non-edible oilseeds, waste cooking oil, and short gestation crops. The roles and responsibilities of all the concerned authorities for biofuels have been captured in the policy document to synergize efforts (PIB 2018).

Feedstocks and processes of ethanol production

Raw materials containing sugars, or materials which can be transformed into sugars, can be used as fermentation substrates. The fermentable raw materials can be grouped as (i) direct fermentable sugar (ii) starchy materials, and (iii) lignocellulosic biomass. Commercially, direct fermentation of cane and beet molasses, sugarcane, sugar beets, and in small quantities sweet sorghum and fruit juices to produce ethanol has been reported by many researchers (Prasad *et al.*, 2007). Sugar-containing materials like molasses, sweet sorghum, and fruit juices do not require any pretreatment. In contrast, a starchy, lignocellulosic material needs pretreatment and hydrolysis to convert these materials into fermentable substrates for ethanol production (Sun and Cheng, 2002).

Sugar-containing materials that can be transformed into glucose, used as fermentation substrates under anaerobic conditions, glucose is converted to ethanol and carbon dioxide by glycolysis. The phosphorylation of carbohydrates is carried out through the metabolic pathway, and the end products are 2 moles of ethanol and carbon dioxide (Ingram *et al.*, 1898). The overall reactions to liberate energy for biosynthesis (Eq. 2) Produce two moles of ethanol and CO_2 for every mole of glucose consumed, although microorganisms like fungi, bacteria, and yeast can be used for ethanol fermentation. Specific yeast (*Saccharomyces cerevisiae*) is commercially used to ferment glucose to ethanol. Theoretically, 100g glucose produces 51.4 g of ethanol and 48.8 g of carbon dioxide. However, in practice, the microorganisms use some of the glucose for growth, and the actual yield is less than 100% (Badger, 2002).

Ethanol production from grain involves milling of grain, hydrolysis of starch to release fermentable sugar, followed by inoculation with yeast. Chemically, starch is a polymer of glucose. Yeast strains cannot use starch directly for ethanol production. Therefore, grain starch must be wholly broken down to glucose by a combination of two enzymes, *viz.*, amylase and amyloglucosidase, before it is fermented by yeast to produce ethanol (Prasad *et al.*, 2007). The biochemical reactions and processes involved in starch hydrolysis and fermentation shown in Fig. 1 and 2 and given in Eqs. 1 and 2.

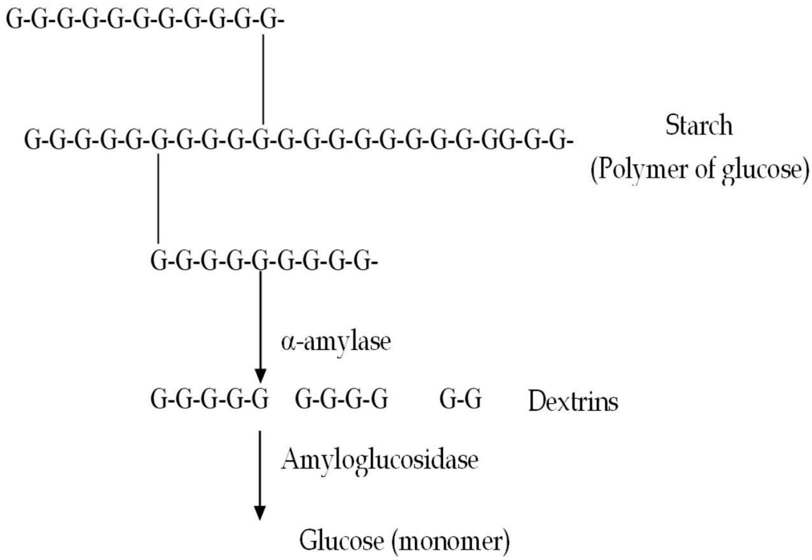

Figure 1: Enzymatic hydrolysis of starch to glucose

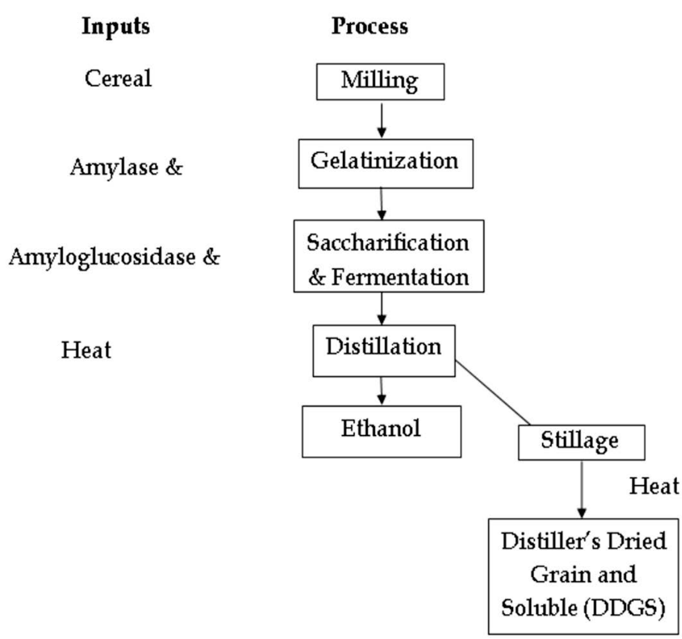

Figure 2: Flow chart of ethanol production from cereal grains

$(C_6H_{10}O5)n+nH_2O \rightarrow nC_6H_{12}O_6$………………………………… (1)

$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$+energy (stored as ATP)………… (2)

Milling is the first step in ethanol production, and the purpose is to break up cereal grains into smaller particles that better adsorb water. The particles must be small enough to yield high water access, but they should not be too small so that they cause problems in the recovery of co-products. The most common mill used in distilleries is a hammer mill, with hammers that rotate at high speed, crushing the grains in the grinding chamber. A retention screen is used to hold back the largest milling particles. Debranned grain meal is produced by bran removal before milling (Prasad and Dhanya, 2011a).

Each process based on cereal grains starts with a mixing stage, where grain meal and water are mixed under heat. The temperature and duration time varies, but temperatures around 40-60°C and duration time between a few minutes to 30 minutes are standard. The mash is moved to a liquefaction tank where it is heated to 90°C for two h. The enzyme α-amylase is added to break down starch into dextrin. At approximately 65 °C, starch granules have absorbed so much water that they swell into large gel-filled sacs with a lost crystalline structure. That phase is called gelatinization, where the mash has a very high viscosity. The swollen granules are now permeable for α-amylase, allowing it to penetrate and break down starch, which markedly reduces mash viscosity. The high liquefaction temperature is also used to minimize bacterial contamination (Prasad *et al.*, 2007)

The next process step is saccharification, where dextrin is broken down into glucose by the enzyme glucoamylase (Fig. 2). The mash is kept at around 60 °C, and the pH is adjusted to 4.0-4.5. Fermentation is carried out with the addition of yeast that converts sugar produced during pretreatment to ethanol. After separation of fibers and yeast from the fermented mash, ethanol is extracted by distillation. The remaining spillage from ethanol production is processed to produce distiller's dried grains and solubles (DDGS), which is an attractive ingredient for animal feed (Sheorain and Chavan, 2000).

Lignocellulosic biowaste is such an abundant and inexpensive resource that existing supplies could support the sustainable production of liquid transportation fuels (Joseph and Ronald, 2010). Lignocellulosic materials can be transformed through pretreatment and hydrolysis process, into hexoses and pentoses, can be used as fermentation substrates under anaerobic conditions (Figure 3). Methods and technology for C6 sugar (hexoses) fermentation are well established (Eq. (2). Conversion of C5 sugars (pentoses) to ethanol is a relatively new practice. The ability to ferment pentoses (C5) along with hexoses (C6) is not widespread among microorganisms. The overall reactions to liberate energy for biosynthesis (Eq. 3) produce five moles of ethanol and CO_2 for three moles of pentoses consumed (Prasad *et al.* 2007).

$3C_5H_{10}O_5 \rightarrow 5\,C_2H_5OH + 5CO_2$+energy (stored as ATP)………. (3)

S. cerevisiae can convert only hexose sugars to ethanol. The most promising yeasts that can use both C5 and C6 sugars are *Pichia stipitis, Candida shehatae*, and *Pachysolan tannophilus* (Steve *et al.* 2004). Thermo-tolerant yeast could be more suitable for ethanol production at the industrial level. In this concern, two approaches are addressed. The1st approach has been to genetically modify the yeast and other natural ethanologens with additional pentose metabolic pathways. The 2nd approach is to increase ethanol yields by genetic engineering in microorganisms that can ferment both hexoses and pentoses. Thus, the effective utilization of the xylose component of hemicellulose in addition to hexoses offers the possibility to significantly reduce the cost of ethanol production (Steve *et al.* 2004; Prasad *et al.* 2007).

As Fig. 3 shows, four necessary steps are involved in the lignocellulosic biomass conversion to ethanol: (1) pretreatment of raw biomass, (2) enzymatic hydrolysis for fermentable sugar production (3) ethanol fermentation and (4) distillation (Olsson and Hahn-Hagerdal, 1996). The cellulosic biomass is first pretreated to begin breaking down the material and generating more surface area for the second step, hydrolysis. Hydrolysis is accomplished either using enzymes or chemicals. In this step, the complex carbohydrate chains in the biomass are broken down into simple sugars. Finally, these sugars are fermented by microorganisms (yeast or bacteria), which produce ethanol in a dilute form. In order to concentrate the fuel grade anhydrous ethanol, distillation techniques are used (Lynd *et al.*, 2005; Balat and Balat, 2008).

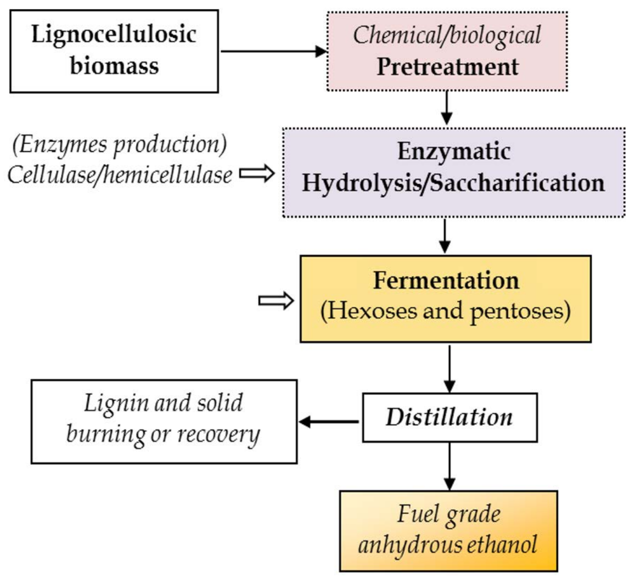

Fig. 3. Conversion of lignocellulosic biomass to ethanol

Agri-Resources constitute a vast resource of biomass consisting of sugars, starch, cellulose, and lignocellulosic residues. The enormous quantity of available biomass has a considerable potential for ethanol production using appropriate enzymes. By comparison, the straw of all crops had 470-502 kg carbohydrate equivalent per ton of biomass. In the process of conversion, 1 kg of glucose polymer yields 1.1 x 0.511 kg ethanol (Garcha *et al.*, 1987). The substrate energy from the biomass is used by the enzymes catalyzing the conversion for their sustenance. It was assumed, based on the earlier reports, as 10% of energy is also lost during the process of transformation due to the inefficiency of the industrial process. These losses were assumed as 5% for sugarcane (sugars-based conversion), 10% for starchy cereals and tubers, and 20% for cellulose/hemicellulose based straw products. Considering the density of ethanol as 0.785 g / cc at 25°C and concentration 95% (by weight), the ethanol potential could be calculated for each product as follows (Garcha *et al.*, 1987):

$$\text{Ethanol (95\%) liters/ton fresh biomass} = 1000\text{ kg fresh} \times \text{dry weight fraction} \times \text{carbohydrate fraction} \times 1.1 \times 0.511 \times (0.9 * \text{conversion efficiency})/0.785/0.95$$

The ethanol equivalent of major crops and their crop residues could be calculated assuming the appropriate dry weight fraction of different products. The results showed that the ethanol potential was highest for wheat being 403 liters per ton of biomass followed by rice and corn (394 liters/ton), jowar (382 liters/ton), and bajra (366 liters/ton). By comparison, cassava with relatively less water content and high carbohydrates had a high ethanol potential of 157 liters/ton of biomass, as against these, crop residues (straw of different crops) had similar ethanol potential of 250-265 liters/ton of biomass (Prasad and Dhanya, 2011b).

Greenhouse gas mitigation by ethanol

Currently, managing energy, air quality, and greenhouse gas (GHG) emissions are the key initiatives related to sustainability goals in the world. Because most of the GHG and air quality issues are attributable to energy consumption, the ethanol address these issues collectively. Energy management involves adopting initiatives with two primary goals (i) to improve fuel or energy efficiency, (ii) and to reduce potential adverse impacts resulting from energy consumption. Ethanol enhances the performance of the fuel, supports better fuel efficiency, and therefore helps lower emissions. Conversion of biomass feedstock to ethanol and its use as a supplement to fossil-fuels is more environmentally friendly than fossil-fuels alone. Currently, most biofuel systems, including ethanol, result in GHG emission reductions, while advanced ethanol production from 2nd-generation (biofuels from biowaste) could provide even higher GHG mitigation (SRREN, 2011; Bessou, 2010).

The influence of ethanol on the slowdown of climate change also motivates its production. Theoretically, net emissions of greenhouse gases (GHG) from ethanol may reach zero because the carbon emitted while burning was sequestered during photosynthesis. Most studies have found that the use of 1st-generation biofuels results in emission reductions of 20 to 60% of CO_2eq relative to fossil fuels. Expected reductions for future commercialized 2nd-generation biofuels are in the range of 70 to 90% of CO_2eq relative to fossil fuels (Bessou, 2010). The use of cellulosic biomass for energy production is expected to result in significantly higher carbon sequestration compared to starch and sugar-based biofuel (Tilman *et al.*, 2006; Farrell, 2006).

Larson *et al.* assessed GHG emissions from transportation fuels, petroleum fuels, first-generation biofuels (sugar and starch-based ethanol, oilseed-based biodiesel), and selected second-generation biofuels derived from lignocellulosic biomass (ethanol and Fischer-Tropsch diesel) on a well-to-wheel basis (Gaffney and Marley, 2009). Substituting biofuels for petroleum-based fuels was found to have the potential to reduce lifecycle GHG emissions directly associated with the fuel supply chain. Second-generation biofuels (with lifecycle GHG emissions between -10 and 38 g CO_2eq/MJ) were reported to provide higher mitigation potential over first-generation biofuels (with lifecycle GHG emissions between -19 to 77 g CO_2eq/MJ) compared to 85 to 109 g CO_2eq/MJ for petroleum fuels (Gaffney and Marley, 2009). Figure 4 shows a range of reductions of GHG emissions per vehicle-km (v-km) obtained from various studies.

Air quality improvement by ethanol

The emissions from engines using gasoline or petrol have sulfur dioxide (SO_2), unburned hydrocarbons (HC), nitrogen oxides (NO), carbon monoxide (CO), and suspended particulate

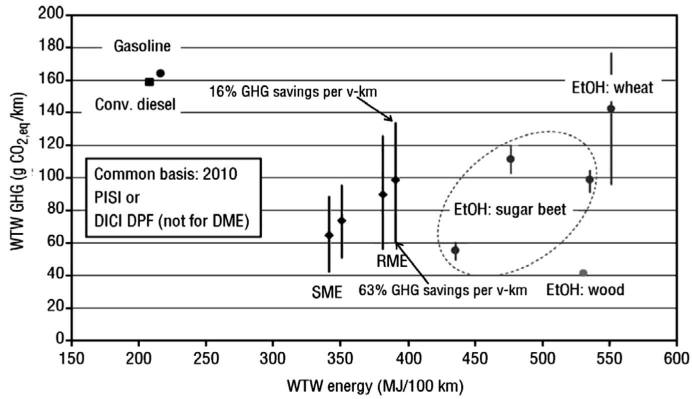

Fig. 4. A range in reductions of GHG emissions from biofuel vs. gasoline and diesel (Larson and Kartha, 2000).

Note: EtOH = ethyl alcohol (ethanol); SME = soy methyl ester; RME = rape methyl ester; PISI = port injection spark ignition; DICI DPF = direct injection compression ignition with diesel particulate filter.

matter (SPM), which causes atmospheric pollution and responsible for deteriorating air quality. The pollutant gases, mainly nitrogen oxides, and hydrocarbons, react in the presence of sunlight by way of a series of photochemical to form the secondary pollutant ozone and released in the troposphere, the chief component of smog. CO is a deadly poison, and the inhalation of fine particulate matter (PM2.5) is a severe health concern. Ethanol-gasoline blend is one of the best options for air quality improvement (Peter *et al.*, 2003). As a fuel additive, ethanol changes the emissions profile of gasoline, creating a cleaner, safer transport fuel. Emission tests performed with ethanol E10, E15, E22, and E100 blends confirm that significant reductions in several air pollutants (Table 1).

Overall, a 41% reduction in particulate matter and 5% NOx and 27% CO emission has been observed with E15 blends (Prasad and Dhanya, 2011a). A comprehensive evaluation of the use of E 7.7 ethanol-blended fuel on the bus fleet under the Karnataka State Road Transport Corporation

Table 1. Reduction in pollution emission with different percentages of Ethanol blending

Pollutant	Emission (%)		Emission (g/km)	
	10% ethanol	15 % ethanol	22% ethanol	100 % ethanol
Particulate matter	27	41	0.08	0.02
NOx	4	5	0.45	0.34
Carbon monoxide	20	27	0.76	0.65
Unburned hydrocarbons	-	-	0.004	0.02
Sulfur dioxide	-	-	0.064	0.0

(KSRTC) was conducted, estimating the reduction in air pollution emissions and its impact on the air quality. The results showed a considerable decrease in particulate matter, CO, CO_2 and NOx (UNFCCC, 2015), Considering air toxics, the addition of ethanol to gasoline has been observed to reduce benzene, 1,3-butadiene, toluene, and xylene emissions, but may increase acetaldehyde emission (Niven, 2005; Yung-Chen *et al.,* 2011).

Ethanol-gasoline blends may result in a mitigation effect on exhaust emissions of the criteria pollutants, most organic compounds, and on ozone-forming potential. The high-mileage car also showed an emission decrease while using ethanol-gasoline blends. In contrast, the toxicity-based emission ranking for the six air toxics of ethanol-gasoline blends showed high emission based on cancer and acute-effects. For criteria air pollutant emission reduction and ozone air quality improvement, the ethanol-gasoline blends are recommended for use as an alternative fuel in in-use passenger cars; ethanol content up to 20% in gasoline (E20) still suitable to be used in the vehicle. However, in view of toxicity, the use of ethanol-gasoline blends needs more evaluation, especially in the case of high ethanol content (Yung-Chen *et al.,* 2011).

Carbon cycle, net energy balances and Ethanol

The actual benefits which may be realized from ethanol depend on the energy and carbon balances, indicating the magnitude of fossil fuel inputs (and relative GHG emission) corresponding to fossil fuel savings (and avoided GHG emissions) due to its use as alternative fuels (SRREN, 2011). A study conducted by Confederation of Indian Industry calculated the net energy and carbon balance for selected categories of ethanol, which are summarized in Table 2.

Table 2. Net energy balance and carbon balance for selected categories of Ethanol

Feedstock	Net Energy Ratio	Net Energy Balance (GJ /kl)	Net Carbon Balance (tCO2e/kl)	% Carbon emission reduction
Molasses	4.57	19.11	- 1.1	75%
Sweet Sorghum	7.06	21.57	- 1.4	86%
Cellulosic (Bagasse)	4.39	25.41	- 1.7	70%
Cellulosic (Rice straw)	3.32	22.79	- 1.6	68%

Source: CII (2010)

The study shows that the net energy and carbon balance per year is highest for Jatropha-based biodiesel. The significant energy contribution from the co-products (seed husk, seed cake, and glycerol) obtained during biodiesel production; contributes almost half of the total energy generated during the end-use stage. Sweet sorghum-based ethanol was observed to have the best conversion efficiency in terms of converting input energy to output energy (CII, 2010).

Future of ethanol

As technology evolves, research improves, and policy responds, the competitiveness of ethanol with other alternative technologies will transform as a function of economics and environmental concerns beyond those considered now. The second-generation cellulosic ethanol may be able to provide massive benefits and can contribute significantly to the secure energy future for India. The Government of India has also shown its support to remove impediments to the growth of the biofuel industry, with the union cabinet chaired by the Prime Minister, Mr. Narendra Modi approving its direct sale by private manufacturers and suppliers as a measure to encourage production and marketing of biofuels. The prime minister also sought collective R&D effort and collaboration towards the clean energy path at the G20 summit held in Brisbane, Australia in 2014. Also, with the consideration regarding the allowance of 5% biodiesel blending by bulk users such as railways and defense establishments, the blending situation is expected to improve and reduce India's dependence on crude oil to some extent (Economic Times, 2014).

Conclusion

Ethanol is considered as eco-friendly and carbon-neutral fuel because entire carbon dioxide (CO_2) released during the burning of ethanol had been sequestered from the atmosphere for the growth of crops. The government of India has undertaken several policy measures to augment the production and use of ethanol during the past decade at the national level. Ethanol is primarily used in transport, either pure or blended form, along with petrol. The agricultural residues which currently left unused or of less utilization can be a useful and cheap resource to meet the entire demand of biomass for ethanol production provided the technology for its conversion is available and cost-effective. Since ethanol is made entirely from biomass, it does not contain any sulfur, and having an oxygen content in it, improves the combustion efficiency of ignition engines and lower the emissions. Increased use of ethanol could be an essential strategy and viable option for managing India's energy security, mitigation of climate change, and air pollution reduction.

Acknowledgments

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Agri-business potential in sugarcane and its bio-based products

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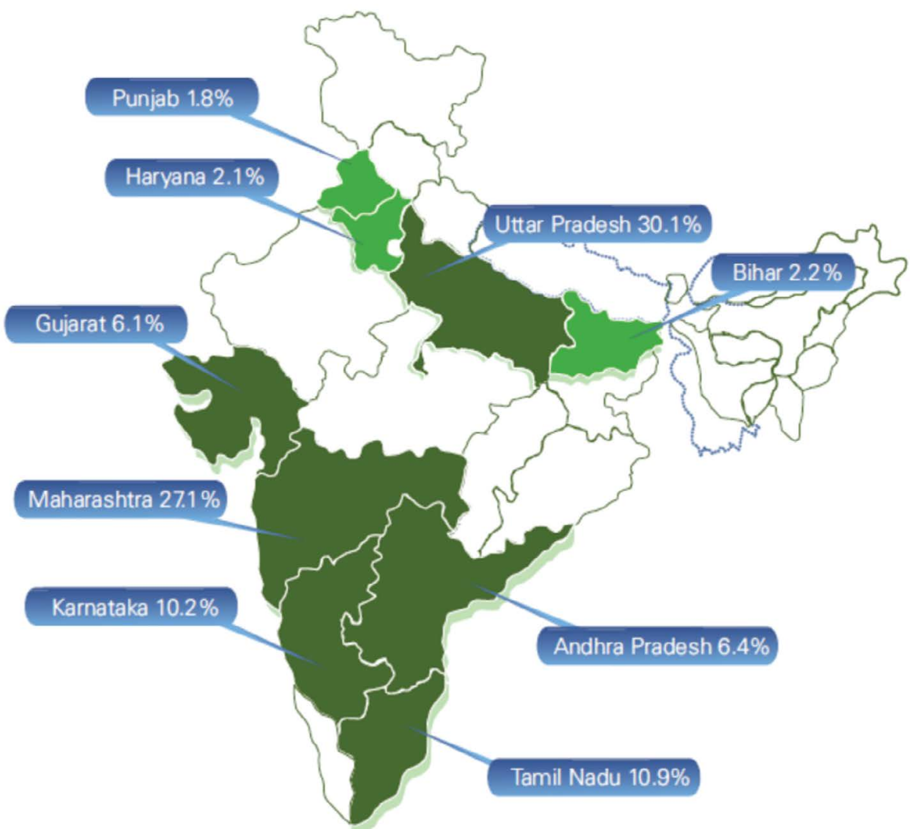
Sugarcane is mainly an industrial crop as the cane is supplied to sugar industries, where various products, from its juice are prepared by using a series of industry. The by-products from sugarcane further require some form of industry. Only a fraction of its production is used in small scale industry for making local '*Khandsari*' and '*gur*'. Sugarcane's products like sugar and fermented products are very important in making and preserving various kind of medicines like syrups, liquids; capsules etc. Sugarcane provides a juice, which is used for making white sugar, and jaggery (*gur*) and many by-products 1ike bagasse and molasses. Bagasse is used as a fuel, for production of fiber board, papers, plastics and furfural. Molasses is used in distilleries for the manufacture of ethyl alcohol, butyl alcohol, citric acid *etc*. Rum is the best potable spirit made from molasses. Molasses, also, is used as an additive to feeds for livestock. Green tops of cane are a good source of fodder for cattle. Its remains are good manure in alkaline and saline soils.

Bio-based economy or bio-economy refers to all economic activity derived from scientific and research activity focused on the development of bio-based processes and products. In India, area under sugarcane is around based on the satellite images procured in the latter part of June 2018, the total acreage under sugarcane in the country is estimated to be around 54.35 lakh hectares in 2018-19 SS, which is about 8 per cent higher than 2017-18 sugar season's cane area of around 50.42 lakh ha. India's centrifugal sugar production in marketing year (MY) 2018/19 (Oct-Sept) is expected to rise 4.2 per cent to a record 33.8 million metric tonnes (MMT). Uttar Pradesh will be the largest producer of sugar in India, for the third year in a row. A higher sugarcane production forecast of 415 MMT on 5.2 million hectares (MH) will contribute to the above estimates. Assuming normal market conditions, sugar mills will be encouraged to use up surplus inventory of up to 6 MMT. With incentives, this surplus could be exported, as out-year sugar supply will be 31 per cent over consumption and normal stock requirements (34.4 MMT).

A vibrant market for bio-based products exists in rural and semi-urban a area which is around ₹ 500 million business per annum. The sugarcane industry is gradually transforming into sugar complexes by producing sugar, bio-electricity, bio-ethanol, bio-manure and bio-chemicals; these contribute about 1.1% to the national GDP. Currently, the turnover of the sugarcane and sugar related agribusiness is over ₹ 85 thousand crore per annum, out of which around ₹ 65 thousand crore accrues to the sugarcane farmers of the country. In view of the growing agri-business opportunities based on sugarcane crop and its bio- products sugar mills are being transformed into sustainable bio-refineries that fully exploit the potential of the crop. These changes are generating new integrated industries (lump sugar, chemicals, biodegradable utensils etc.) for regional communities in low emission manufacturing technologies. The contribution of these activities to the turnover of the industry at the moment is around ₹ 10–12 thousand crore which is likely to increase substantially in imminent future.

Background

Sugarcane is one of the world's largest crops. As per satellite data currently available, the area under sugarcane cultivation is estimated to be 49.31 lakh hectares (lh), about 10 per cent lower than the cane area of 55 lh in the 2018-19 (October 2018 to September 2019) season. Sugarcane is one of the best converter of solar energy into biomass and sugar. The biomass containing fiber, lignin, pentosans and pith can be converted into value added products by application of suitable chemicals, biochemicals and microbial technologies. More than 45 million sugarcane growers in India out of which 65% of the rural population depend on this agro-based industry. FPOs can help India's farmers reap the benefits of collectivisation. Sugar industry gets ₹ 6,268 crore export subsidy. One-district-one-product scheme to help UP become USD 1 trillion economy. In India, many industries are consuming agricultural produce as their raw material and generate various types of wastes. In which, sugarcane industries are one of them, generating huge amount of by-products, such as molasses, bagasse and press mud *etc*.



Indian sugar producing states

Area, production and utilization of sugarcane in India

Sugarcane	Area[1]	Yield[1]	Product[1]	Sugar[1]	*Khandsari*[2]	*Gur*[2]	Seed[2]
	Mha	MT/ha	MMT	MMT	MMT	MMT	MMT
1990/91	3.69	65.39	241.05	122.32	13.18	76.63	28.93
1995/96	4.15	68.02	282.09	174.76	10.00	67.27	30.06
2000/01	4.32	69.35	299.32	176.65	11.00	75.75	35.92
2001/02	4.41	67.09	295.95	180.32	10.50	69.62	35.51
2002/03	4.52	63.58	287.38	194.33	9.50	49.07	34.49
2003/04	3.94	59.39	233.86	132.51	10.00	63.29	28.06
2004/05	3.66	64.74	237.08	124.77	9.50	74.36	28.45
2005/06	4.20	66.93	281.17	188.67	8.50	50.26	33.74
2006/07	5.15	69.03	355.52	222.00	10.00	80.86	42.66
2007/08	5.06	68.81	348.18	249.91	7.00	49.49	41.78
2008/09	4.44	64.19	285.02	145.00	6.50	99.32	34.20
2009/10	4.18	70.01	292.30	185.55	6.50	65.17	35.08
2010/11	4.89	70.09	342.38	240.00	7.50	53.79	41.09
2011/12	5.08	71.07	361.03	257.00	7.00	53.70	43.32
2012/13	5.06	67.38	341.20	251.50	7.00	41.75	40.94
2013/14	5.01	70.26	352.14	234.32	8.00	67.56	42.25
2014/15	5.14	70.44	362.33	265.40	8.00	45.45	43.48
2015/16	4.96	70.25	348.45	238.00	8.50	60.13	41.81
2016/17	4.38	70.02	306.70	193.30	8.50	68.09	36.80
2017/18	4.95	79.80	395.00	278.00	9.00	60.60	47.40
2018/19	5.20	79.81	415.00	292.00	9.00	55.00	49.80

Note: Figures for 2017/18 and 2018/19 are FAS estimates.
Source: [1] Directorate of Economic and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India
[2] FAS/New Delhi Estimate.

Sugarcane products and its by-products

Sugarcane is a rich source of carbohydrates. It is used as:

(a) Food: sucrose, fructose, syrups, and jaggery

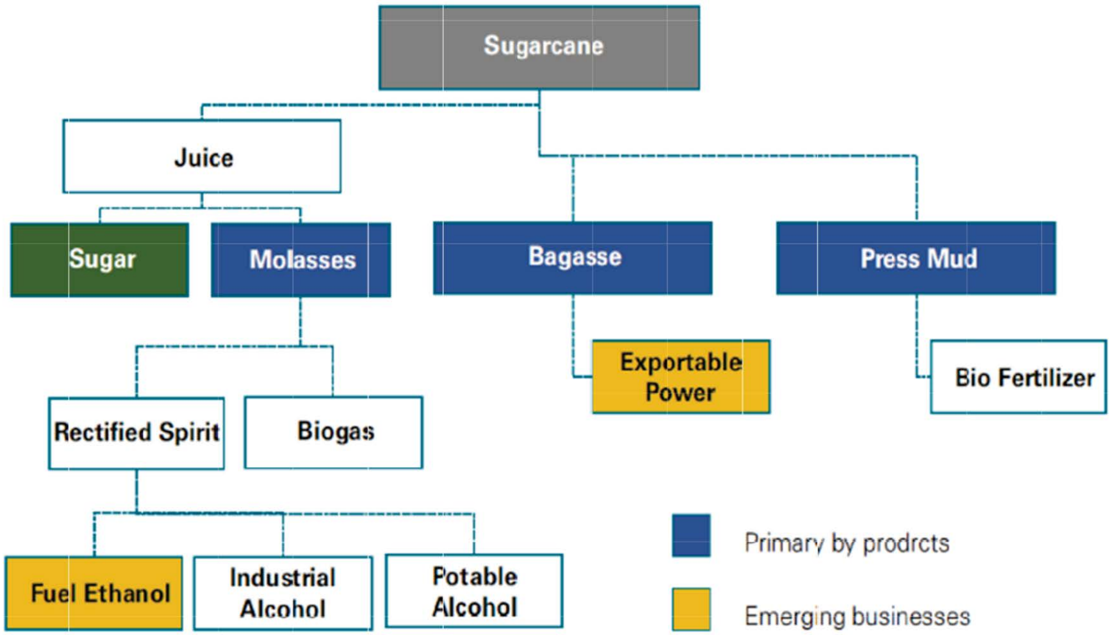
(b) Fiber: cellulitic materials

(c) Fodder: green leaves, top portion

(d) Fuel: residue/waste materials

(e) Chemicals: alcohol, bagasse and press mud

Though sugar is the main product from sugarcane industry, but many value added products can be derived from diversification of the so formed end -products.



Flow diagram of different by-products from sugarcane industry

Table 1. Main by-products of the sugar industry

S. No.	Sector of economy	Value added products produced from sugarcane
1.	Food	Sweeteners (traditional, modern, synthetic), Vitamins, Amino acids, Beverages, Fats and Oils, Edible proteins (Single Cell Protien and Mushroom)
2.	Health	Juice, Vinegar, Chemical, Antibiotics, Anti-cholesterol, Lingo-meds, Enzymes
3.	Fertilizers, Compost, Food, Feed, Fodder and Forages	A range of food, feed, fodder, fertilizer and forages.
4.	Fermentation Industry	Solvents, Plastics, Alcohol based chemicals, Anti-corrosive compounds, Tenso-active compounds, iocides.
5.	Energy, Biogas, Bagasse fuel, Fuel Alcohol	Bagasse as Fuel, biogas, Co-generation of power
6.	Transportation	Ethanol-Petrol/Diesel blends (Gasohol)
7.	Education and Culture	Text books, Note books, Newsprints, Writing and printing paper

Table 2. Sugarcane by-products produced by the sugar industry in India (Mt)

State / MY →	2016/17 Revised	2017/18 Estimate	2018/19 Forecast
Andhra Pradesh	6.1	6.7	7.5
Bihar	5.5	5.0	5.3
Gujarat	11.2	12.0	13.0
Haryana	5.8	6.0	6.0

Table 3. Centrifugal sugar price (Prices in ₹ per MT)

Year	2016	2017	2018	Per cent change
January	31,750	39,400	35,410	10
February	33,500	39,700	35,550	10
March	36,200	38,400	33,940	12
April	36,300	39,000	31,900	18
May	36,350	39,700		
June	37,800	39,200		
July	39,000	39,910		
August	38,500	40,300		
September	39,100	40,360		
October	39,300	40,260		
November	38,000	39,450		
December	38,200	36,700		
Exchange rates	67.11	65.12	64.54	
	Local currency ₹/US $			

Note: Exchange rates for 2016, 2017 and 2018 refer to respective marketing years (October– September).

Table 4. State-wise sugar production (in thousand metric tonnes) in India

State / MY →	2016/17 Revised	2017/18 Estimate	2018/19 Forecast
Andhra Pradesh	6.1	6.7	7.5
Bihar	5.5	5.0	5.3
Gujarat	11.2	12.0	13.0
Haryana	5.8	6.0	6.0
Karnataka	21.5	32.5	39.0
Maharashtra	42.0	106.0	110.0
Punjab	5.0	5.0	5.0
Tamil Nadu	10.0	6.8	6.0
Uttar Pradesh	87.0	110.0	112.0
Others	8.4	8.0	8.8
Total	202.50	298.00	312.50

Sources: MYs 2016/17 is industry and government estimate; MYs 2017/18 and 2018/19 are FAS/New Delhi Estimates.
Note: Excludes *Khandsari* sugar, as state-wise breakup is not available

Advantages of sugarcane by-products

Setting up industries based on the sugarcane by-products have several advantages:

- The waste material can be converted into valuable products by adopting suitable tools, tactics and technologies.
- It creates employment opportunities especially in the field of agri-business aand in rural areas, thus, improving the economic status of people involved in sugar industries.
- The most important aspect of utilizing these byproducts is that it helps in minimizing the pollution hazards and help in maintaining the eco-friendly environment.

By-products of sugar industry

Ethanol

It can be used as a bio-fuel alternative to gasoline and is widely used in cars in Brazil. It is the primary product of sugarcane processing, rather than sugar. In Brazil, gasoline contains at least 22 per cent bio-ethanol. The production of ethanol from sugar cane is more energy efficient than from corn or sugar beets or palm/vegetable oils. Furthermore, if bio-fuels are used for crop production and transport, the fossil energy input needed for each ethanol energy unit can be very low.

Press mud

Organic waste, such as press mud or filter cake is characterized as a soft, spongy, amorphous and dark brown to brownish material. It is generated during the purification of sugar by carbonation or sulphitation process. Press mud supplies a good amount of organic manure and can be an alternate source of plant nutrient and act as a soil ameliorates.

Bagasse

It is obtained during the extraction of juice from cane. It is a dry pulpy residue and is fibrous in nature. It is used as a bio-fuel or at industrial level, it is used as a binding material. In general, bagasse contains major portion as cellulose, hemicelluloses and lignin in the proportion of 47–52, 25–28, and 20–21%, respectively.

Molasses

It is produced during sugar production from raw juice. It is a viscous liquid which can be separated by massecuite. It contains higher microbial activities used for the production of alcohol and/or ethanol, or fuel for ethanol.

Spentwash

The raw spentwash generated after fermentation and distillation is acidic in nature, having dark brown color with unpleasant odour, high COD and BOD (1,00,000 and 45,000 mg L^{-1}). Bio-methanation is one of the options to treat such organically rich raw spentwash. With the adoption of primary treatment, 1100 million cubic feet of methane gas per annum is generated in India which is used for steam generation and to run the boilers.

Bio-compost

Bio-compost is prepared by mixing press mud and distillery spent wash in the ratio of 1:2.5. A consortium of efficient microbial decomposers, viz., *Phanerocheate chrysosporium*, *Trichurus spiralis*, *Pacelomyces fusisporus*, *Trichoderma* spp., *etc.*, are sprayed on the press mud and mixed thoroughly using aerotiller which makes the press mud aerable and hastens the process of decomposition.

Agri-business potential in sugarcane

Sugar industry in the country is producing large amount of wastes as their by-products and its disposal as well as management are the major tasks. It can be used in agriculture for crop production as soil ameliorant, organic source of nutrients to plants, medium for microbial inoculants for producing bio-fertilizer, bio-compost, *etc*. Though these wastes are largely available, due to their bulky nature, their transportation to the application site involves a lot of expenditure. Therefore, suitable technologies should be developed to reduce their voluminous bulk to concentrated end products.

Potential uses

- Raw sugarcane: chewed to extract the juice
- Sugarcane juice: a combination of fresh juice, extracted by hand or small mills, with a touch of lemon and ice to make a popular drink, known variously as air tebu, *usacha rass, guarab, guarapa, guarapo, aseer asab* and *ganna sharbat*.
- Syrup: a traditional sweetener used in soft drinks, now largely supplied in the US by high fructose corn syrup, which is less expensive because of corn subsidies and sugar tariffs.
- Molasses: used as a sweetener and a syrup accompanying other foods, such as cheese or cookies. In the United States, molasses is a common sweetener and flavoring agent in many baked goods such as gingerbread and Boston brown bread *etc*.
- It can be used to make rum. Rum is, therefore, common in regions of the world where sugarcane or sugar beets are heavily cultivated because of the abundance of molasses.
- It is also responsible for the dark, rich flavor and texture of brown sugar. Brown sugar is produced by combining refined white sugar with approximately 5% molasses.
- It is added to some tobacco products for flavor. Flavored tobacco is used in *hookahs*.
- Jaggery: It is a solidified molasses, known as *gur* or *gud* or *gul* in India, is traditionally produced by evaporating juice to make a thick sludge and then cooling and molding it in buckets. It is used as sweetener in cooking traditional entrees, sweets and desserts.

Apart from the above, processing, packaging and marketing of these by-products into fine products will popularize and accelerate its usages in agribusiness and entrepreneurship development.

Conclusion

Sugarcane industries are age-old industrial practices in India which contribute a significant amount of by-products as waste. Handling and management of these by-products are huge task, because those require lot of space for storage. However, it provides opportunity to utilize these by-products in agricultural crop production as organic nutrient source. Therefore, it is attempted to review the potential of sugar industries by-products, their availability, and use in agricultural production. A large number of research experiments and literatures have been surveyed and critically analyzed for the effect of sugarcane by-products on crop productivity and soil properties. Application of sugar industries by-products, such as press mud and bagasse, to soil improves the soil chemical, physical, and biological properties and enhanced the crop quality and yield. A huge possibility of sugarcane industries by-products can be used in agriculture to cut down the chemical fertilizer requirement. If all the press mud is recycled through agriculture that helps in saving of costly chemical fertilizers. Application of sugarcane industries by-products reduces the recommended dose of fertilizers and improves organic matter of soil during the crop production. It can also be used in combination with inorganic chemical fertilizers and can be packed and marketed along with commercial fertilizer for a particular cropping system. That helps in reduce the storage problem of sugarcane industries by-products across the India. Sugarcane and its by-products enhance the resource & contribute to more economically & socially sustainable sugarcane production in the development of Agribusiness sector in developing countries resulting in significant opportunities to enhance the rural economy.

References

Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India, New Delhi Estimate.

MYs 2016/17 is industry and government estimate; MYs 2017/18 and 2018/19 are FAS/New Delhi Estimates.

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Indian Sugar Mills Association, Industry and Trade Sources.

Latest media reports indicate that the Commission for Agricultural Costs and Prices, GOI has recommended a FRP for sugar season 2018/19 at ₹ 275 per quintal at 9.5 per cent recovery level subject to a premium of ₹ 2.68 per quintal for every 0.1 per cent point increase in the recovery rate.

INVITED PAPERS

Sugarcane diseases: A major hurdle in doubling farmer's income

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Sugarcane is one of the vital cash crop of India. Several regions of the country have commercial cane cultivation with different scientific tools, simultaneously various disease problems have also been occurred in the regions. The most important disease *i.e.* red rot is caused by *Colletotrichum falcatum* Went and this disease responsible for the elimination of many elite commercial varieties. Next to that, two other fungal diseases Smut (*Sporisorium scitamineum*) and wilt (*Fusarium sacchari*) also caused various problems to cane cultivation in Uttar Pradesh. So many foliar disease along with systemic fungal diseases caused serious damage to cane crop. Likewise stalk diseases, various foliar diseases occurred during monsoon and dry weather condition. Beside fungal diseases many diseases caused by viruses, bacteria and phytoplasma also made enormous impact on performance of many sugarcane varieties during the previous decades. Various diseases such as grassy shoot, yellow leaf, mosaic, leaf scald and bacterial top rot/red stripe caused serious damage to cane crop. Farmers may be advised for earlier planning to manage primary infection of this disease in Co 0238. It is also a need of the day to follow recommended integrated disease management (IDM) practices to check the heavy losses at farmer fields. IDM could be useful for cane growers to enhance the farmer's income.

Keywords: Sugarcane, red rot, smut, wilt, pokkah boeng, sugar factory, incidence percent.

Sugarcane is an important agro based industrial crop of Uttar Pradesh (UP). Sugarcane is grown in 27.94 lakhs hectare with an average productivity of 80.50 tonne per hectare and 11.46 per cent sugar recovery. The sugarcane industry remains one of the main pillars of the economy of Uttar Pradesh. A popular early maturing sugarcane variety Co 0238 plays a major role to increase sugar recovery and sugarcane productivity of UP. The variety Co 0238 occupies more than 80 per cent of the cane area of central Uttar Pradesh. The traditional cane cultivation is very common among the farmers due to less awareness of the scientific farming including IDM in sugarcane. The traditional farming is very helpful to build up the inoculum of diseases in the field. The red rot disease was responsible for the elimination of many elite commercial varieties such as Co 312, Co 658, Co 997, Co 1148, Co 6304, CoC 671, CoC 8001, CoC 85061, CoC 86062, CoC 90063, CoC 92061, CoJ 64, CoSe 92423, CoS 8436 etc in the past in India.

Extensive survey of various sugar factory areas were conducted during pre and post monsoon to record the incidence of major diseases such as red rot, smut, wilt, GSD, YLD and pokkah boeng.

Sugarcane industries are facing serious problems due to red rot and other disease such as smut, wilt, GSD, YLD and pokkah boeng diseases. Natural incidence of red rot disease was recorded on variety Co 0238, during previous year. Disease severity varied upto 98 per cent on Co 0238 in affected field of central UP in 2018-2019. Disease severity in Co 0238 was reported up to 98% in Khambarkheda, 95% in Loni, 85% in Hariyavan, 65% in Ajbapur, 60% in Kumbhi, 50% in Pilibhit, 45% in Maqsoodapur sugar factory zones. Similarly, it was also observed on same variety from Rosa (20-22%), Gola (10-25%), Gularia (15-20%), Hargoan (2-25%), Nigohi (1-35%) and Jawaharpur sugar factory areas of central UP (Fig. 1 & 2). Red rot was also succumbed on varieties CoJ 88, CoS 97264 and CoPant 84211 with incidence between 5% and 25% in Palia and Gola factory zones, respectively. The variety Co 0238 also affected by smut ranging from stray to 30 percent in Gola, Nigohi, Maqsoodapur, Nigohi, Kumbi and Ajbapur sugar factory areas. Smut was reported on Co 0118 (Stray), CoJ 88 (2%) from Biswan and Palia sugar factory zones, respectively. Similarly, it was also noticed up to 30 percent on variety CoS 13231 in research farm of Shahjahanpur.

The incidence of wilt disease varied from 2 to 5 per cent on variety Co 0238 from Kumbhi, Maqsoodapur, Nigohi and Pilibhit factory areas. Mix infection of red rot and wilt also noticed from 5-50 percent on variety Co 0238 in Khambarkheda, Ajbapur and Loni sugar factory areas. Grassy shoot disease was observed on Co 0238, Co 0118, Co 98014, CoS 08279, UP 05125 and CoLk 94184 ranging from stray to 50 percent in field of Shahjahanpur and Lakhimpur Kheri districts. The incidence of pokkah boeng varied from stray to 50 percent on Co 0238 from various factory areas. Knife cut stage of pokkah boeng was recorded on Co 0238 and CoS 0118 at Ajbapur and sugar factories zones. Similarly, other varieties namely Co 0118, CoS 08272, CoS 8436, CoS 08279, CoLk 94184, CoS 97264, UP 05125 and CoJ 88 were found affected by this disease. Severity of yellow leaf disease was noticed up to 60 per cent on CoS 09232 at Shahjahanpur farm. It was also observed on Co 0238 and CoS 08272 ranging from 10 to 30 per cent. Sugarcane mosaic, rot (Bacterial), leaf binding diseases and Leaf scald were also noticed on various varieties including Co 0238 at various sugar factories zones of central UP.

Fig. 1. Red rot symptoms of sugarcane.

Fig. 2. Damaged sugarcane crop of Lakhimpur district of central Uttar Pradesh.

Disease management

Management of red rot has been a challenging. It has been observed that once the disease has appeared in the field it is tough to manage. Most of the recommended management practices hence are aimed at prophylactic measures to reduce pathogen build up in the soil. In view of diversity in the kinds of pathogens, a single method would not be useful to mitigate the losses from red rot, hence IDM should be practiced.

Clean cultivation

Clean cultivation is the primary prerequisite for growing a healthy sugarcane crop. This starts with the selection and planting of healthy setts, preferably in a healthy field. This practice reduces the load of initial inoculum and helps in checking the sett borne diseases. This practice of sett selection should be religiously followed if one really desires to check the damage from the diseases. Removal of diseased plants (roguing), as and when detected, also helps in reducing the inoculum available for the secondary spread.

Inter-culture operations like earthing up, wrapping and propping, and sanitation practices like the removal of dead plant residues and old leaves and weeds should be implemented for good crop and clean cultivation. This practice also prevents the crop from the attack of the pests and diseases by rendering the microclimate uncongenial for the pathogens.

Seed nursery program

Strict enforcement of a clean nursery programme is essential to remove pathogen from primary seed materials. Seed material free from diseases, pests and mixtures of other varieties must be ensured. The nurseries even with as low as one per cent red rot incidence must be deleted from the seed programme. Quality seed of infected should be replaced with healthy seed. Robust seed replacement programme has to be initiated in the affected area and the farmers have to be educated adequately to use quality seed from any research centre or authorized centre. Farmer may also be advised to have seed cane nurseries. Quality seed should be raised using single bud of healthy cane by treating apparently healthy canes using moist hot air (54^0C for 2½ hours) or hot water treatment (52^0C for 2 hours) and subsequent generations are raised with inspection. The single bud sett should be soaked at least for half an hour in water suspension of systemic fungicide (2g/litre) before planting.

Roguing of diseased plants

The traditional practice of roguing (uprooting) of the diseased plants has become the main stay in the present day management of sugarcane diseases. Systematic roguing of the diseased sugarcane plants is of prime importance in maintaining a healthy ratoon and plant crop.

Agronomic practices

The incidence of red rot can be reduced through good cultural practices, such as clearing fields of excessive trash and efficient drainage. Agronomic practices that hasten germination are important in reducing seed rotting and obtaining good stands. The effective tips to manage red rot as outlined are:

- Affected fields should not be permitted for ratooning even if negligible red rot incidence is noticed in the plant crop.
- Crop rotation of sugarcane followed by rice for one season or with other crops for two seasons will reduce severity of red rot. Farmers should start crop rotation after disease incidence taking a crop of rice or wheat.
- Green manuring with *Dhaincha* are also mandatory for infected field sanitation. This agronomic practice not only restores the lost vigour of the soil but also reduces the number of propagules of pathogens like *Rhizoctonia*, *Pythium*, *Fusarium* and *Colletotrichum* and thus ensures a good sugarcane crop.
- The affected field along with adjoining field should be harvested immediately. The affected filed should be ploughed up without any delay and field should be made from the stubbles. The stubble and other sugarcane crop residues may preferably be destroyed by burning.

Biological control

Antagonistic biological control agents, such as *Trichoderma* and *Pseudomonas* species, have been used to successfully reduce losses due to red rot. The nursery plot should be treated with bio-product containing *Trichoderma* or *Pseudomonas*. Red rot disease of sugarcane was observed to be biologically managed through *Trichoderma harzianum* and *T. viride.* Application of *Trichoderma* (20 kg /ha) mixed with sanitized decompose press mud / FYM (mixed with 200 kg FYM/ press mud) at the time of planting to boost internal disease resistance, plant vigour and higher yield. *T. harzianum* and *Pseudomonas spp.* possess the ability to protect the crop from soil borne inoculum of red rot and the efficacy is because of the chitinase enzyme produced by them.

Resistant varieties

Effective control of red rot has been mainly through the use of resistant varieties such as CoS 13235, CoS 08272, Co 0118, Co 98014, CoLk 94184, UP 05125, CoS 13231, CoS 08279 etc. In India, the breeding work is primarily focused on developing red rot resistant varieties. But as the pathogen is highly variable in nature, therefore, even if a disease resistant variety is released for cultivation, it gets susceptible to red rot disease within 8–10 years because of the development of new more virulent races of the pathogen.

Chemical treatment

Regular watch of the apparently healthy sugarcane crop and adjoining area are necessary to save crop from any disease. Generally, red rot infection appears in the month up to July. The initial symptom of red rot appears on leaf mid-rib (Spindle infection). Later on, destruction and uprooting of the affected clumps without fail and broadcast of 10-20 gram bleaching powder at the place of infected soil. Soil inoculum may also be destroyed by using drenching of 0.2 per cent suspension of Thiophenate Methyl. Once red rot detected in earlier month, rest of the crop may be sprayed with a systemic fungicide (0.2% Thiophenate Methyl or Carbendazime) at a month interval up to monsoon. Carbendazime, mancozeb and propiconazole can be sprayed to control pokkah boeng, rust disease in sugarcane.

Quarantine

Quarantine regulations govern the introduction of plant material from high-risk areas. In our country, many sugarcane diseases have spread from one place to another with the active help of human agency. The unrestricted movements of seed cane from one district or state to another have been largely responsible for the migration of spread of red rot in different regions. The recent introduction of the disease in Karnataka and Maharashtra was due to introduction of seed material of highly susceptible varieties was brought from red rot endemic area. Hence there is a need for restricting transport of cane from an infected zone to disease free zones. The seed material from outside state is procured only from research stations with proper phytosanitory certificate.

Improved manual tools and equipment for sugarcane cultivation

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Sugarcane is an important industrial crop of India grown in an area of 5.04 million ha with production of 411 million tonnes. Indian agriculture, in general, is characterized by small and scattered type operational land holdings and sugarcane cultivation is no exception. As reflected in 2015-16 census, more than 86.0 per cent of the land holdings are less than 2.0 ha farm size and are in the category of small and marginal farmers, 13.3 per cent of the farmers are in the range of medium farmers having holding size in the range of 2-10 ha. Small size and scattered holdings make the mechanization scenario more complicated and thus need a special strategy and considerations so as to make the proposition feasible and economically viable. The sugarcane cultivation involves different operations such as seed bed preparation, planting, weeding/interculturing, spraying, harvesting including detrashing and transportation. Out of these, most operations are still being carried out by male and women farm workers with traditional manual tools and equipment. The poorly designed conventional tools reduce the work efficiency of the operation with increased drudgery to the operator ultimately cause physical stress on the worker. Keeping view the above considerations, ICAR-IISR Lucknow has developed some improved manual tool and equipment *viz.* manual detrasher-cum-detopper, manual sett cutting machine, manual multicrop planter, manual weed cleaner, solar powered manual sprayer for sugarcane cultivation. These low cost manual tools and equipment has better capacity and efficiency with lot of drudgery saving as compared to the conventional practices.

Introduction

Sugarcane is an important industrial crop of India grown in an area of 5.04 million ha and production of 411 million tonnes with an average productivity of 81.5 tonnes/ha. Uttar Pradesh state is the largest producer of sugarcane as it contributes 46.21 % of the total area and 43.65% of the total production in the country but have the average yield less than the national average. In India, the majority of the farm holdings fall under small and marginal category (86%) and the average size of land holding is about 1.08 ha (Table 1). Table also revealed that number of land holdings having less than 2.0 ha farm size has increased in 2015-16 as compared to 2010-11. The density of agricultural workers per thousand hectares is about 2,218. Gender perspective of agricultural workers indicates that about one half of the agricultural labour are women (Table 2). The sugarcane cultivation involves number of operations *viz.* seed bed preparation, planting (seed sett cutting, furrow making, placement of seed sett in furrows, fertilizer and chemicals application, soil covering over sett), weeding/interculturing, spraying, harvesting including de-trashing and transportation. Most of these operations are being done still with conventional tools and equipment which are very time & labour consuming (more than 500 man-days/ha) and involve lot of drudgery which ultimately increases the cost of operation and reduces the net profit to the growers. The human

Table 1. Number and size of operational holding by size group

Category of holdings	No. of holdings ('000 no.)		Area ('000 ha)		Average size of holdings (ha)	
	2010-11	2015-16	2010-11	2015-16	2010-11	2015-16
Marginal (<1 ha)	92826 (67.0)	100251 (68.45)	35908 (22.5)	37923 (24.0)	0.39	0.38
Small (1.0-2.0 ha)	24779 (17.9)	25809 (17.6)	35244 (22.08)	36151 (22.9)	1.42	1.40
Semi-medium (2.0-4.0 ha)	13896 (10.0)	13993 (9.55)	37705 (23.6)	37619 (23.8)	2.71	2.69
Medium (4.0-10.0 ha)	5875 (4.2)	5561 (3.79)	33828 (21.2)	31810 (20.15)	5.76	5.72
Large (10.0 ha & above)	973 (0.7)	838 (0.57)	16907 (10.6)	14314 (9.06)	17.38	17.07
All holdings	**138348 (100.0)**	**146454 (100.0)**	**159592 (100.0)**	**157817 (100.0)**	**1.15**	**1.08**

Source: Agriculture Census 2015-16 (Phase I), Agriculture Census Division, Department of Agriculture, Co-operation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India, 2019

Table 2. Gender perspective of agricultural workers

(in Millions)

Agricultural Workers	Cultivators (Main & marginal)	Agricultural labour (Main & marginal)	Male cultivators (Main & marginal)	Male sgricultural labour (Main & marginal)	Female cultivators (Main & marginal)	Female agricultural labour (Main & marginal)
Total	127.3	106.8	85.4 (67.1)	57.3 (53.6)	41.9 (32.9)	49.4 (46.3)
Rural	124.7	102.4	83.4 (66.9)	54.7 (53.4)	41.2 (33.1)	47.7 (46.6)
Urban	2.6	4.3	1.9 (73.6)	2.6 (60.5)	0.65 (26.0)	1.7 (39.5)

participation especially women are there in carrying out most of these operations such as seed sett cutting, seed sett placement, weeding, harvesting and de-trashing with traditional tools (Table 3). The conventional tools are poorly designed and resulted in reduced efficiency of the operator and increased drudgery in performing the operations and ultimately cause physical stress to the worker. Hence, the small improved manual tool plays an important role in enhancing the capacity, efficiency and reducing the drudgery of the operator, when 86% land holdings in the country are less than 2.0 ha and scattered also and about 50% farm worker are women. So, keeping these factors in mind, ICAR-IISR, Lucknow has developed/modified some manual tools and equipment to reduce drudgery with enhanced efficiency.

Table 3. Gender participation and labour requirement per hectare in sugarcane cultivation

S.No.	Operations performed	Gender involvement	Equipment/ method used	Man-h/ ha	Man-days/ ha
1.	**Land preparation**				
a.	Ploughing & harrowing	Male	Bullock plough/tractor cultivator	126	21
b.	Removal of grass	Male & female	Manually by sickle	296	50
2.	**Planting of cane**				
a.	Sett cutting	Male & female	Manually by sickle	90	15
b.	Furrow opening	Male	By bullock plough/ tractor cultivator/ridger	55	9
c.	Dropping of setts	Male & female	Manually	5	1
d.	Dropping of fertilizer	Male & female	Manually	5	1
e.	Dropping of insecticides	Male	Manually	5	1
f.	Closing of furrow	Male	Bullock plough	7	1
g.	Planking	Male	Manually bullock/ Tractor planker	8	1
3.	**Interculture**				
a.	Hoeing (2 times)	Male	*Desi* plough	100	16
b.	Hoeing (4 times)	Male	*Kudal*	1018	166
c.	Weed picking (2 times)	Male & female	By hand sickle	447	74
4.	**Top Dressing (1time)**	Male & female	By hand	15	3
5.	**Earthing-up (1 time)**	Male	Spade	667	111
6.	**Stubble Shaving (1time)**	Male	Spade/*Kudal*	144	24
7.	**Harvesting**	Male & female	*Gandasa*/different types of knives	600	100
			Total	**3588**	**594**

Developed improved manual tools and equipment

IISR manual cane node/bud chip cutting tool

A manual machine was developed for doing three operations separately *viz.* cutting cane node, bud chip scooping and seed sett cutting of sugarcane as seed material required for sugarcane planting by various methods (Fig.1). The machine has a handle, high carbon steel blade, a scoop and platform to fix the machine. One person can easily operate by holding cane in one hand and pressing handle with other hand for the required operation.

Fig. 1. IISR manual cane node/bud chip/sett cutting machine

IISR sugarcane manual stripper cum detopper (new models)

For detrashing and detopping, ICAR-IISR has developed a hand tool which does the job of stripping of dry leaves and cutting the green top satisfactorily. The stripper removes the dry/green leaves by separating them and pushing them away from cane stalk. The green top is then cut with a knife provided for this purpose on the stem of the stripper. This sugarcane detrasher works satisfactorily but was slightly heavy (393 g) to use for a longer duration. Hence, three new models of sugarcane stripper cum detopper were designed, developed and tested at the Institute Farm (Fig. 2). The technical specifications of these models are given in Table 4. Two individuals (male and female) who have experience of sugarcane harvesting for more than five years were selected for operating these tools. After harvesting of cane, data of cane stripping and de-topping with all these tools were taken for 20 minutes continuous work by the operator (Table 5). It was observed that using Model III, male and female operator has maximum number of cane stripped and detopped as compared to other two Models without any exertion and discomfort.

Table 4. Technical specifications of the sugarcane stripper cum detopper

Parameter	Model I	Model II	Model III
Weight (g)	408	398	225
Material of blade	High carbon steel	High carbon steel	High carbon steel
Thickness of blade (mm)	3.0	2.0	2.0
Thickness of cutting edge (mm)	0.5	0.5	0.5
Dia. of hand grip (mm)	35	30	30
Cutting length of the blade (mm)	110	95	85
Material of handle	Wood	Wood	PVC
Overall dimensions (LxB) (mm)	370x60	350x75	310x55

Model I **Model II** **Model III**

Fig. 2. Developed sugarcane stripper cum de-topper

Table 5. Test results of sugarcane stripper cum de-topper (Variety: CoPK 5191)

Parameter	Model I		Model II		Model III	
	Male	Female	Male	Female	Male	Female
Time (min)	20	20	20	20	20	20
No. of cane stripped & de-topped	107	65	86	66	116	99
Weight of the clean cane (kg)	48	29	38	31	50	45
Green top weight (kg)	10.5	7	7.5	9	15	10
Dry trash (kg)	5.8	4.2	4.3	5.4	9.1	5.5

Manual multi crop planter for sowing intercrops in sugarcane

A single row manual multicrop planter was designed and developed for sowing intercrops in sugarcane (Fig. 3). PVC rotor with vertical grooves on periphery was used for metering the seed. As per the crop seed physical dimensions, these rotors are of different sizes. There is a provision to change the rotors as per the crops to be sown. The drive to the seed metering shaft was from ground wheel through chain and sprocket. Two persons were used to operate the machine. Testing of the machine was carried out for sowing of black gram, lady finger, wheat and mustard as intercrop in sugarcane.

An experiment was conducted at Institute farm for sowing of wheat and mustard as intercrop in sugarcane in November 2018. Sugarcane was planted with tractor operated deep furrow sugarcane cutter planter (75 cm row spacing) and sugarcane trench, planter (30:150 cm spacing) on 26 Nov. 2018. In each trench two rows of sugarcane was planted by machines at 30 cm spacing and at 30 cm depth. Then two rows of wheat and mustard were sown with manual multicrop planter on the 80 cm ridges width formed in between two trenches. One row of wheat and mustard was taken on ridges formed (50 cm) with deep furrow sugarcane planter. The effective field capacity of the machine was 0.07 and 0.10 in wheat and mustard, respectively. The crop stand was observed good (Fig. 4).

Fig. 3. Manual multicrop planter for sowing intercrop in sugarcane

Fig. 4. Intercropping of wheat and mustard in sugarcane with manual multicrop planter

Manual weed cleaner for weed management

A manual light weight weed cleaner was developed based on the principle of wiping (or brushing) for weed control in between crop rows by using non-selective herbicides *i.e.* glyphosate (roundup) to the targets (weeds) by direct contact without damaging the crops (Fig. 5 & Table 6). The herbicide solution is supplied to an absorbent surface *i.e.* spongy roller in weed cleaner. The weed cleaner was calibrated for herbicide dose and volume of water. Testing of weed cleaner was carried out at Institute farm. Weed cleaner was tested at the farm in sugarcane field planted at 75 cm row spacing. One person is required to operated the cleaner. The capacity of the cleaner was 0.04 ha/h at operating speed of 2.0 km/h. The discharge rate was observed 470 l/ha.

Table 6 . Technical specifications of manual weed cleaner

Particular	Value
Overall size (mm) (LxW)	1780x330
Effective working width (mm)	200
Main pipe length & diameter (mm)	1520 & 60
Roller width & diameter (mm)	210 & 95
Length of pipe and dia. (mm) above the roller	210 & 16 (4 small holes of dia. 0.8 mm)
Capacity of the pipe (m^3)	0.005041 (5.0 litre)
Weight of the wiper (kg) (without chemical)	2.0
Tentative cost of the wiper (₹)	2500/-

Fig. 5. Manual light weight weed cleaner

Solar powered manual sprayer

A solar powered manual sprayer was developed for spraying herbicide/fungicide in different crops (Fig. 6). The technical specification of the sprayer has been given in Table 7. The height of the spraying can be adjusted from 300 mm to 1000 mm. Preliminary testing of this sprayer has been carried out at Institute farm for spraying pre-emergence herbicide in sugarcane.

Fig. 6. Solar powered manual sprayer

Table 7. Technical specifications of the solar powered manual sprayer

Overall dimensions (LxWxH) (mm)	1830 x 2930 x 1550
Minimum base height (mm)	300
Maximum height (mm)	1000
Type & No. of nozzles	Flat fan nozzles, 7
Nos. of wheels & dia. (mm)	3,670
Nos. of battery & pump used	2 each
Battery voltage & capacity	12 V, 8Ah
Pump voltage, press., flow rate	12V, 5.09 kgf/cm^2, 3.1 l/min
Pipe length, dia. & capacity	1900 mm, 200 mm, 65 litre
Power of solar panel used	20 W
Another drum capacity & separate pipe used	220 litre, 30 m

Fig. 7. Operation of sprayer in the field

Table 8. Performance results of sprayer during preliminary testing

Effective width (mm)	3600
Average speed of operation (km/h)	1.8
Average force required to pull the sprayer (kgf)	18
Average discharge of nozzle (ml/minute)	614
Average discharge of all nozzles (l/minute)	4.3
Effective field capacity (ha/h)	0.52
Time to cover 1 ha area (h/ha)	1.92
Field efficiency (%)	80
Battery backup after fully charging (self charging by solar also during operation)	> 6 h

The effective field capacity of the sprayer was observed 0.52 ha/h with field efficiency 80% at average speed of 1.8 km/h. The sprayer takes about 71% less time as compared to knapsack sprayer to cover one hectare area.

Conclusion

The improved manual tools and equipment enhances the capacity and efficiency of the operation with less time, cost and drudgery as compared to conventional practices. So, these manual tools need to be popularized for wide adoption among the farmers.

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Multifold increase in sugarcane farmers income through healthy seed production and different sustainable higher crop production modules: Success story of a farmers participatory initiative

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Sugarcane agriculture in the country is passing through a transformation phase from conventional to advanced cultivation practices. Research institutes, particularly ICAR-Sugarcane Breeding Institute, Coimbatore had played a vital role in revolution of sugarcane agriculture in the country by developing two miracle cane varieties *viz.*, Co 86032 for tropical and Co 0238 for sub-tropical India. Due to tremendous tillering potential, erect, tall, thicker canes and non lodging characters, cane variety Co 86032 has changed the farming practice from normal 90 cm row to row distance to 120-180 cm row to row distance, hence make mechanized harvesting possible in tropical India. Similarly, thicker cane, fast & very tall growth habit, high tillering potential, wider adaptability and better ratoonability characteristics of Co 0238, revolutionized cane agriculture in the North India through increased cane yield (84.5 t/ha, Haryana, 79.26 t/ha UP, 81.0 t/ha Punjab; during crop season 2017-18, Source Cooperative Sugar Feb, 2019) under conventional method of sugarcane cultivation and more than double yield under wider spaced planting methods. Presently 25.23 lakh ha (73.25%) out of 34.44 lakh ha total sugarcane area of subtropical states is occupied by the varieties developed by ICAR-SBI Regional C entre, Karnal, which accounts >50% of the total area under sugarcane cultivation in India. Wonder variety Co 0238 alone contributes 22.9 lakh ha area followed by Co 0118 (0.95 lakh ha). The demand for healthy seed of varieties Co 0238 and Co 0118 increased many folds with the expansion in their area. The lesser availability of land with ICAR-SBI Regional Centre, Karnal (only 8-10 acres of area available every year for breeder seed production activities) was the biggest hurdle to meet out the seed demand of the nation. This was addressed by involving properly trained farmers in seed production activities. They were given breeder seed of varieties Co 0118 and Co 0238 in small quantity (for 1-2 acres) and their fields were periodically monitored by the breeders of the Centre involved in seed production. Stakeholder having bulk demand for varieties Co 0238 and Co 0118, were suggested to purchase directly from the farmers fields. Every year, 40,000-50,000 quintals of seed used to be supplied from Karnal district alone. This initiative made Karnal a seed hub for sugarcane varieties and helped in faster spread of these varieties in sub-tropical states. ICAR-SBI, Coimbatore and its Regional Centre, Karnal had worked on various crop geometry modules along with intercropping. The frequent visits of the scientists at farmers field and farmers to the Regional Centre, Karnal for seed and crop management related queries provided platform for the scientists to implement advanced crop production module at farmers field. Due to adoption of seed production programme of the centre, the farmers got following advantage – (i) They could vacate their fields early, (ii) Save the harvesting and transportation charges and (iii) Got higher cane yields by about 12.5% (weight of top and trash), as seed is sold with tops and trash without any deduction.

Details of modules

To help the sugarcane farmers in achieving per unit higher crop yield and income, five modules were suggested to the farmers after testing their feasibility by ICAR-SBI at its Headquarters Coimbatore and at Regional Centre, Karnal. The details of the modules are as follows:

1. Raising sugarcane at normal row to row spacing as seed crop: Under this module, the sugarcane crop is being raised at conventional narrow spacing at row to row distance of 90 cm using healthy tissue culture generated nucleus seed as planting material. It is slightly different over conventional practices adopted by the farmers of NWZ for following points. a) Single budded setts are used as planting material compare to 3-4 budded setts in farmers practice, b) Planting is done in furrows, opened in dry soil conditions at 90 cm row to row spacing followed by light covering of setts with soil and immediate light irrigation compare to farmers practice of planting under sufficient moisture conditions at 75 cm row to row spacing, followed by deep burring of setts by flattening of soil with the help of heavy wooden plank, followed by no irrigation till 45 days, c) Compulsory earthing-up and finishing all the doses of fertilizer till earthing up compare to no earthing up and applying of nitrogenous fertilizers till Sept-Oct in farmers practice, d) Sale of the crop at 10-12 month crop stage as seed which includes 12-15% additional weight of tops & trash and saves harvesting and loading cost compared to sale of the crop as supply to mill, which is to be harvested and processed by removing tops & trash before loading for transportation to sugar mills and farmers needs to bear the labour cost in conventional practice.

2. Raising sugarcane at wider row spacing as seed crop: This module is similar to the first module except row to row distance, which is kept at 120-150 cm depending on the time of planting. The details of spacing adopted by the farmers is given in Table 1.

3. Raising sugarcane at wider row spacing as seed crop coupled with intercrops: This module is similar to the previous module. The only difference is that suitable intercrops are being taken in the inter rows space after sugarcane planting.

4. Raising sugarcane at wider row spacing as commercial crop for supply to sugar mill: This module is similar to module two but the crop is raised for supply to sugar mill, hence, no additional advantage in yield from sugarcane tops & trash and charges for harvesting, cleaning, loading and transportation to sugar mill needs to pay by the farmers.

5. Raising sugarcane at wider row spacing as commercial crop for supply to sugar mill coupled with intercrops: This module is similar to module 3 except that the crop is raised for supply to sugar mill, hence, no additional saving in tops & trash and charges for harvesting, cleaning, loading and transportation to sugar mill.

Selection of the farmers for adoptions of modules: The training and visit activities by the breeder seed production group of the centre sensitized the farmers of the zone towards adoption of newer approaches for achieving per unit area higher yield and net income. In a series of contacts and trainings, interested farmers were convinced for adoption of any of the five module. Each modules were adopted in at least one acre of area in the farmers field. The details of selected farmers who adopted the different modules is given in Table 1. The healthy seed material of varieties mainly Co 0238, Co 0118 and Co 05011 was provided to these farmers. The seed team of the Karnal centre, frequently visited the farmers field at regular intervals.

Table 1: Details of farmers who followed the ICAR-SBI RC, Karnal advised sugarcane farming modules

S. No	Farmers Name and Address	Module	Variety	Intercrop	Season of Planting; row to row and spacing
Haryana					
1	Jai Bhagwan, Mehamadpur, Karnal	Module I	Co 0118	-	Spring; 90 cm
2	Neeraj, Mehamadpur, Karnal	Module I	Co 0238	-	Spring; 90 cm
3	Himanshu, Lalupura, Karnal	Module I	Co 0118	-	Spring; 90 cm
4	Puran Chand, Dhakwala Gujran, Karnal	Module I	Co 0118	-	Spring; 90 cm
5	Sompal, Dhakwala Rodan, Karnal	Module I	Co 0118	-	Spring; 90 cm
6	Deepak Kadiyan, Beri, Jhajjar	Module I	Co 0238	-	Spring; 90 cm
7	Deepak Kadiyan, Beri, Jhajjar	Module I	Co 05011	-	Spring; 90 cm
8	Mahesh Wadhwa Kachhwa, Karnal	Module II	Co 0238	-	Spring; 120 cm
9	Shabir Ali Vill-Jadoli, Karnal	Module II	Co 0238	-	Spring; 120 cm
10	Jagbir Sandhu, Gagseena, Karnal	Module II	Co 0238	-	Spring;120 cm
11	Angrej Singh, Kharindwa, Kurukshetra	Module II	Co 0238	-	Spring; 120 cm
12	Vikas Panjeta, Kharkali, Kurukshetra	Module II	Co 0118	-	Spring;120 cm
13	Bhagat Singh, Kahangarh, Kurukshetra	Module II	Co 0238	-	Spring; 120 cm
14	S.C. Verma, Budhanpur, Karnal	Module III	Co 0118	Mustard	Autumn; 120 cm
15	S.C. Verma, Budhanpur, Karnal	Module III	Co 0238	Mustard	Autumn; 120 cm
16	Gian Ghai, Kachhwa, Karnal,	Module III	Co 0238	Vegetables	Autumn; 120 cm
17	Gurmukh Singh, Kahangarh, Kurukshetra	Module III	Co 0118	Potato	Autumn; 120 cm
18	Amrik Singh, Kahangarh, Kurukshetra	Module III	Co 0118	Mustard	Autumn; 120 cm
19	Bhagat Singh, Kahangarh, Kurukshetra	Module III	Co 12029	Chickpea	Autumn; 120 cm
20	Bhajan Singh, Kahangarh, Kurukshetra	Module III	Co 0118	Chickpea	Autumn; 120 cm
21	Vikas Panjeta, Kharkali, Kurukshetra	Module IV	Co 0238	-	Autumn; 120 cm
22	Pradeep Kumar, Seedhpur, Karnal	Module IV	Co 0238	-	Autumn; 135 cm
23	Tejpal Singh, Samana Bahu, Karnal	Module IV	Co 0238	-	Autumn; 135 cm
24	Balwant Singh, Rindal, Karnal	Module IV	Co 0238	-	Autumn; 120 cm
25	Rinku, Batan Khedi, Karnal	Module V	Co 0238	Garlic	Autumn; 120 cm
26	Tejpal, Barsalu, Karnal	Module V	Co 0238	Chickpea	Autumn; 150 cm
27	Inderjeet Singh, Kamalpur Rodan, Karnal	Module V	Co 0238	Chickpea	Autumn; 150 cm
28	Devendra Rana, Bal Pawana	Module V	Co 0238	Mustard	Autumn; 150 cm

29	Inam Khan, Jadoli, Karnal	Module V	Co 0238	Garlic	Autumn; 150 cm
Uttar Pradesh					
30	Dev Kumar Tyagi, Badkali, Muzaffarnagar	Module II	Co 05011	-	Spring; 120 cm
31	Sudhir Kumar, Bidvi, Saharanpur	Module III	Co 0238	Chickpea	Autumn; 120 cm
32	Arvind Malik, Badhai Kalan, Muzaffarnagar	Module III	Co 98014	Chickpea	Autumn; 135 cm
33	Arvind Malik, Badhai Kalan, Muzaffarnagar	Module III	Co 0118	Lentil	Autumn; 135 cm
34	Arvind Malik, Badhai Kalan, Muzaffarnagar	Module III	Co 0238	Green Pea	Autumn; 135 cm
35	Arvind Malik, Badhai Kalan, Muzaffarnagar	Module III	Co 05011	*Kabuli* Chickpea	Autumn; 135 cm
36	Basid Khan, Taprana, Shamli,	Module IV	Co 0238	-	Autumn; 150 cm
37	Omkar Tyagi, Badkali, Muzaffarnagar	Module IV	Co 0238	-	Autumn; 150 cm
38	Akashdeep, Kutubpur, Muzaffarnagar	Module IV	Co 0238	-	Autumn; 120 cm
39	Umesh Kumar, Titavi, Muzaffarnagar	Module V	Co 0238	Papaya	Autumn; (75:300:75) cm
40	Basid Khan, Taprana, Shamli,	Module V	Co 0238	Vegetables	Autumn; 150 cm
41	Mahipal Singh, Titavi, Muzaffarnagar	Module V	Co 0238	Chickpea	Autumn; 150 cm

Estimation of expenditure and income: Since the selected farmers belongs to Haryana and Uttar Pradesh state, the average cane yield of these states *viz.*, 84.5 t/ha (Haryana) and 79.2 t/ha (UP) registered during crop season 2017-18 (Cooperative Sugar Feb 2019) was considered in calculating expenditure and income at SAP cane price ₹ 3400/tonne (Haryana) and ₹ 3250/tonne (UP). The cost of cultivation for UP was ₹ 270 per quintal (CACP estimate ₹ 243 (C2) + transport and insurance cost (₹ 27/quintal) and for Haryana was ₹ 291/- (C2 cost, Additional Cane Commissioner, Haryana). While calculating the average expenditure for the farmers, who adopted seed production modules (I, II & III), the estimated labour cost involved in harvesting and transportation charges @ ₹ 580/tonne for Haryana and @ ₹ 500/tonne for UP calculated at state average productivity (84.5 tonne/ha ₹ 49010 for Haryana and 79.26 tonne/ha for UP, ₹ 39630), was deducted from the final expected expenditure of the states. The farmers who adopted wider row planting method utilized only 45 quintals of seed compared to 80 quintals under conventional method, hence for Haryana (@ ₹ 330) and UP (@ 325), there was saving of ₹ 11550 and ₹ 11375, respectively for seed in the cost of cultivation under wider row planting. Intercrops *viz.*, chickpea (seven farmers), Mustard (four farmers), multiple vegetables (two farmers), garlic (two farmers) potato, pea, lentil, Kabuli chana and papaya were cultivated by one farmer each. The expenditure incurred for cultivation of intercrops was also added up in the head expenditure under different modules. The gross income was calculated from sugarcane (cane yield x SAP rate), intercrops and added up figures are shown in the Tables. By deducting the expenditure from the gross income net income was calculated.

Impact analysis

Impact on cane yield: In module I, cane yield increased by 26.9 t/ha (31.87%) over the state average of 84.5 t/ha. The average yield of the module II, was 140.4 t/ha (66.1% and 77.08% higher over the average yield of Haryana and U.P., respectively). Module III *i.e.* sugarcane seed crop at wider row spacing along with suitable intercrop depicted average cane yield of 132.1 t/ha, which was 66.65% and 56.31% higher over average cane yield of UP and Haryana respectively. In Module IV, the average cane yield was 147.9 t/ha (75% and 86.5% higher over average cane yield of Haryana and U.P. States, respectively). In module V, there was 65.11% and 76.03% improvement in average cane yield over the states average cane yield of Haryana and U.P., respectively.

The crop yield also differ due to planting season. Module I and II represents spring planted crop where average yield was 111.4 t/ha and 140.4 t/ha, respectively. The spring planted sugarcane as seed crop under wider row spacing (module II) had 26.03% higher yield compare to sugarcane planting at conventional spacing. The least improvement (1.32 times) was observed in module I *i.e.* producing sugarcane as sole seed crop under conventional spacing, since tops and trash contributing nearly 12.5% weight are not removed from seed crop hence benefited the farmers in terms of higher cane yield.

Impact on the cost of cultivation (CoC): The cost of cultivation of sugarcane under conventional method of planting at 84.5 t/ha and 79.26 t/ha average cane yield for UP and Haryana was ₹ 2,45,895 and ₹ 2,14,002, respectively. The cost of cultivation of sugarcane under modules I, II, III, IV and V was ₹ 1,96,885, 1,82,134, 1,75,998, 2,67,908 and 2,65,267, respectively which was 24.89% (₹ 49,010), 32.51% (₹ 59,205) and 32.16% (₹ 56,608) lower in module I, II, III over conventional method state average). This is because the crop was sale as seed crop, hence farmers could save harvesting and transportation cost. The cost of cultivation under module II and III was lower compare to module I, because of lesser requirement of seed under wider row planting. Higher expenditure was incurred in module IV (15.36%; ₹ 35681) and V (13.39%; ₹ 31332) over the average conventional method, because of harvesting and transportation of additional yield produced under these modules. Since intercrops were also taken under module III and V, considering CoC of intercrops the average expenditure in module III and V was ₹ 2,31,614/- and ₹ 3,18,016/-, respectively.

Impact on farmers income: The net income under module I was ₹ 2,45,895, which was 4.39 times higher over state average (₹ 4,1405/-). Raising sugarcane seed crop under wider row spacing (module II) provided an average net income of ₹ 2,91,866, which was ₹ 2,50,149/- higher over the net average income from conventional practice (₹ 41,718/-). By adoption of this module the farmers could able to earn 6.99 times higher and ₹ 250149/- additional income. Module III, generated highest net income from sugarcane (₹ 2,65,022), it was 6.27 times higher over state average. In addition the cultivation of intercrops under this module also yielded ₹ 81,999/- profit to the farmers. Combining sugarcane and intercrop, farmers from this module could able to earn ₹ 3,47,021/- as net income, compare to state average it was 8.2 times higher. Among the intercrops multiple vegetables (cauliflower, cabbage, tomato, onion) gave highest net income of ₹ 1,37,500/- followed by potato (₹ 1,16,589/-). The farmers who cultivated multiple vegetables and potato as intercrop in sugarcane seed crop could able to increase their net income by 9.63 times and 9.11times higher respectively.

Module IV and V were adopted using variety Co 0238 alone as sole crop during autumn season under wider spacing (module IV) and with intercrops (module V). The net income under module IV was ₹ 2,25,271 (5.32 times higher over conventional practice of ₹ 42,343). The net profit from sugarcane crop was ₹ 2,01,430/- under module V. It was 4.77 fold higher over conventional practice of the region (₹ 42,226/-). Combining the profit from the intercrops (₹ 1,34,008/-) this module generated a profit of ₹ 3,35,438 (7.94 fold higher over conventional practice). The highest income of ₹ 4,58,038/- (10.51 fold higher) was generated from sugarcane (75 cm : 300 cm : 75 cm) + papaya intercrop (by Mr Umesh Kumar), followed by ₹ 4,34,035/- (by Mr Bashid Khan) where multiple vegetables *viz.*, potato, green chickpea, cauliflower, cabbage, garlic, radish, fenugreek, mustard, sugarbeet, turnip, tomato, bottle guard, bitter guard and cucumber were cultivated as relay intercrop in autumn planted sugarcane.

Comparative performance of the modules: Module IV (147.9 t/ha) was the best performer for cane yield (t/ha) followed by Modules II (140.4 t/ha), V (139.5 t/ha), III (132.1 t/ha) and I (114.4 t/ha). In terms of percent improvement over average cane yield of Haryana and Uttar Pradesh, Module IV (75.03% higher over Haryana and 86.60% higher over Uttar Pradesh) and module II (66.15% higher over Haryana and 77.14% higher over Uttar Pradesh) were the top performer.

In terms of per cent increase in net income over states average of Haryana and Uttar Pradesh, module III, generated 738.1% and 695.05% higher net income over states average of Haryana and Uttar Pradesh, respectively. The next best modules were V (710.14% and 669.48% higher over Haryana and UP average), II (604.91% and 569.52% higher over Haryana and UP), IV (444.07% and 416.76% higher over Haryana and UP) and I (339.49% and 317.43% higher net income over Haryana and UP). Form the adoption of modules I, II, III, IV and V, the net income was 4.39, 7.05, 8.38, 5.44 & 8.10 times higher over state average of Haryana and 4.17, 6.70, 7.96, 5.17 & 7.69 times higher over state average of Uttar Pradesh, respectively.

The benefit cost (BC ratio) ratio, an indication of return per unit investment of money was 1.17 and 1.20 for the states average of Haryana and Uttar Pradesh for sugarcane cultivation. It indicates that per ₹ investment for cane cultivation gave ₹ 0.17 return in Haryana and ₹ 0.20 in Uttar Pradesh. The BC ratio of modules I, II, III, IV and V was 1.92, 2.6, 2.49, 1.84 and 2.05, respectively, indicates that the seed production modules II (1.6 or 160%), III (1.49 or 149%) and I (0.92 or 92%) gave higher net return per unit investment of money. Similarly modules V (1.05 or 105%) and IV (0.84 or 84%) also gave good return. Compared to Haryana state average, the BC ratio was 64.69%, 122.74%, 113.53% , 57.56% and 75.87% the highest under modules I, II, III, IV and V, respectively. Similarly, it was 59.86%, 116.21%, 107.27%, 52.93% and 70.71% higher under these modules over the BC ratio of UP state average.

Impact of sugarcane variety: The impact of varieties is studied for Co 0118 and Co 0238 only as these two varieties were cultivated by 10 and 26 farmers, respectively. The average yield of Co 0118 was 124.3 t/ha and it was adopted in seed production modules I (112.5 t/ha), II (135.0 t/ha) and III (125.5 t/ha). Whereas variety Co 0238 produced an average yield of 136.03 t/ha and was adopted in all the five modules (I, 115 t/ha; II, 139.5 t/ha; III, 138.25 t/ha; IV,147.9 and V, 139.5). So compared to Co 0118, variety Co 0238 produced 11.73 tons (9.44%) higher cane yield which in monetary terms is ₹ 39,882 for Haryana and ₹ 38,123 for Uttar Pradesh.

Impact on the quality seed production of the centre: The programme achieved grand success as the healthy seed production increased by 6.8 times (during 2017-18, compare to 2007-08). Since beginning of the project in 2007-08 to 2018-19, a total of 58,147.8 quintals of quality seed was produced and from sale of the seed a revenue worth ₹ 1,00,33,642/- was generated. The major improvement in seed production started from year 2013-14, and the highest progress was achieved during 2017-18 (11,962.4 quintals) and 2018-19 (16,924.3 quintals) after starting FPSP (Farmers participatory seed programme).

Table 2. Year-wise sale of Breeder seed and revenue generation at ICAR-SBI RC, Karnal

Year	Total (quintals)	Revenue earned (₹)
2007-08	2487.3	3,43,251/-
2008-09	2429.3	3,73,278/-
2009-10	2959.6	5,94,067/-
2010-11	2719.8	6,04,355/-
2011-12	2181.0	5,08,723/-
2012-13	2217.1	5,02,015/-
2013-14	3014.3	9,07,314/-
2014-15	3507.5	10,76,077/-
2015-16	4246.1	13,16,285/-
2016-17	3766.2	11,92,958/-
2017-18	11965.4	10,53,400/-
2018-19	16924.3	15,61,919/-
Total	58417.8	1,00,33,642/-

This initiative helped the Institute in faster replacement of unhealthy seed material with tissue culture generated disease free seed material.

Conclusion: The response of sugarcane under wider row spacing in big plots at farmers field is very impressive as it reflected in increased cane yield from 31.83% to 86.6% over conventional sugarcane cultivation (75 cm row to row) of Sub-tropical India. The net income of the farmers increased 3.46 to 10.51 times with an average of 6.6 times higher over the average net income from sugarcane cultivation of the region. Cultivating sugarcane as seed crop for sale under wider row spacing during autumn season with suitable intercrop, gave highest net income of ₹ 3,47,021/- (738.11% and 696.05% higher over Haryana and UP state average). The autumn season of planting under wider row spacing gave 18.51% higher harvestable biomass (seed crop yield) yield compared to spring season of planting under wider spacing. Sugarcane variety Co 0238 produced higher cane yield (9.44% higher) over Co 0118. Adoption of any of the sustainable crop production modules preferably with suitable intercrops, in larger scale will be very useful in increasing per unit profitability, intermittent income from intercrops and achieving the great goal of Government of India towards doubling farmers income.

Fig 1. Performance of different modules for Cane yield (t/ha)

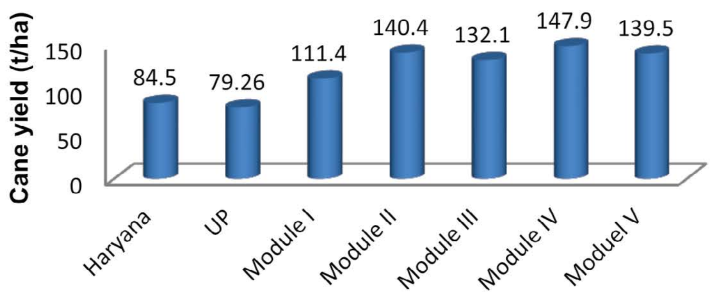


Fig 2. Cost of cultivation under different modules

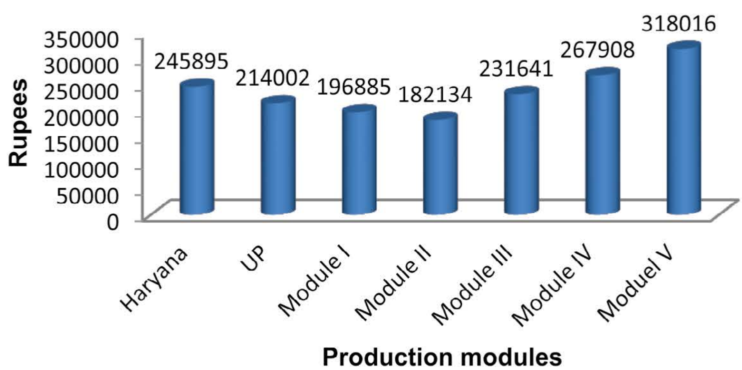


Fig 3. Gross income under different modules

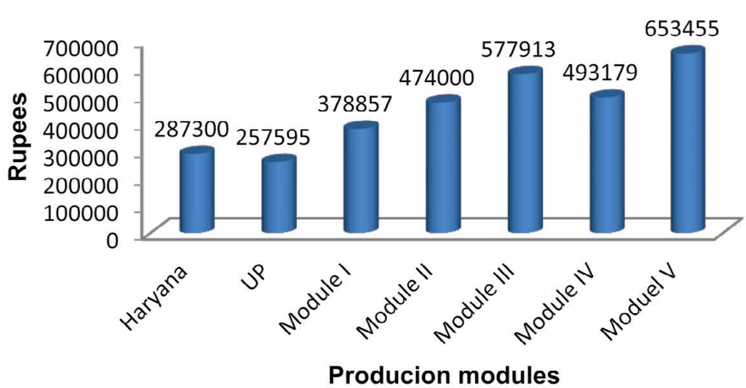


Fig 4. Net income under different modules

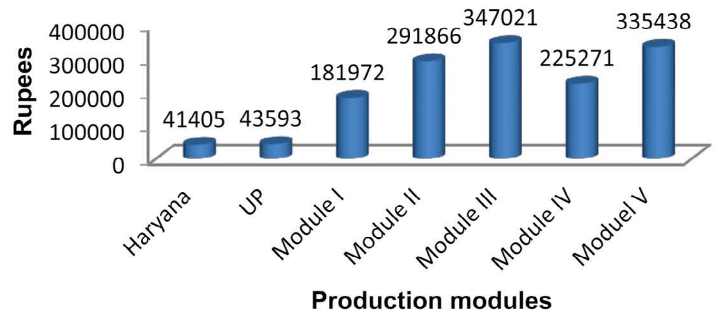


Fig 5. Percent change over state average yield

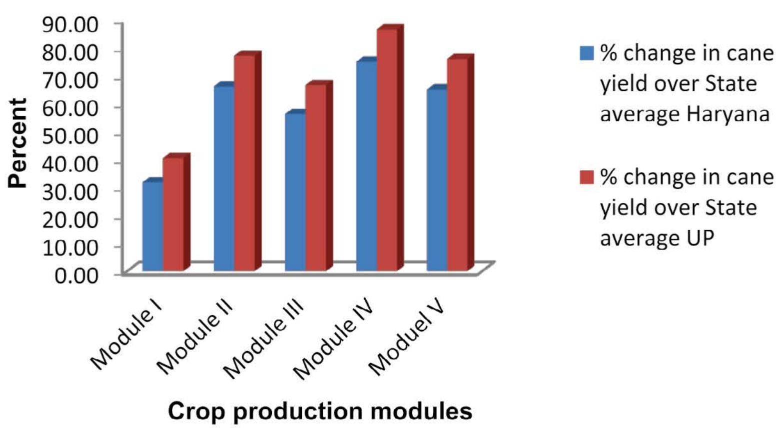
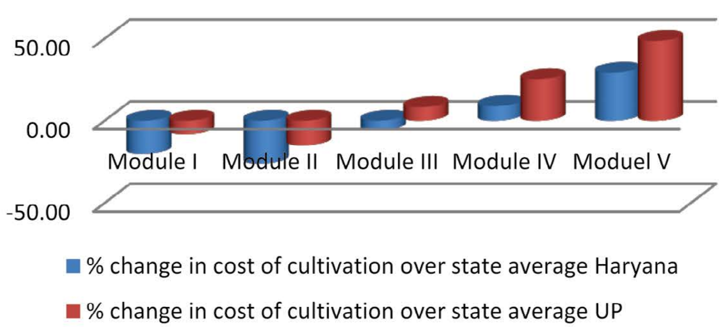


Fig 6. Percent change over state average cost of cultivation



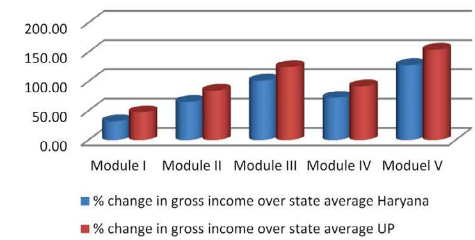


Fig 7. Percent change in gross income over state average

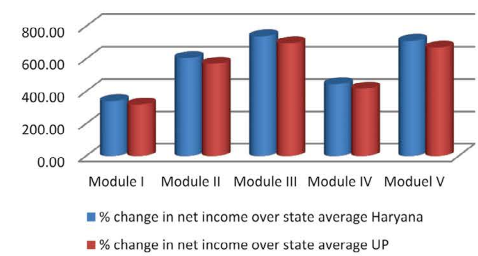


Fig 8. Percent change in net income over state average

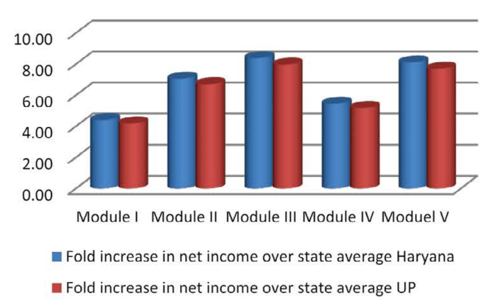


Fig 9. Fold increse in net income over state average

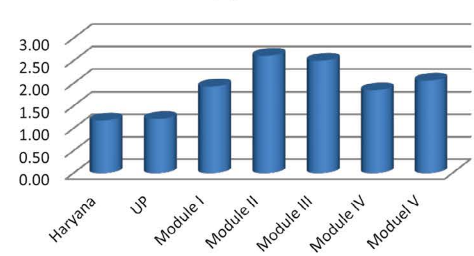


Fig 10. Benefit cost ratio of different modules of crop production

Feasibility of bioethanol production in integrated sugar-energy complexes in India: An economic analysis

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ABSTRACT

Sustainable sugarcane development and its diversified processing are vital for raising farmers' income and welfare in an agrarian economy. An attempt has been made in this study to link farm and non-farm enterprises and explore possibilities of doubling sugarcane farmers' income. The present study is based on data collected from 22 integrated sugar-energy complexes having ethanol distillery through personal interview with the help of pre-tested survey schedule especially designed for the purpose. The information was collected for three production seasons 2016-17, 2017-18 and 2018-19. The standlone sugar mills have to modernized through their conversion into an integrated sugar-energy complexes by product diversification processing units such as distilleries, co-generation, bio-CNG units, Bio-fertilizer units and food processing units. The findings revealed that the B-heavy molasses could be utilized for bio-ethanol production with minimum changes in the existing distillery. The utilization of B-heavy molasses improved capacity utilization, efficiency and ethanol supply for EBP programme. The comparative economics of bioethanol production from B-heavy molasses and final C-molasses revealed that bioethanol production through B-heavy molasses gave per unit net income of ₹ 13.62 to the distillery as compared to ₹ 11.22 per litre by final C-molasses route. The results concluded that there was substantial reduction (20-25%) in steam consumption for distillery operation and nearly 25% reduction in amount of spent wash generation which helps in effective implementation of pollution control measures of CPCB and NGT. The bioethanol is a cost effective fuel as it is 20-25 % cheaper than petrol. There would be savings to public exchequer in the form of reduction in crude oil import bill and the Government may reduce subsidies on petroleum products. The productivity gain and cost reduction would be key facts to enhance farmers' income by year 2022. The study concluded that the Government should take policy decision to address sugar mills and farmers' problem to enhance per unit profitability to realize goals of farmers' income and welfare by adoption of technologies, entrepreneurship development and diversifying production, processing and allied activities in villages.

Key words: Surplus sugar production, bio-ethanol, B-heavy molasses, Ethanol blending policy, bio-ethanol price incentives

Introduction

As an agro-industrial cash crop, sugarcane has enormous potential for fulfilling the future demand of sweeteners and green energy for food-fuel security. The cost of sugar production in integrated sugar–energy complexes has upward trends overtime and net revenue from sugar because of demand and supply mismatch has not enhanced significantly and economic benefits accrued by sugar mills through sale of sugar and by-products have not been shared with major stakeholder-farming community. India has mammoth demand of bio-ethanol, CNG, and bio-fertilizers for harmonizing non-renewable fossil fuel, carbon credit build-up and power cogeneration for green energy production. Sugarcane farming has revolutionized income and employment opportunities to nearly 7.5 million farmers, 1.25 million skilled workers employed in sugar mills, jaggery units and ancillary industries. The annual contribution of sugarcane and sugar sector in Gross Value of Agriculture (GVA) was ₹ 1.00-1.10 lakh crore, out of which nearly ₹ 80,000- 85000 crore paid to cane farmers for raw material supply to mills. Everyone knows that India produced 32.5 and 33.0 million tonnes (MT) sugar against the domestic annual consumption demand of nearly 25-25.5 MT which led to huge sugar stock inventory and cane price arrears during sugar season 2017-18 and 2018-19, respectively. India has sugar stock to maintain supply and price stability. This sector also contributes ₹ 4,700 crore to the Central Govt., besides providing ₹ 3400 crore to States Governments in the form of various taxes such as cane development society's commission and GST on sugar, ethanol and co-products. Indian sugar sector is passing through critical phase of economic hardship due to excess sugar production which led to low sugar prices in domestic as well as International market.

The bio-ethanol blended with petrol which is produced from sugarcane, sugar beet, sweet sorghum and other based feedstock's have tremendous future potential, which could help in petroleum import substitute and foreign exchange saving by way of its blending with petrol to the extent of 20 per cent in the existing petrol operated vehicle engine technologies. To assist the sugar industry, the Govt. of India has enhanced bio-ethanol procurement prices to be paid by the Oil marketing companies (OMC) to the sugar mill. The Govt. of India has also provided soft loan of ₹ 4,400 crore to sugar mills for creation of new or upgradation of existing ethanol distillery and also promised to bear a bank interest subvention of ₹ 1,332 crore during sugar season 2018-19.

Sugarcane as bio-energy crop should be promoted for bio-ethanol and power co-generation as excess sugar production creates demand–supply mismatch and market disequilibrium. To promote bio-energy sustainability, the Govt. has focused its thrust on biofuels. The new National Biofuel Policy envisages an integrated approach for biofuels production from various types of crop residue and agricultural waste. It will help farmers to become *Urjadata from Anndata* (P.M. Inaugural Speech, *Krishi Kumbh* 2018). A key initiative has been undertaken to produce compressed biogas from biomass waste in integrated sugar-energy complexes and also made a target to set-up new compressed biogas plants in different parts of India. The OMCs have offered assured price and off take guarantee to procure compressed biogas. The Govt. of India also aims to achieve 10% bio-ethanol blending in petrol by the year 2022 to minimize dependency on petroleum energy import and to promote exploitation of environment-friendly fuel and boost sugarcane agriculture and sugar mills sector. The market driven pricing of petroleum products reflects the changes in line with the international crude oil price. The Indian fuel standards are the best and also comparable to the world and India BS-VI complaint fuel should be supplied all over India from April 2020. The green bio-energy production from integrated sugar processing complexes has enormous potential not only for long-term sustainability of sugar mills but also to produce green energy and check environmental pollution through carbon sequestration and carbon credit. The Govt. of India permitted diversion of B-heavy molasses and utilization of sugarcane juice for enhancing the production of bioethanol and reduce sugar production to maintain sugar market price. The utilization of B-heavy molasses over C-molasses for bioethanol production could be preferred as it could be implemented in a traditional sugar mill having distillery with minimum modification in the installed setup.

Besides it, the Govt. of India has also prioritized its goals to double farmers' income by the year 2022, on occasion of 75th year of Indian Independence to address farmer's welfare and bring parity amongst farmers' income and non-farm workers. To achieve these goals, there is need to adopt 'multi-dimensional strategies such as more crops per drop of water, quality seeds and nutrients as per soil health, investments in and cold chains to minimize post-harvest losses, promote value addition in food processing, implementation of National Agricultural Markets and e-platforms (e-NAM) to eliminate limitations of APMC, mitigate risk through PMFBY crop insurance scheme at lower premium, promote allied activities such as dairying, poultry, bee-keeping, horticulture and fisheries *etc*. To double farmers' real income by the year 2022 on base year 2015-16, it should have 10.41 per cent growth rate in annual agricultural income as compared to current growth rate in farm income 2.1-4.0 per cent during past decades. Therefore, it is essential to revisit policy, development plan strategy for farmers' welfare in the long run. There is a need to adopt an integrated approach to integrate sources of farm and non-farm income growth. Keeping in view, significance of farm and non-farm activities in improving the farmers' income, objectives of the present paper are (i.) to work-out economics of bio-ethanol production from B-heavy and final molasses in sugar-energy production complexes in India (ii) to identify resource constraints and challenges faced by the sugar mills and suggest strategies for improving their economic viability and farmers' income.

Methodology

The study was conducted in two major sugarcane producing states namely Uttar Pradesh and Maharashtra, which accounts for 75-80 per cent contribution in sugarcane and sugar production in India. The primary data on various techno-economic parameters, cane supply to sugar mills, resources constraints *etc*., was collected from 10 sugar mills in Maharashtra and 12 sugar complexes in Uttar Pradesh to draw an aggregate sample of 22 integrated sugar-energy complexes having ethanol distillery units through personal interview with the help of pre-tested survey schedule especially designed for the purpose. The information was collected for three production seasons *viz*., 2016-17, 2017-18 and 2018-19. The net income, profit and economic viability of sugar mills were estimated by using standard statistical methods. The simple tabular analysis and appropriate statistical tools was used to assess the economics of bioethanol production by utilizing different raw material and resource saving in diversion of B-heavy molasses and sugarcane juice for ethanol production in integrated distillery with sugar mills.

Results and Discussion

Comparative economics of bio-ethanol production from B-heavy and C-molasses

Indian economy is developing rapidly facing threats and challenges of ever increasing automobile sector energy demand primarily fulfilled by imported petroleum fossil fuels. The domestic crude oil production is insufficient to cope up with demand which leads to enormous demand and supply disequilibrium. To maintain supply and price stability, its demand supplemented with imports of crude oil at the cost of foreign exchange draining out. The bio-energy production from sugarcane has significance for sustainability of Indian sugar sector in the long run. The energy demand for transport and automobile sector has growing continuously. It is basically met by imported crude oil which leads to huge drain of foreign exchange from India for import bill payment of petroleum products. As per new Ethanol Blending Programme (EBP) Policy 2018, bio-ethanol may partially supplement fossil fuels as the Government has fixed 10 and 20 per cent bio-ethanol blending targets with petrol by year 2020 and 2030, respectively. In order to balance sugar demand–supply equilibrium and enhance the bio-ethanol production, the Government of India announced differential price policy for bio-ethanol production from different routes such as conventional (C-molasses), B-heavy losses and directly from sugarcane juice. The surplus sugar production during past seasons has depressed domestic sugar price. Therefore, sugar mills have lost their profitability which led to accumulation of huge cane price arrears due to poor paying capacity to the farmers. To reduce sugar production, the Govt. of India has taken policy decisions and permitted diversion of B-heavy molasses and sugarcane juice directly for ethanol production during season 2018-19. The utilization of B-heavy molasses for bioethanol production leads to reduction in steam consumption and power saving to sugar mills. Due to switching over from 3 Massecuite to 2 Massecuite boiling lead to sugar colour improvement and savings in expenses towards manpower wages, repair and maintenance to the sugar mills. The B-heavy molasses have 25-30 per cent higher ethanol recovery because of high concentration of fermentable sugar. It leads to higher fermentation, distillation efficiency; reduce steam consumption for distillation and reduction in effluent spent wash generation during distillery processing.

The bioethanol production from final C- molasses, a by-product of sugar industry is commonly practiced in our country by fermentation of diluted molasses followed by distillation. The bio-ethanol recovery depends on total reducing sugar content of molasses and varies from 225-240 litres per tonne molasses utilized. The cost of bioethanol processing in distillery depends on molasses market price. Due to limited availability of C-molasses *vis.-a-vis.*, requirement of bio-ethanol to achieve 10% EBP targets, it is not possible to enhance ethanol supply without harnessing the potential of other feed stocks shown in Table 1.

Table 1. Possible alternative raw material for bio-ethanol production in India

Particulars	Conversion of organic molecule in bio-ethanol	Sources of available raw material
1st Generation raw material	Sugar (glucose, fructose, sucrose)	Final C-molasses and B-Heavy molasses
		Sugarcane juice and Sugar beet juice
		Sweet sorghum (stalks) juice
	Starch	Food grains (corn, sorghum, rice, wheat, millets, barley *etc*.)
		Cassava, sweet potato, potato *etc*
2nd Generation raw material	Cellulose and h emicelluloses	Lignocellulosic biomass (bagasse, sugarcane trash, corn cobs, rice straw *etc*.)
	Complex mixed organic materials	Pet coke and Municipal solid waste

To achieve EBP targets, Government has adopted variable price policy for improving supply of bio-ethanol with the higher prices for bio-ethanol produced from B–heavy molasses and directly from sugarcane juice. The integrated sugar mills having distillery could take into account comparative economics of bioethanol production and sugar. Besides its, diversion of B-heavy molasses and adoption of flexi policy for sugar and ethanol production by the sugar mills may boost ethanol supply for 10 per cent EBP and also maintain sugar demand- supply scenario for stabilizing domestic market prices.

The National Biofuels Policy 2018 permitted bio-ethanol production from different raw materials, such as cane juice, corn, and damaged and surplus food grains. The Government has fixed remunerative prices for ethanol made directly from cane juice, B-heavy molasses, final C-molasses and damaged grains under EBP Programme. The Oil Marketing Companies have invited bids for demand of nearly 511 crores litres. Therefore, it is recommended that the sugar-energy complexes should take advantage of opportunity and modernized exiting or set up new bio-ethanol production distilleries. It will provide them flexibility to control surplus sugar production and divert the same towards bioethanol production. The Indian sugar mill need not worry too much for fluctuating cane production, sugar prices or inventory build-up of unsold sugar. However, sugar mills have to improve themselves to meet the standards of the CPCB and the NGT. Despite the Government incentives and policy support to improve bio-ethanol production, many mills had apprehension and doubts about the huge investment needed for upgrading the existing distillery units or set up new distillery facilities.

The bio-ethanol production directly from sugarcane juice/ mixed juice in India was initiated at M/s Suguali and Lauria Sugar Units of HPCL in Bihar. It was not succeeded due to technical and economic reasons. With the remunerative ethanol prices made directly from cane juice, the matter again came into limelight and integrated sugar complexes working on comparative economics and capital investment needed for making suitable changes in the existing system. The sugar mills persons reported the issue of 100% diversion of cane juice for ethanol should be considered after proper thinking and past history of sugarcane production cyclic ups and down in different states due to various reasons. The comparative economics of bioethanol production from B-heavy molasses and final C-molasses considering various techno-economic parameters was worked out and presented in Table 2. It revealed that the bioethanol production through B-heavy molasses gave per unit net income of ₹ 13.62 to the distillery as compared to ₹ 11.22 per litre by conventional final C-molasses route. Hence, under the present level of stock, surplus supply, low prices, sugarcane and sugar production; economics of bioethanol production during past 3-4 sugar seasons, diversion of B–heavy molasses for ethanol production could be a viable option for enhancing economic feasibility of sugar sector. It requires minimum changes in existing sugar mill or distillery processing structure. The economic analysis reveals that under the present bioethanol pricing pattern, it appears encouraging for diversion of B-heavy molasses for ethanol production. The study concludes that the sugar mills should understand the importance of bioethanol production to fulfill the 10% EBP targets as equilibrium in sugar demand-supply would ensure better and stable domestic price and maintain sustainability of Indian sugar sector in the long run.

Table 2. Economics of ethanol production from B-Heavy and C molasses during 2018-19

Particulars/ Economic parameters	Final C-molasses	B-heavy molasses
Sugarcane crushing capacity (In TCD)	5000	5000
Sugar recovery (%)	12	10.5
Molasses production (in % cane crushed)	4.5	6.5
Sugar production(tonne/day)	600	525
Molasses production (tonne/day)	225	325
Sugar price (₹/tonne)	31000	31000
Molasses price (₹/tonne)	5000	10000
Ethanol price (₹/litre)	43.46	52.43
Sugar production losses (tonne)	0	75
Sugar revenue losses (In ₹ Lakh)	0	23.25
Cost of C molasses (In ₹ Lakh)	11.25	11.25
B-heavy molasses price (In ₹ Lakh)	0	32.5
Bio-ethanol recovery (litre/tonne)	230	375
Bio-ethanol production(litre/day)	51750	121875
Revenue from bio-ethanol((In ₹ Lakh/ day)	22.49	63.90
Raw material cost (₹ /litre)	21.74	28.31
Conversion cost (₹ /litre)	10.50	10.50
Cost of bio-ethanol production (₹ /litre)	32.24	38.81
Net profit to distillery unit (₹ /litre)	11.22	13.62

The bioethanol procurement price during past 6-7 years was compiled from various sources and presented in Table 3. Keeping in view, surplus sugar production, low sugar prices, huge cane price arrears and revenue losses to the sugar mills forced the Govt. to hike bio-ethanol price and adopt variable prices for bioethanol produced from different feed stocks.

Table 3. Procurement price of bioethanol produced from various raw materials

(Bio-ethanol price in ₹ /litre)

Particular/ year Raw material	Old Price 2012-13	2016-17	2017-18	2018-19	2019-20
Sugarcane juice	-	-	47.49	59.19	59.48
B-heavy molasses	-	-	47.49	52.43	54.27
Final C-molasses	27.0	39.0	43.26	43.46	43.75

During sugar season 2018-19, the Government declared premium of ₹ 52.43 and ₹ 59.13 per litre as bio-ethanol price produced from B-heavy molasses and directly from cane juice, respectively as compared to existing ethanol price of ₹ 43.46 per litre produced through conventional final molasses route. Besides these incentives, applicable GST and transportation charges would be paid by the OMCs. The OMCs have been instructed to give priority for procurement of bio-ethanol produced from sugarcane juice, B heavy molasses as compared to conventional C molasses.

The diversion of B-heavy molasses and its utilization for bio-ethanol production may reduce the sugar production up to 15-20% and increase bio-ethanol production by 125-200% as indicated in Table 4. The major constraints in adoption of flexi sugar-bio-ethanol production plan are need of huge initial investment on modernization of distillery and storage capacity. The sugar mills are in dilemma that the existing policy will sustain in long run. If sugar-energy complex of 5,000 TCD willing to adopt complete flexi plan of diversion of whole sugarcane for ethanol production, it requires a modern distillery 350-400 KLPD capacity along with storage facility as reported in Table 4. It needs additional financial outlay of approximately ₹ 500-650 crore.

Table 4. Comparative analysis of sugar production loss and bio-ethanol production gain

Particulars	Sugar recovery (%)	Sugar production decrease (%)	Bio-ethanol production gain	Constraints and added economic advantages
Conventional route	11.6-12.4	-	-	Sugar mills having distillery needs no new investment
B-heavy molasses	10.1-11.0	15-20	1.25 to 2.0 time increase in bio-ethanol	Huge investment to enhance BH storage and distillery capacity
Partial sugarcane juice	6.0-8.0	35-55	3.1 to 3.4 time increase in bio-ethanol	Need additional investment to enhance storage and distillery capacity
Total sugarcane juice	0	0	6.9 to7.5 time increase	Require 350-400 KLPD distillery with 5000 TCD sugar mills

The diversion of B-heavy molasses for ethanol production would reduce steam consumption in sugar led to bagasse saving, improvement in sugar colour, size and enhance power export from cogeneration unit. The sugar mills would also have some saving in poly packing/gunny bags due to less sugar production. It would reduce interest burden on sugar stock, transport cost and minimize per litre effluent treatment cost to the integrated sugar-energy complex. The Bio-fuel Policy 2018 fixed target to achieve 20 per cent ethanol blending with petrol by year 2030. Besides it, the Government has targeted to achieve initial milestone of 10 per cent of ethanol blending with petrol by year 2022. The average ethanol blending with petrol during 2018-19 would be more than 7 per cent in 10 States in major states of India. It is expected that out of total ethanol supply of 750 crore litres, 210 crore litres would be from B-heavy molasses/sugarcane juice. The Government has decided to provide interest subvention on loans for new and expanded ethanol production capacities to increase bio-ethanol production capacity. The Government has approved nearly 260 bio-ethanol projects for subsidised loans. The sugar mills will have to tie up with banks for their implementation. The Central Pollution Control Board (CPCB) and National Green Tribunal (NGT) have issued the guideline to all integrated sugar energy complexes having distilleries. They should comply with 'zero discharge' norms, as some mills have been either fined or ordered for closure. The ethanol requirement for India would be 330 crore litres for achieving 10 per cent blending with petrol during the year 2019-20, against which sugar mills contracted for 245 crore litres supply, supplied nearly 175 crore litres during the year 2018-19, which was sufficient to achieve average 5.5 per cent blending at country as a whole.

Policy support for strengthening Indian sugar sector

The swelling sugarcane price arrears are the major concern as accumulated dues have crossed ₹ 17,500 crore on sugar mills for the season 2018-19. Sugar production in two major states Uttar Pradesh and Maharashtra have achieved new record of 22.5 million tonne sugar production. The sugar production in India has gone up to 33 MT during sugar season 2018-19. Hence, Indian sugar sector have to face economic hardship due to low sugar prices and might led to glut in domestic and international market.

- The Govt. of India has encouraged sugar export through reduction in export tax. The sugar export yet to improve as prices in global market is low. To improve economic viability of Indian sugar sector, the Govt. of India decreased GST on ethanol from 18% to 5% and declared higher premium price to encourage diversion B heavy molasses and partial sugarcane juice for ethanol production.
- The Uttar Pradesh Power Corporation Limited (UPPCL) and UP Electricity Regulatory Commission (UPERC) have proposed to reduce power tariffs by 35% in the next five years for bagasse-based co-gen power supplied by sugar mills. The prevailing electricity tariffs of ₹ 6.19 to ₹ 6.75 per unit for the purchase of cogenerated power reduced by ₹ 2.00 to 2.25 per unit, beleaguered sugar mills to face economic revenue loss of nearly ₹ 500 crore as annual power supply bill by sugar mills to UPPCL was approximately ₹ 1,500 crore. The new tariffs would be determined for captive and non-conventional energy generating plants (CRE) regulation, applicable on co-generation of power from bagasse, biomass, solar plants *etc*.
- The Government has made obligatory Minimum Indicative Export Quota (MIEQ) for sugar export promotion. The sugar millers demands more economic incentives to make sugar exports viable with prevailing international sugar prices, bumper sugar production and demand-supply disequilibrium led to market glut. The Government has permitted 2.5 m t raw sugar and 3.5 m t refined sugar export under MIEQ scheme for the sugar season 2018-19 to clear surplus stocks and improve cash flow to mill for cane price arrears payment. These policy measures may reverse domestic market sugar price trend.
- The Cabinet Committee on Economic Affairs (CCEA) has approved higher prices for bioethanol derived from different raw materials under the EBP Programme for the sugar season 2019-20. Besides it, GST and transportation charges will be paid by OMCs. They are advised to fix realistic transportation charges for long distance bio-ethanol transportation. The OMCs should give priority for bio-ethanol produced from sugarcane juice/sugar/sugar syrup followed by B heavy molasses and C molasses.

Conclusion, policy options and action plan

The standlone sugar mills have to modernized through their conversion into an integrated sugar-energy complexes by product diversification processing units such as distilleries, co-generation, bio-CNG units, bio-fertilizer units and food processing units. The findings revealed that the B-heavy molasses could be utilized for bio-ethanol production with minimum changes in the existing distillery. The utilization of B-heavy molasses improves capacity utilization, efficiency and ethanol supply for EBP programme. There is substantial reduction (20-25%) in steam consumption for distillery operation and nearly 25% reduction in amount of spent wash generation which helps in effective implementation of pollution control measures of CBCB and NGT. The bioethanol is a cost effective fuel as it is 20-25 % cheaper than petrol. There would be savings to public exchequer in the form of reduction in crude oil import bill and the Government may reduce subsidies on petroleum products.

The economic disparity has widened the gaps over time. The disparity between farmers' and non-farm worker income was the key reason for agrarian distress. The non payment of cane prices and accumulation of cane price arrears had negative effect on farm investments and forced number of sugarcane farmers to shift farming to other remunerative high value crops especially in sub-tropical region. The net income earned by the farmers may be crucial to address agrarian distress. This is a welcome step for achieving goals set for doubling farmers' income by the year 2022, and reduces economic disparity amongst farmers and non-farm income groups. There is a need to suggest strategies to be followed to achieve higher growth rate and recommend institutional mechanism for its implementation. In short run, strategies for increasing productivity and profitability would be revival of three tier seed cane multiplication programme, quality seed supply for varietal planning and replacement of rejected cane varieties. Farmers' income could be enhance through better ratoon management, reduce cost through mechanization, INM, drip irrigation, intercropping and eco-friendly bio-IPM strategies *etc*. There should by long term cane reserve area allotment policy for sugar mills for sugarcane development. There is a need to remove cane supply indent (*Purchi*) system in Uttar Pradesh for adoption of mechanical sugarcane harvester in large area. It concludes that the State Government should take policy decision to address sugar mills and farmers' problem to enhance per unit resource use efficiency and profitability for realizing goals of higher farmers' income and sugar sector self sustaining growth in future.

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Sugarcane: Current status and developmental programmes in India

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Sugarcane (*Saccharum* spp.) is an important industrial crop accounts for about 7% of the total agriculture output of the country grown in tropical and sub tropical regions of the country. It provides raw material for the second largest agro-based industry after textile. India is the second largest producer of sugarcane after Brazil. 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. About 0.5 million people in sugar mills and 8 million sugarcane farmers, their dependents and a large mass of agricultural labour are involved in sugarcane cultivation, harvesting and ancillary activities, constituting 7.5% of the rural population.

1. Global Scenario

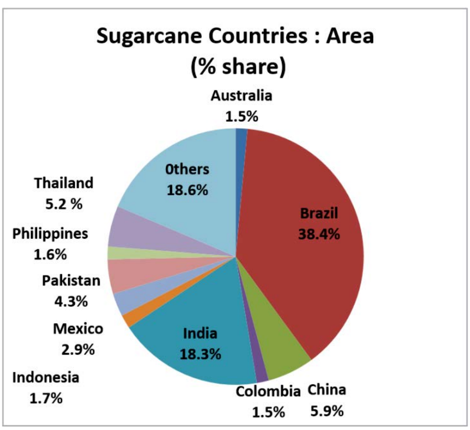
Sugarcane is grown in more than 115 countries with an area of 26.60 million ha with a total cane production of 1871.85 million tonnes and productivity of 70 tonnes/ ha. (FAO, 2017). Brazil, India, China, Thailand, Mexico, Pakistan and Australia are the major white sugar producing countries. Brazil is the largest sugarcane growing country followed by India and China. These three countries contributed about 63% area and 65% production of sugarcane in the world. As regard to the productivity is concerned, the highest average productivity was recorded in Colombia (98 tonnes/ha) followed by Australia with 81 tonnes per ha. The area, production and yield during 2013-2017 of ten major countries are:

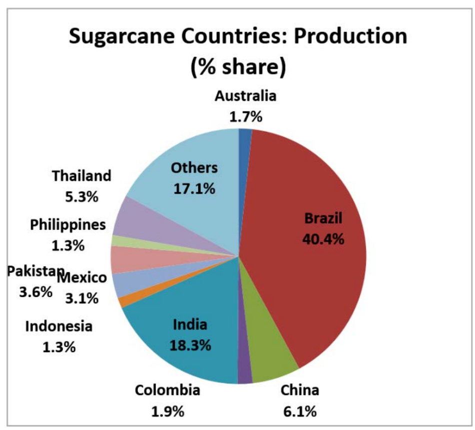
Major sugarcane growing countries: Area (Lakh ha)

Country	2013	2014	2015	2016	2017	Average	% share
Brazil	101.95	104.20	101.11	102.23	101.84	102.27	38.4
India	50.00	49.90	50.70	49.50	43.89	48.80	18.3
China	18.25	17.68	14.86	14.12	13.77	15.74	5.9
Thailand	13.22	13.53	14.01	14.09	13.68	13.71	5.2
Pakistan	11.72	11.41	11.32	11.31	12.17	11.59	4.4
Mexico	7.83	7.62	7.59	7.81	7.72	7.71	2.9
Indonesia	4.71	4.73	4.56	4.58	4.30	4.58	1.7
Philippines	4.37	4.32	4.21	4.10	4.38	4.28	1.6
Colombia	4.06	4.01	4.09	4.02	3.97	4.03	1.5
Australia	3.29	3.75	3.77	4.47	4.54	3.96	1.5
Others	49.15	49.36	49.77	49.15	49.51	49.39	18.6
World	**268.55**	**270.51**	**265.99**	**265.38**	**259.77**	**266.04**	**100**

Major sugarcane growing countries: Production (Lakh tonnes)

Country	2013	2014	2015	2016	2017	Average	% share
Brazil	7680.90	7361.09	7502.90	7685.64	7585.48	7563.20	40.4
India	3412.00	3521.42	3623.33	3484.48	3060.69	3420.38	18.3
China	1287.35	1261.54	1077.29	1037.89	1047.93	1142.40	6.1
Thailand	1000.96	1036.97	941.39	900.90	1029.46	981.94	5.3
Pakistan	674.60	628.27	654.82	654.51	734.01	669.24	3.6
Mexico	611.82	566.73	553.96	564.47	569.55	573.31	3.1
Colombia	348.76	381.57	361.39	347.60	346.38	357.14	1.9
Australia	271.36	305.18	323.79	344.03	365.62	322.00	1.7
Philippines	245.85	250.30	229.26	223.71	292.87	248.40	1.3
Indonesia	284.00	257.54	253.49	233.25	212.13	248.08	1.3
Others	3197.94	3259.40	3198.05	3135.35	3171.16	3192.38	17.1
World	**19015.54**	**18830.01**	**18719.67**	**18611.83**	**18415.28**	**18718.47**	





Major sugarcane growing countries: Yield (tonnes/ha)

Country	2013	2014	2015	2016	2017	Average	YI
Colombia	85.90	95.15	88.36	86.47	87.25	88.62	126
Australia	82.40	81.38	85.89	76.96	80.53	81.23	115
Mexico	78.14	74.37	72.99	72.28	73.78	74.32	106
Brazil	75.34	70.64	74.21	75.18	74.48	73.96	105
China	70.54	71.35	72.50	73.50	76.10	72.60	103
Thailand	75.72	76.64	67.19	63.94	75.25	71.64	102
India	68.24	70.57	71.47	70.39	69.74	70.09	99
Philippines	56.26	57.94	54.46	54.56	66.87	58.09	83
Pakistan	57.56	55.06	57.85	57.87	60.31	57.76	82
Indonesia	60.30	54.45	55.59	50.93	49.33	54.21	77
Others	65.06	66.03	64.26	63.79	64.05	64.64	92
World	**70.81**	**69.61**	**70.38**	**70.13**	**70.89**	**70.36**	**100**

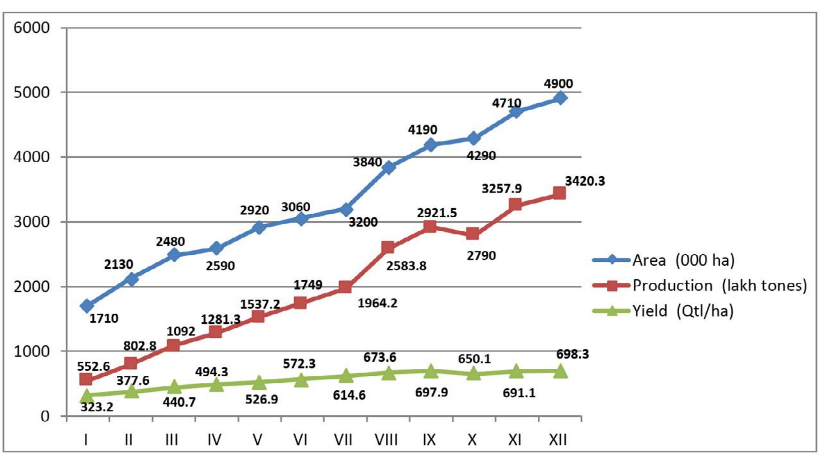
Source : FAO Stat, 2017, YI- Yield Index

2. National Scenario: Plan-period

The average area under sugarcane during first plan (1951-56) was 1.71 million ha with production of 55.36 million tonnes and yield of 32.32 tonnes/ha. During XII plan (2012-17), the area coverage was 4.90 million ha with production of 342.03 million tonnes and productivity was 69.83 tonnes/ha. This showed that there was rise in area about 3 times, production 6 times and productivity 2 times over first plan. The plan-wise area, production and yield as under:

Plan-wise area, production and yield in India

Plan period	Area (Million ha)	Production (Million tonnes)	Yield (tonne/ha)	% increase over previous plan		
				Area	Production	Yield
I (1951-56)	1.71	55.26	32.32	-	-	-
II (1956-61)	2.13	80.28	37.76	24.33	45.26	16.84
III (1961-66)	2.48	109.20	44.07	16.56	36.03	16.71
IV (1969-74)	2.59	128.13	49.43	4.60	17.33	12.17
V (1974-78)	2.92	153.72	52.69	12.56	19.97	6.59
VI (1980-85)	3.06	174.90	57.23	4.75	13.78	8.63
VII (1995-90)	3.20	196.42	61.46	4.58	12.30	7.38
VIII (1992-97)	3.84	258.38	67.36	20.03	31.54	9.60
IX (1997-2002)	4.19	292.15	69.79	9.12	13.07	3.62
X (2002-07)	4.29	279.00	65.01	2.53	-4.50	-6.86
XI (2007-12)	4.71	325.79	69.11	9.83	16.77	6.32
XII (2012-17)	4.90	342.03	69.83	3.90	4.99	1.04



3. National Scenario: All India

The present sugarcane scenario has been changed, if we compare the present status with 1930-31, it showed that area has been increased by 5 folds, production 11 folds and productivity 2.5

folds. The main reason attributed to development of varieties, production technologies and increase in area under irrigation. The maximum area and production was estimated during 2018-19 (5.11 million ha and 400.16 million tonnes), whereas, productivity was the highest (80.20 tonnes/ha) during 2017-18. The area, production and yield from 1930-31has been depicted below:

Area, production and yield of sugarcane in India

Year	Area (000 ha)	Production (000 tonnes)	Yield (tonnes/ha)	Area under irrigation (%)
1930-31	1176	36354	30.90	-
1940-41	1617	51978	32.10	-
1950-51	1707	54823	32.10	67.3
1960-61	2415	110001	45.50	69.3
1970-71	2615	126368	48.30	72.4
1980-81	2667	154248	57.80	81.3
1990-91	3686	241045	65.40	87.0
2000-01	4316	295956	68.60	92.2
2010-11	4886	342382	70.10	92.7
2011-12	5038	361037	71.70	94.8
2012-13	4998	341198	68.30	95.2
2013-14	4993	352141	70.50	95.3
2014-15	5067	362333	71.50	90.2
2015-16	4927	348448	70.70	-
2016-17	4436	306070	69.00	-
2017-18	4737	379905	80.20	-
2018-19*	5114	400160	78.25	

Source : E&S, DAC&FW, *- IV Advance Estimates

4. States' Scenario

The sugarcane is cultivated in an area of 48.56 lakh ha with production of 359.38 million tonnes and yield of 74.00 tonnes per ha (Average 2014-15 to 2018-19). The maximum area and production is recorded in Uttar Pradesh (45% area and 43% production) followed by Maharashtra (19% area and 21% production) and Karnataka (9% area and 10% production). These three states contributed about 73% area and 75% production of the country. During 2016-17, the area under sugarcane declined and estimated at 44.36 lakh ha which was 10% less as compared to 2015-16 due to moisture stress prevailed in the most parts of Maharashtra and Karnataka states. The area was recouped during 2017-18 to some extent but not reached up to level of 2015-16. The area estimated during 2018-19 at 51.14 lakh ha and production to 400.16 million tonnes were the highest ever for sugarcane. The highest production was recorded in Uttar Pradesh during 2017-18 (177.03 million tonnes) followed by Maharashtra (82.98 million tonnes) and Karnataka (31.14 million tonnes).

As far as the average productivity is concerned, Tamil Nadu recorded maximum (99 tonnes/ha) followed by West Bengal (94 tonnes/ha) and Karnataka (83 tonnes/ha). The area, production and yield of major states during 2014-15 to 2018-19 have been shown below:

State wise area of sugarcane

(Lakh ha)

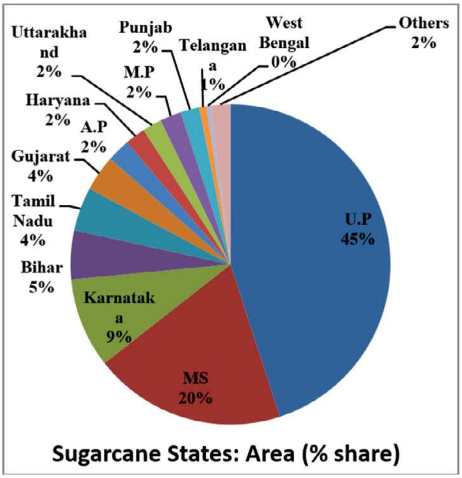
Sl. No.	State	2014-15	2015-16	2016-17	2017-18	2018-19*	Average	% Share
1	Uttar Pradesh	21.41	21.69	21.60	22.34	22.24	21.86	45.0
2	Maharashtra	10.30	9.87	6.33	9.02	11.63	9.43	19.4
3	Karnataka	4.80	4.50	3.97	3.70	5.06	4.41	9.1
4	Bihar	2.54	2.44	2.40	2.34	2.26	2.40	4.9
5	Tamil Nadu	2.63	2.52	2.18	1.72	1.65	2.14	4.4
6	Gujarat	2.08	1.57	1.69	1.82	1.67	1.77	3.6
7	Andhra Pradesh	1.39	1.22	1.03	0.99	1.02	1.13	2.3
8	Haryana	0.97	0.93	1.02	1.14	0.94	1.00	2.1
9	Uttarakhand	1.02	0.97	0.93	0.90	0.91	0.95	1.9
10	Madhya Pradesh	1.11	1.03	0.92	0.98	1.18	1.04	2.1
11	Punjab	0.94	0.90	0.88	0.96	0.95	0.93	1.9
12	Telangana	0.38	0.35	0.29	0.35	0.40	0.35	0.7
13	West Bengal	0.18	0.17	0.21	0.19	0.19	0.19	0.4
14	Others	0.92	1.11	0.91	0.92	1.04	0.98	2.0
	Grand Total	**50.67**	**49.27**	**44.36**	**47.37**	**51.14**	**48.56**	

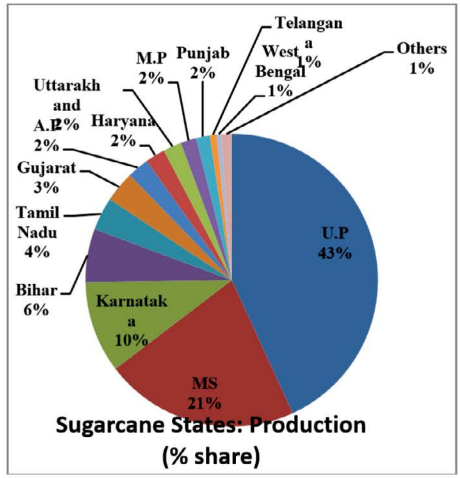
State wise production of sugarcane

(Million tonnes)

S.No.	State	2014-15	2015-16	2016-17	2017-18	2018-19*	Average	% Share
1	Uttar Pradesh	133.06	145.39	140.17	177.03	179.71	155.07	43.1
2	Maharashtra	84.70	73.68	52.26	82.98	92.44	77.21	21.5
3	Karnataka	43.78	37.83	27.38	31.14	42.01	36.43	10.1
4	Tamil Nadu	28.09	25.49	18.99	17.15	16.21	21.19	5.9
5	Bihar	14.03	12.65	13.04	13.82	11.66	13.10	3.6
6	Gujarat	14.33	11.12	11.95	12.07	12.04	12.30	3.4
7	Andhra Pradesh	9.99	9.35	7.83	7.79	8.09	8.61	2.4
8	Haryana	7.17	6.69	8.22	9.63	7.57	7.86	2.2
9	Punjab	7.04	6.61	7.15	8.02	7.77	7.32	2.0
10	Uttarakhand	6.17	5.89	6.48	6.27	6.33	6.23	1.7
11	Madhya Pradesh	4.57	5.28	4.73	5.43	6.96	5.39	1.5
12	Telangana	3.34	2.41	2.06	2.60	2.80	2.64	0.7
13	West Bengal	2.11	2.08	1.55	1.44	1.66	1.77	0.5
14	Others	3.95	3.98	4.26	4.53	4.91	4.27	1.2
	Grand Total	**362.33**	**348.45**	**306.07**	**379.90**	**400.16**	**359.38**	

Source : E&S, DAC&FW, *- IV Advance Estimates





State wise productivity of sugarcane

(tonnes/ha)

Sl.No.	State	2014-15	2015-16	2016-17	2017-18	2018-19*	Average	YI
1	Tamil Nadu	106.79	101.15	87.11	99.81	98.24	99.00	134
2	West Bengal	117.0	122.10	73.81	75.00	88.00	93.94	127
3	Karnataka	91.20	84.07	68.97	84.08	83.00	82.68	112
4	Maharashtra	82.23	74.65	82.56	92.00	79.50	81.88	111
5	Punjab	74.90	73.44	81.25	83.58	81.83	79.03	107
6	Haryana	73.90	71.94	80.59	84.50	80.37	78.56	106
7	Andhra Pradesh	71.85	76.64	76.02	78.68	79.32	76.19	103
8	Telangana	87.97	68.86	71.03	74.41	70.00	74.63	101
9	Uttar Pradesh	62.15	67.03	64.89	79.25	80.81	70.95	96
10	Gujarat	68.89	70.83	70.71	66.33	71.97	69.66	94
11	Uttarakhand	60.40	60.72	69.68	69.68	69.55	65.81	89
12	Bihar	55.30	51.84	54.33	59.14	51.70	54.68	74
13	Madhya Pradesh	41.14	51.26	51.41	55.41	58.95	51.67	70
14	Others	39.78	35.86	46.81	43.83	47.21	43.55	59
	All India	**71.51**	**70.72**	**69.00**	**80.20**	**78.25**	74.00	100

Source : E&S, DAC&FW, *- IV Advance Estimates , YI- Yield Index

5. Production constraints

- Continued mono-cropping of sugarcane for several years leads to nutritional imbalance and decrease in soil organic carbon. About 4.5 to 7.9 % losses in cane yield was reported due to soil degradation. Excess nitrogenization (unbalanced application of N alone) was also another concern in this crop.

- Improper nutrient balance- Micronutrient deficiency particularly Fe. Zn, Mo were reported from Northern Karnataka and parts of Tamil Nadu.
- Poor ratoon stands- Ratoon occupies 50-55% area but farmers do not pay much attention on agronomic practices, 10-1 % gaps reduces the crop stand, Although ratoon produce much higher number of tillers, around 65-70% tillers die out and do not contribute to the yield. Insect pests and diseases problems are also higher in ratoon crop.

Biotic and Abiotic Stresses

- Drought- Frequently drought like situations/moisture stress prevailed in parts of Maharashtra, Karnataka, Tamil Nadu in past few years led to decline in crop coverage and productivity. This warrants the introduction/development of genotypes suitable for drought condition.
- Flood and water logging- Floods are also major constraints in states like Uttar Pradesh, Bihar, Odisha, Coastal Andhra Pradesh and parts of Maharashtra where the stagnated water remain in the fields for many days. Water logging affects all stages of crop growth and can reduce germination, root establishment, tillering and growth resulting in reduction in yield.
- Pest and diseases- Due to diseases, losses in yield has been estimated about 10-15%. The incidence of yellow leaf disease, Pokkah boeng diseases and wooly aphids, root borer, white grub insect pests in many parts of sugarcane growing areas was the major concern in last few years.
- Depleting water resources - Sugarcane is a water intensive crop. It requires about 30-40 irrigations on an average in tropics. Moderating the water use for sugarcane cultivation is the need of the hour, since water is a limited resource.
- Climate change- Rise in the temperature, decrease or altered rainfall pattern, drought, floods, water logging, increased CO_2 etc. are affecting the sugarcane crop. High temperature is likely to impact plant growth, yield (reduced by 20-30%), increased weed competition, increased incidence of pests and diseases and most importantly, juice sucrose content *vis-à-vis* recovery. The sucrose losses in standing crop and after harvest (post harvest) stage are bound to increase due to high temperature
- Marketing and post harvest constraints- Bulkiness, non-storability, post-harvest deterioration, restricted buyers, government regulations etc.

6. Future strategy

6.1. Horizontal expansion: There is hardly any possibility of additional area forthcoming under sugarcane due to decreasing availability of arable land. Sugarcane is also facing stiff competition from foodgrains, 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 stabilize at around 5.5 million hectares by the year 2030. It is further assumed that additional area will be available from intercropping of other crops in a sugarcane based cropping system.

6.2. Varietal expansion- Varietal planning and replacement of old and rejected varieties**.** The projected demand at year 2030 will be 600 million tonnes of sugarcane which can be met mainly by increasing the productivity and quality of the crop. The average productivity level needs tremendous boost and it should be around 100-120 tonnes/ha mark by the year 2030, the best performing varieties need to expand. To meet the targeted white sugar requirement, improvement in sugar recovery to 11.0-11.5% also needs attention.

6.3 Seed cane production: The seed cane demand needs through estimation based on the recommended seed cane replacement rates. Strengthening of seed cane programme involving research organizations, cane developing agencies, sugar mills and farmers.

6.4. Reducing the cost of cane cultivation – By balance use of INM, water use efficiency through micro-irrigation, land use efficiency through companion cropping, bio-intensive IPM, IDM and mechanizing sugarcane farming.

6.5. Effective water management- Sugarcane crop is considered as water guzzling crop, by adopting micro-irrigation, the water quantity will be saved. Drip irrigation system has proved to be a great success in terms of water saving up to 30-41% and increase in the yield by about 20-30 % in sugarcane crop. The state like Maharashtra started adopting micro-irrigation technology – drip system and targeted to cover all sugarcane cultivated area under this system.

6.6. Diversification and value addition through production of jaggery and allied products- emphasis should be given on production of diversified products from sugarcane *viz.* quality jaggery, vinegar to capture elite market and even to explore export market.

6.7. Enhancement of ethanol blended petrol programme (EBP)- By the year 2022, blending target has been fixed for 20%. During 2018-19, about 8% blending is estimated to be achieved which need to be further extended to meet the target fixed.

6.8. Intercropping in sugarcane- Intercropping of pulses, oilseeds, cereals, vegetables with sugarcane need to be promoted to utilize the inter space till the sugarcane crop develop canopy (90-120 days) and to get interim return from the intercrop.

6.9. Diversification of sugar factories into bio-refineries or multi product factories or Agro-business Complexes or smart factories producing sugar as per requirement and utilization of by product to other value added products (Cellulosis ethanol, surfactants, xylitol & dietary fibres).

6.10 Improving the productivity of ratoons through good management practices. Popularization of Ratoon Management Device (RMD).

7. Policy intervention

7.1. Price policy: Minimum support price (MSP) including additional incentives (Bonus) on procurement of crop produce from the states:

The Minimum Support Price or Fair and Remunerative Price (FRP) in sugarcane is declared by the Govt. of India every year to protect the benefits of the sugarcane growers keeping in view the inflation of the inputs and other parameters. The State Government also declare State Agreed Price (SAP) for Sugarcane over the FRP. The minimum statutory price/fair & remunerative price of sugarcane fixed by the Government was as under:

Year	Minimum statutory price of sugarcane (₹ per quintal)	Linked to basic sugar recovery % cane	Premium on every 0.1% increase in sugar recovery % cane (₹ per quintal)	Range of minimum sugarcane price on the basis of Col. 1, 2 & 3 (₹ per quintal)
2000- 01	59.50	8.50	0.70	59.50 to 96.60
2001- 02	62.05	8.50	0.73	62.05 to 100.74
2002- 03	69.50	8.50	0.82	69.50 to 113.78
2003- 04	73.00	8.50	0.85	73.00 to 118.90
2004- 05	74.50	8.50	0.88	74.50 to 110.58
2005- 06	79.50	9.00	0.88	79.50 to 112.94
2006- 07	80.25	9.00	0.90	80.26 to 119.85
2007- 08	81.18	9.00	0.90	81.18 to 118.98
2008- 09	81.18	9.00	0.90	81.18 to 123.48
2009- 10	129.84 (FRP)	9.50	1.37	129.84 to 179.16
2010-11	139.12 (FRP)	9.50	1.46	139.12 to 197.52
2011- 12	145.00 (FRP)	9.50	1.53	145.00 to 203.14
2012- 13	170.00 (FRP)	9.50	1.79	170.00 to 241.60
2013-14	210.00 (FRP)	9.50	2.21	210.00 to 302.82
2014-15	220.00 (FRP)	9.50	2.32	220.00 to 310.48
2015-16	230.00 (FRP)	9.50	2.42	230.00 to 324.38
2016-17	230.00 (FRP)	9.50	2.42	230.00 to 321.96
2017-18	255.00 (FRP)	9.50	2.68	NA
2018-19	275.00 (FRP)	10.00	2.75	NA

Source: Cooperative Sugar, Vol. 50, No.10, June 2019.

7.2. Developmental Programme Implementation

A. Past

A Central Sector Scheme (CSS), the Sustainable Development of Sugarcane Based Cropping System (SUBACS) was under implementation from 1995-1996 to 1999-2000 in 191 districts of 20 States and one Union Territory. Following strategies were undertaken under the scheme:

1. Propagation of improved crop production technologies through organization of field demonstration on farmers holdings and training of farmers including farm women and extension workers
2. Setting up the Heat Treatment Plant for multiplication of disease free seed and making available healthy seed material to the farmers
3. Encouraging the use Integrated Pest Management (IPM) Technology
4. Introduction of tissue culture technique for quicker multiplication of seed material
5. Replacement of low-yielding varieties with high yielding varieties having biotic and abiotic resistance
6. Planting and harvesting of sugarcane
7. Use of improved farm implements for promoting a sense of competition among farmers for maximizing of productivity

Pattern of assistance in sustainable development of sugarcane based cropping system (SUBACS):

S. No	Components/ interventions	Unit	Pattern of assistance
1	Demonstration of technology on sugarcane production		
a	Frontline demonstrations through ICAR System	ha	₹ 15000/- per demonstration of one hectare (100% GoI)
b	Field demonstration by Govt. on farmers' fields	ha	₹ 5000/- per demonstration of 0.5 hectare (on 75:25 basis)
2	Transfer of technology to farmers and extension staff		
a	National level training by three leading national Sugarcane institute *viz.* IISR, Lucknow; SBI, Coimbatore and Vasant Dada Sugar Institute, Pune.	No.	₹ 12500/- per training programme (100% GoI)
b	State level training by State Government for two days with 30 participants		₹ 12500/- per training programme (on 75:25 basis)
c	Farmers training by State Government		₹ 5000/- per training programme (on 75:25 basis)
3	Implements		
a	Improved bullock drawn/ manually operated	No.	@ 50% of cost limited to ₹ 1500/- per implement per farmer (on 75:25 basis)
b	Tractor operated (Sugarcane planter, Rotavator *etc.*)	No.	@ 25% of cost limited to ₹ 10000/- per implement per farmer (on 75:25 basis)
4	Strengthening of existing tissue culture units of ICAR Research Institute/ SAUs/ NGO units	No.	₹ 5 Lakh per unit (100% GoI)
5	Strengthening of existing bio-pesticides units of ICAR Research Institute/ SAUs/ NGO units	No.	₹ 5 Lakh per unit (100% GoI)
6	Seed Production		
a	Breeder Seed through ICAR/ SAUs/ NGOs	ha	₹ 20000/- per hectare (100% GoI)
b	Multiplication of seed on contract basis by the State Govts.	ha	10% of the cost of cultivation or ₹ 2000/- per ha. whichever is less (on 75:25 basis)
7	Setting up/Strengthening of heat treatment plant in district/research station/KVKs/Sugar factory/ *Taluka* Seed Farm *etc*.		₹ 2 lakh per plant without accessories (on 75:25 basis)
8	Productivity award to sugarcane growers	No.	₹ 25000 per award at district level (on 75:25 basis)
9	Drip irrigation		
a	Infrastructure on drip irrigation	ha	90% of cost subject to the ceiling of ₹ 25000/- per ha. for small and marginal, SC/ST and woman farmers and 70% of cost subject to ₹ 25000 per ha for other farmers (on 75:25 basis)
b	Demonstration on drip irrigation	ha	₹ 22500 per hectare (on 75:25 basis)
10	Transfer of Technology trough electronic media, printing of literature, video films, seminars, symposia *etc*.		100% by GoI
11	Contingency to State for POL *etc*.		₹ 30000/- per districts (75:25 basis)

From October 2000, the Crop Oriented Centrally Sponsored Scheme was implemented in different States subsumed with Macro Management Mode on Agriculture (MMMA) with the approval of Planning Commission. The pattern of assistance changed to 90:10 between GOI and State Govt. The main components were same as it were in the SUBACS with the flexibility to incorporate new components as per the requirement of the State. The main component of the scheme were: Field demonstration, IPM demonstration, Farmers training, State level training, Distribution of implements (Manual/tractor drawn), Seed multiplication, MHAT Plant, Drip irrigation infrastructure, Bio-fertilizer distribution, Biological control *etc*.

Pattern of assistance in sugarcane development programme under macro management mode

S. No	Components/ interventions	Unit	Pattern of Assistance
1	Demonstration of technology	No.	0.5 ha. @ ₹ 7500/- per demonstration
2	Distribution of farm implementation	No.	**a)** Bullock/manual drawn @ 25% of the cost limited to ₹ 2500/- per unit. **b)** Tractor/power drawn @ 25% of the cost limited to ₹15000/-
3	Multiplication of planting materials (Cane setts)	ha	**a)** Foundation nursery @ 10% of the cost limited to ₹ 4000/- per ha. **b)** Primary nursery @ 10% of the cost limited to ₹ 2,000/- per ha.
4	Training	No.	**a)** Farmers: 50 farmers for 2 days @ ₹ 10000/- per training. **b)** State level: 30 participants for 3 days @ ₹ 20,000/- per training.
5	Setting up of Moist Heat Treatment Units for treatment of planting material by Farmer's Association/Mills	No.	@ 50% of the cost per plant including generator, limited to ₹ 3,00,000/-.
6	Supply of drip irrigation Infrastructure	ha	@ 50% of the cost limited to ₹ 30,000/-. per ha.
7	Setting up/Strengthening up **a)** Tissue culture lab **b)** Bioagent lab by SAU /ICAR Instt., Mills	No.	@ 25% of the cost limited to ₹ 10,00,000/-. per tissue culture lab or bioagent lab.
8	Monitoring/Inspection/visit/ Preparation of reports, POL *etc.* as contingency	Distt.	₹ 50,000/- lump sum per major sugarcane growing district.
9	Area specific intervention		10% of allocation
10	**OTHER COMPONENTS**		
a	Assistance for boring of tubewells/ pumpsets	No.	@ 25% of cost limited to ₹ 12,000/- per set.
b	Assistance for distribution of micro-nutrients	ha	@ 25% of cost limited to ₹ 1000/- per ha.
c	Distribution of planting material and soil treatment chemicals	ha	@ 25% of cost limited to ₹ 1000/- per ha..
d	Visit of farmers to model farms, institutes *etc*.	Nos.	40 sugarcane farmers @ 50% of the cost limited to ₹ 50,000/-

B. Present

i) National Food Security Mission-Commercial Crops : Sugarcane: The Government of India has approved Crop Development Programme -Sugarcane for enhancing the production and productivity under National Food Security Mission- Commercial Crops (NFSM-CC) w.e.f. 2014-15. Under this Scheme, thrust has been given on transfer of technology through demonstrations and training in order to extend benefits to the farmers. From 2015-16, in view of increased devolution to the States on account of implementation of recommendations of 14th Finance Commission, NFSM is being implemented on sharing basis between the Government of India and States on 60:40 basis for general category States & 90:10 basis for North East & hilly States. However, the Central Agencies are funded 100% by GOI.

Pattern of assistance- NFSM-Commercial Crops - Sugarcane

Sl. No.	Component	Unit cost	Implementing agency
1	Demonstration on intercropping and single bud chip technology with Sugarcane.	₹ 9000 per ha (₹ 8000 for inputs & ₹ 1000 for contingency)	ICAR/SAUs/KVKs/NGOs/ Cooperatives/State Dept. of Agriculture
2	Assistance for Breeder Seed Production	₹ 40000 per ha (₹ 34000 for inputs & ₹ 6000 for contingency)	SAUs/ ICAR and Sugarcane Research Institute
3	Production of tissue culture raised plantlets/ seedlings	₹ 3.5 per seedlings	Sugarcane Institutions, Sugar Factories, NGOs
4	National Level Trainings (25 Participants X 2 days)	₹ 50000 per training	ICAR/IISR/SBI/UPCSR
	State level training (20 participants X 2 days)	₹ 40000 per training	SDA
5	Distribution of plant protection chemicals and Bio agents	₹ 500/ha or 50% of the cost, whichever is less	SDA/ICAR
6	Local Initiatives	As per the state specific need limited to 25% of total allocation	
7	Contingencies & Electronic Print Media	Need based	Directorate of Sugarcane Development (DOSD), Lucknow

ii. NFMS- Intercropping of pulses with sugarcane is under implementation for two years 2018-19 & 2019-20 by the Govt. of India and being implemented from Spring season of 2019 in 13 States. Pattern of assistance is being given as per details given below:

S. No	Name of Component	Unit cost	Implementing agency
1	Demonstrations	₹ 9000/ha	IISR/SBI/State Dept. of Agriculture
2	Distribution of seeds	₹ 5000/Qtl	State Dept. of Agriculture
3	Distribution of PP chemicals/ bio-agents	₹ 500/ha	State Dept. of Agriculture
4	Distribution of bio-fertilizer	₹. 300/ha	State Dept. of Agriculture
5	State level training	₹ 40000/training	State Dept. of Agriculture
6	National level training	₹ 50000/training	IISR/SBI/DOSD

Allocation for development schemes for 2019-20: The Ministry has approved the allocation for above schemes for 2019-20 as per the details given below:

(₹ in Lakh)

Sl. No	State	NFSM- Commercial Crop-Sugarcane			NFSM- Intercropping of Pulses with Sugarcane		
		CS	**SS**	**Total**	**CS**	**SS**	**Total**
1	Andhra Pradesh	18.70	12.47	31.17	0	0	0
2	Telangana	4.96	3.31	8.27	2.234	1.489	3.724
3	Gujarat	15.00	10.00	25.00	8.598	5.732	14.330
4	Haryana	30.26	20.18	50.44	6.762	4.508	11.270
5	Karnataka	45.28	30.18	75.46	31.210	20.807	52.017
6	Madhya Pradesh	35.66	23.78	59.44	5.268	3.512	8.780
7	Maharashtra	289.55	193.03	482.58	50.068	33.378	83.446
8	Tamil Nadu	45.54	30.36	75.90	5.984	3.990	9.974
9	Uttar Pradesh	349.35	232.9	582.25	102.688	68.458	171.146
10	Punjab	23.10	15.40	38.50	5.553	3.702	9.254
11	Uttarakhand	44.02	4.89	48.91	5.982	0.665	6.647
12	Bihar	128.78	85.85	214.63	3.600	2.400	6.000
13	Odisha	33.60	22.40	56.00	0.798	0.532	1.330
	Sub-Total	**1063.80**	**684.75**	**1748.55**	**228.745**	**149.173**	**377.918**
15	ICAR-IISR, Lucknow	40.215	0	40.215	7.00	0	7.00
16	ICAR-SBI, Coimbatore	4.50	0	4.50	0.00	0	0.00
17	UPCSR, Shahajahanpur	7.00	0	7.00	0.00	0	0.00
18	DOSD, Lucknow	10.00	0	10.00	3.00	0	3.00
	Sub-Total	**61.715**		**61.715**	**10.00**	**0**	**10.00**
	Grand Total	**1125.515**	**684.75**	**17550.265**	**238.745**	**149.173**	**387.918**

CS- Central share, SS- State share

Status of sugarcane in Gujarat and Rajasthan

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Introduction

Sugarcane belongs to the family Gramineae is indigenous to India. It is a tropical plant but it can also grow in sub-tropics as in the north India. It is a long duration crop which requires 10-15 and even 18 months to mature. Sugarcane favours hot and humid climate. It requires 21°C-27°C temperature and 75-150 cm rainfall. High humidity (80-85%) favours rapid cane elongation during growth period. Moderate humidity (45-65%) coupled with limited water supply is favourable during the ripening phase and above 40% humidity coupled with warm weather favours vegetative growth. Sugarcane is grown in the world from altitude 35° N and 35° S, from sea level to 1000 m of altitude or little more. It may be cultivated on a variety of soils including loams, clay loams, black cotton soils, brown or reddish loams and even laterites but deep loam soils are the best suited for its cultivation. Sugarcane is nutrient exhaustive crop, hence, the soil should be rich in nitrogen, calcium and phosphorous.

Distribution

Presently, sugarcane is grown in an area of 16 m ha in over 79 countries. The global raw sugar production is 112 m t. Globally, India stands first in area (47.37 lakh ha) (2017-18) and second in production after Brazil. In India, Uttar Pradesh stands first in area (22.34 lakh ha), followed by Maharashtra, Karnataka, Tamil Nadu, Bihar, Gujarat, Andhra Pradesh, Telangana, Haryana, Punjab and Uttrakhand. Though, area and production are mainly concentrated in the states of Uttar Pradesh, Maharashtra, Tamil Nadu and Karnataka. Tamil Nadu registeres the highest yield in sugarcane production in India. Gujarat contributes an area of 182 thousand ha in sugarcane cultivation (2017-18) and Surat, Bhavnagar, Rajkot, Junagadh and Jamnagar are major sugarcane growing districts of Gujarat. Rajasthan contributes 5.4 thousand ha area (2017-18) only and Sriganganagar, Kota, Chittorgarh, Bundi, Bhilwara and Udaipur are major sugarcane growing districts in Rajasthan.

Economic Importance

Indian sugar industry has been a focal point for socio-economic development in the rural areas by mobilizing rural resources, generating employment, higher income and transport & communication facilities. It is a remunerative crop to the farmers cultivated with different crop rotations. One or two ratooning is also practiced in sugarcane. Sugarcane is also cultivated in intercropping with pulses like mungbean and urdbean. A part of sugarcane is also used as fodder. It is first choice of the farmers where the geographical situation favours its growth.

Industrial importance

India is the largest consumer of sugar in the world and the Indian sugar industry is the second largest agro-industry located in rural India. The sugar industry is also the second largest agro-based industry, next only to textiles, in the country. Sugarcane and sugar beet are the main sources of sugar in the world. Out of total sugar produced in the world, 60 per cent is obtained only from sugarcane. Sugarcane is one of the major cash crops of India. The cultivation of sugarcane and development of sugar industry runs parallel to the growth of human civilization and is as old as agriculture. In the present scenario too, sugarcane and sugar continue to be important for Indian rural economy. Sugarcane is main source of sugar, *gur* and *khandsari*. It provides raw material for manufacturing alcohol. It also produces ethanol, an eco-friendly and renewable energy for blending with petrol. The crushed cane residue can be more beneficially used for manufacturing paper instead of using as fuel in mills.

Area, production and productivity

Among the sugarcane growing countries of the world, India stands first in area (4737 thousand ha) with the production of 3,79,905 thousand tonnes (2017-18). In general, the area, production and yield are static, though, minor changes are there. Gujarat contributes an area of 182 thousand ha with the production of 12 million tonnes, whereas, Rajasthan contributes a small area of 5.4 thousand ha with the production of 382 thousand tonnes of sugarcane (2017-18).

Table 1. Area (000 ha), production (000 tonnes) and yield (kg/ha) of sugarcane

State	Factor	2013-14	2014-15	2015-16	2016-17	2017-18	Mean
Gujarat	Area	174.0	208.0	157.0	169.0	182.0	178.0
	Production	12550.0	14330.0	11120.0	11950.0	12072.1	12404.4
	Yield	72126	68894	70828	70710	66330	69688
Rajasthan	Area	5.3	5.6	6.1	6.9	5.4	5.9
	Production	362.9	408.9	531.3	488.7	381.9	434.7
	Yield	68989	73404	86511	71294	70364	74188
All India	Area	4993.3	5066.8	4927.1	4435.7	4737.1	4832.0
	Production	352141.8	362332.8	348448.4	306069.0	379904.9	349779.4
	Yield	70522	71511	70720	69001	80198	72388

Source: Directorate of Economics & Statistics, DAC&FW, GOI.

Constraints in sugacane production

Though, there are so many reasons of low productivity of sugarcane in Gujarat ad Rajasthan but the important are as follows:

Uncertain weather conditions

It requires hot and humid climate with average temperature of 21°-27°C and 75-150 cm rainfall. In the latter half, temperature above 20°C combined with open sky helps in acquiring juice and its thickening. Heavy rainfall results in low sugar content and deficiency in rainfall produces fibrous crop. Short cool dry winter season during ripening and harvesting is ideal. Frost is detrimental to sugarcane; similarly, hot dry winds are also unfavorable to sugarcane cultivation.

Climate change

Unpredictable weather condition coupled with temperature extremities (both high and low) adversely affect productivity and also widen scopes of spreading diseases and insect-pests in more disastrous form.

Small and fragmented holdings

Small and fragmented holdings are one of the major constraints in sugarcane cultivation. Small holdings are not as remunerative as large holdings. In case of small holdings, labour cost increases and farmers are always dependent on others for any operation as they are not able to purchase the machines for small holdings.

Monocropping/No crop rotation

Continuous growing of sugarcane on same piece of land, year after year, affected the soil fertility and productivity badly.

Soil condition

The soil should not be too acidic or too alkaline. It should be rich in nitrogen, calcium & phosphorus and able to retain moisture.

Long duration

It is a long duration crop with requires 10 to 15 or even 18 months to mature, depending upon the geographical conditions so once a farmer plants the crop, he doesn't have any option to choose other crop as per market demand or he has to bear with the market fluctuations. In such conditions, sometimes, farmers don't prefer to cultivate sugarcane.

Varietal constraint

Lack of climate resilient high yielding varieties, resistant to biotic and abiotic stresses is again major cause for low productivity.

Lack of quality planting material

Though, a number of improved varieties are available in sugarcane, but it is also true that due to no systematic seed production channel, we are not able to harvest desired productivity of the crop. Till date, farmers are using poor quality planting material resulting in low productivity of crop. We are not able to supply the seed of improved varieties available with us.

Lack of organic matter and inadequate/imbalance fertilizer use

It exhausts the fertility of the soil quickly, hence it requires heavy dose of manures and fertilizers. Fail to apply the required organic matter (FYM, compost, green manuring, and vermin-compost) and fertilizers or imbalance use of fertilizer results in low productivity of the crop.

Seed treatment

Every crop is attacked by so many diseases and insect-pest during the crop season. Seed treatment helps to overcome the initial incidence of insect- pests and seed borne diseases. Negligence in seed treatment also invites biotic stress resulting in low productivity of the crop.

Negligence in ratoon management

In ratooning, sugarcane is cut leaving the roots intact in the soil or it is the second or any other successive crop obtained from the roots left over in the field from the first crop. It became very popular and widely practiced in different parts of the country due to its low cost of cultivation and relatively shorter maturation period. In this system, both cost inputs and time are saved as there is no need for fresh sowing and growing of roots but in case of negligence in ratoon management and with each passing year, productivity decreases. After one or two years ratooning becomes uneconomic.

Inadequate irrigation

Sugarcane requires 75-150 cm rainfall. In case of lesser rainfall, irrigation is required for desirable production. Fail to irrigate the crop at required time, results in low productivity of sugarcane.

Labour intensive

It is a labour intensive cultivation requiring ample human hands at every stage *i.e.* sowing, hoeing, weeding, irrigating, cutting and carrying sugarcane to the factories. Therefore, cheap abundant labour is a prerequisite for its successful cultivation. Improper availability of labour results in low productivity of the crop.

Biotic stresses

Now a days the biotic stresses have emerged as a major challenge in crop cultivation. Sugarcane attacked by so many diseases and insect-pests causing heavy losses to the yield. Due to poor economic condition and improper knowledge, farmers are unable to adopt proper plant protection measures resulting in low yields.

Insufficient extension services/lack of technical knowledge to the farmers

Lack of initiative of extension personnel, lack of exposure of farmers to improved technologies and poor interface among state departments of agriculture & research organization private agencies also results in low yields. The due to Lack of scientific training and demonstration programme, farmers are unaware about newly released crop production technologies and HYVs of sugarcane. Till date, there is wide extension gap between research institutes and farmers fields. Unless the scientific technology is transferred to the farmers through demonstrations, *kisan mela*, media, audio-visual aids or by any method, it is quite impossible to harvest desired production. There is an urgent need to strengthen our extension services to transfer the latest technologies to the farmers without any delay and to ensure regular visit of extension workers to the farmers field.

Fluctuation in rates and delay in payment

Though, there is fluctuation in rates of all agricultural products but sugarcane affects badly. Delay in payment again discourages its cultivation.

Lack of mechanization

Due to poor condition of the farmers, they are not able to purchase the modern machines helpful in crop cultivation.

Burnt cane

Burnt cane is again a major reason of low production and recovery of sugar. In burnt cane, there is 10-15% loss of water. Sugarcane recovery is also less by 1% in burnt cane.

Strategies to improve production of sugarcane

- Planting should be done after proper land preparation. Go for planting recommended for planning.
- Use of quality seed of improved varieties resistant to major disease, pest and having good ratooning ability.
- Irrigation facility should be optimum and regular.
- Seed treatment with insecticide and fungicide to overcome diseases and insect-pests.
- Adoption of crop rotation and intercropping.
- Use of organic, inorganic and biofertilizer as per recommendation to fulfill nutrient requirement of crop/Integrated nutrient management and to maintain soil health.
- Adoption of newly developed technology, mechanization and drip irrigation to overcome labour scarcity and to decrease cost of production.
- Use of tissue culture and one eye bud to minimize seed cost.
- Recycling of sugarcane trash through mulchar composting. It should not be burn before or after harvest of crop.
- Increase the partnership of the farmers in important agricultural practices in sugarcane.
- Avoid burning of the crop.

Components for subsidy required to improve sugarcane production

- Training to sugarcane growers and agriculture staff of sugar factory
- Drip irrigation system
- Biofertilizer/Organic fertilizers.
- Biofungicides, bioinsecticides (Light trap, lure, feroman trap etc.)
- Sugarcane planting materials (Seed) (One eye bud setts, tissue culture plantlets)
- Seed treatment chemicals and implement
- Seed of green manure and intercrop which can be taken up in sugarcane crop
- Sugarcane shredder usingf sugarcane trash
- Sub surface drainage system
- Fencing for protection from animals

Adoption of Sustainable Sugarcane Initiative (SSI) and succeeding ratoon crop management for doubling farmers income in Odisha

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Odisha is endowed with rich natural resources and great bio-diversity with varied genetic resources for different crop development. This natural resource also enriches our cultural heritage. People of the state observe so many festivals and rituals round the year as life style is being from agrarian origin. So the sweetener like *Gur / Jaggery / Khandasari/* white sugar is a prime requirement in each "Odia" house at the time of observing any festival. This sweetener is mainly derived from sugarcane otherwise known as "Noble cane". The farmers of Odisha are cultivating sugarcane from time immemorial. The geographical location of Odisha lies between 170 31' N latitude and 20.31 N latitude and 810 31' E Longitude and 870 31' E longitude. The state is having 480 km of coastal line. The climatic condition is neither tropical nor subtropical. So the tropical and subtropical varieties of sugarcane perform well in Odisha. The area, production and productivity of sugar cane is around 33,000 hectares, 8.15 lakh MT and 70.12 MT per hectare respectively (Cooperative Sugar, 2017). State has the potential for growing sugarcane up to 2.00 lakh hectares as the Rabi irrigation potential has been created to the tune of 13.99 lakh ha (Odisha Agriculture Statistics 2013-14). The productivity can be enhanced to 100 MT/ha owing to the favourable agro-climatic condition available in various regions of the state. In Odisha although the average productivity is at par with national average but growth in productivity has been very poor and the total area under sugarcane is declining rapidly. The productivity of the sugar sector in Odisha is not currently very encouraging owing to various factors, *e.g.*:

- Farmers are sourcing poor quality seed cane from other farmers, which results in low cane production
- Rising costs of cultivation are a discouragement for innovation
- Increasing labour shortages
- Improper cultivation practices, like the usage of poor quality setts
- High sett rate per hectare
- Inappropriate water and nutrient management measures
- Unbalanced use of fertilizer.

To increase output and profitability in the sector, there is need to increase on farm production and productivity of cane and to increase the recovery rate of sugar in mills. Also, there is need to improve the efficiency and to reduce the cost of cultivation by adopting the latest technologies; to have rapid multiplication of disease-free seed of new, improved varieties of sugarcane; and to safeguard the interests of cane growers and the sugar industry by saving cane that could be used for seed purposes. Deriving sugarcane seed from the commercial crop has been responsible for rapid multiplication of a large number of diseases like red rot, wilt, smut, ratoon stunting and grassy shoot. These adversely affect the cane yield and quality. Raising healthy and vigorous sugarcane crops for seed purposes is essential and recommended.

Increasing the farmers' income is the major challenge to supply safe and nutritional food and reducing health risk. Most of the farmers using high inputs for cultivation of sugarcane are deteriorating the quality of environment and increasing the cost of production and reducing the profit per unit area per unit time. At present, there is urgent need of adoption of low cost technologies related to sugarcane production that includes selection of appropriate varieties especially developed for that region, appropriate method of planting, seed treatment before planting in the fields, crop diversification, intercropping, use of bio-fertilizers, use of organic sources of nutrient like farmyard manure(FYM), composting, soil and water conserving practices, reducing the human drudgery in agriculture by adoption of mechanical cultivation, and popularizing the plant protection measures such as use of biological pest control measures. In Odisha, sugarcane is primarily grown by small and marginal farmers. Majority of these farmers having low income are not in position to adopt high cost technology up to the significant level. In such scenario, dependence on high cost external inputs becomes difficult to resource poor farmers due to their low purchasing power. In sugarcane, per cent reduction in the cost of production is directly related to the percent profit. Keeping this in view, an attempt has been made for identification of low cost technology in sugarcane cultivation with objectives to improve productivity, profitability, input use effciency and sustainability of sugarcane agriculture. Most of low cost technologies are based on concept of non-monetary inputs or cost effective input having higher potential to increase the level of profit.

The Sustainable Sugarcane Initiative (SSI) is one such approach that offers some solutions to these mounting problems through a set of principles and practices that 'produce more with less,' getting more output with reduced inputs. For commercial cultivation, a huge quantity (6-8 t/ha) of cane stalk cuttings having two to three bud pieces (25-30 cm long segments) are required for planting in one ha. of field which cost about 22 to 25% of the total production cost (Srivastava *et al*. 1981). Therefore, one of the major items of expenses incurred in sugarcane production is the huge quantity of seed cane material required for its planting. Reducing the seed cane quantity by way of introducing bud chip technology would be the best alternative to cut down the cost and accordingly enhance the returns and sustain sugarcane growing particularly in Odisha where its cultivation is primarily done by small and marginal farmers (Mohanty and Nayak, 2011). Bud chip technology of sugarcane growing has been preferred by many farmers particularly farm women because of drudgery reduction and easy to do planting operations *viz.*, bud chipping, placing bud chips in coco-pith-filled plastic cone trays, nursery raising, transplanting of settlings in furrows *etc.* Sugarcane cultivation by single bud chip technology can improve soil rhizospheric environment, root growth and the nutrients availability in soil due to microbial abundance and diversity besides saving of water, if drip irrigation is adopted (Ramamoorthy and Ramanujam 1993). Therefore, bud chip technology has attracted the attention of large number of sugarcane farmers, development workers in government and sugar sector for its large-scale promotion and adaptation.

So keeping this in view the improved planting techniques & SSI (Sustainable Sugarcane Initiatives) to reduce cost of cultivation and economize the use of valuable seed resource and the technologies for succeeding ratoon crop management for getting yield at par with that plant crop have been taken up. In view of the benefits of using single bud chips for sugarcane planting, extensive research work has been carried out on this aspect at Sugarcane Research Station, Nayagarh besides its validation at the farmers' fields of different parts of Odisha.

On-farm trials in a farmers' field were conducted in participatory mode for the two consecutive cropping seasons of 2015-2016 and 2016-2017 at Giria village under Hinjilicut block of Ganjam district in South East Coastal Plain Zone of Odisha. Single bud chip technology was thus assessed and compared for cane yield increments and economic returns with that of conventionally planted crop at all the five locations during both the years of experimentation.

The constituent elements of SSI are:

1. Raising young cane plants in a nursery using small chips taken from the cane, each with a single bud, and growing them out individually in cups.This allows the cane itself to be used for sugar extraction, rather than being put into the soil to sprout as is the common practice
2. Transplanting these seedlings while still young (25-35 days old) once they have emerged and stabilized
3. Maintaining wide spacing between plants (4 x 2 feet) in the main field when doing the transplanting
4. Providing sufficient moisture to the crop, but avoiding inundation of water
5. Encouraging soil health and fertility by adding organic material to the soil for nutrient enhancement, plant protection and other intercultural practices
6. Practicing intercropping with other crops, such as green gram, black gram, onion, radish and leafy vegetables for more effective utilization of land, which also enhances the health and fertility of the soil.

Table1. Growth and yield of sugarcane grown through bud chip technology and conventional planting methods (Mean of 2015-2016 and 2016-2017 cropping seasons)

Treatments	Germination of cane buds (%) at 45 DAP	Number of shoots/clump at 120 DAP	Number of tillers (000/ha) at 120 DAP	Length of cane (cm)	Girth of cane (cm)	Weight of cane (kg)	Number of millable canes (000/ha)	Brix	Cane yield (t/ha)
Conventional 3 bud sett planting	55.2	4.3	85.64	256	2.85	1.2	83.75	17.6	90.5
Bud chip method of planting	90.3	7.2	96.34	288	3.15	1.32	91.72	18.2	105.8

On-farm trial results (Table 1) clearly indicated that the bud chip technology provided higher cane yield (105.8 t/ha) as against 90.5 t/ha under conventionally planted crop by 3-bud setts, which was higher by 17% over conventional method of planting. The study, thus, suggests that the bud chip technology of sugarcane planting is worth adopting particularly by the small and marginal farmers in Odisha since it is not only high yielding but also cost effective and sustainable. In addition to higher yield and return, intercropping generates mid-season income for sugarcane farmers to meet the expenses for sugarcane cultivation and also fulfils the household requirement of food. The inclusion of short duration, high value crops in sugarcane-based production system as inter-and / or sequential crops holds great promise in increasing the land utilization efficiency, reducing the production cost, economizing the use of market purchased costly inputs and making the system sustainable.

Sustainability of sugarcane production and profit relays on the success of the ratoon crop which occupies at least 50% of cane areas of any point of time. It gives higher net returns than plant crop and requires less attention. But its management has remained quite neglected over years for many reasons. Since the crop is grown on leased land in most areas it is taken as a gift crop without much care and input management. Consequently it suffers from poor germination, seedling mortality and poor plant stand. Poor fertilizer management and plant protection measures which needs special attention.

Therefore, early stubble shaving (plant crop harvested one inch below ground level can overcome this problem and protect mortality), off barring (breaking soil compaction to ensure better root establishment through aeration, moisture and nutrient absorption) and gap filling (with 45 days old poly bag raised seedling to ensure proper plant stand) can ensure a good harvest from the ratoon crop.

Fertilizer management plays a significant role in ratoon growth. Addition of organic matter through trash mulching, re-composting, growing a green manure intercrop is quite possible. All the phosphorus, one third nitrogen (with extra 25% to prevent temporary immobilization) and potash should be applied immediately after stubble shaving and off barring followed by irrigation. All the post-harvest ratoon management becomes effective only with proper nutrition and water supply at the earliest.

Trash management in plant crop and more particularly in ratoon crop is of great significance. All the trash should be collected and spread as mulching which conserves soil moisture in the post harvest summer season and recycles nutrients - paddy organic matter after decomposition with onset of monsoon. The trash composting may be integrated with biofertilizers and chemical fertilizers to be more effective.

The effectiveness of each operation / component with and without fertilizer application has been well explained in Table 2.

Table 2. Yield response to ratoon management practices

Stubble shaving	Off barring	Trash burning	Trash mulching	Gap filling	Plant protection	Cane Yield (t/ha)	
						F_0 (No fertiliser)	F_1(With fertiliser)
x	x	x	x	x	x	36.2	44.2
x	✓	✓	x	x	x	40.1	52.3
✓	✓	✓	x	x	x	42.3	69.9
X	✓	x		x	x	45.0	78.3
✓	✓	x	✓	x	x	48.4	83.8
✓	✓	x	✓	x	✓	51.3	88.4
✓	✓	x	✓	✓	✓	55.0	98.2

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Potential of sugarcane–pulse intercropping in doubling farmers' income and nutritional security in Madhya Pradesh

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Introduction

- Sugarcane is a tropical plant and grown as cash crop in the world. India is the world's second largest sugar producer. In India, it is grown about 51 Lha with production of 4002 Lt. *(IVth Adv. Est. 2018-19)*. The average sugarcane yield in the country is about 74 t/ha *(Avg. 2014-15 to 2018-19)*. About 80% of sugar is obtained from sugarcane and the remaining 20% is produced through sugar beet. An average consumption of sugar is about 24 kg /person / year.
- India's sugar industry is the second largest contributor in agricultural GDP (approx. 6%) after cotton textiles. The sugarcane cultivation and sugar industry in India plays a vital role towards socio-economic development of the rural areas by mobilizing rural resources and generating higher income and employment opportunities. About 7.5 percent of the rural population, covering about 60 million sugarcane farmers is dependent and it is labour intensive crop, involved in cultivation, harvesting and ancillary activities.
- As per the notification, 535 mills have been allocated 20.5 lakh tonne of sugar for sale in the current month. This quota is 1.5 lakh tonne less as compared to the allocation for November 2018. Additional quota of sugar has been given to those mills that have completed more than half of the export quota during the 2018-19 season (October, 2019). The government has fixed fair and remunerative price (FRP) of sugarcane at Rs 275/quintal for the current marketing year. The FRP is the minimum price that sugarcane farmers are legally guaranteed to get from sugar mills. The crop, which has a more than 10 per cent recovery rate, will get an additional Rs 2.75 per quintal for every 0.1 per cent increase.
- Fluctuating trends in sugar production requires main focus on sugar. Thus development of climate resilient technologies to sustain the crop productivity as well as sugar production. Research and development efforts to increase productivity and sugar recovery have also shown desired results. Although, keeping in view the potential of sugarcane, there is still large scope to increase sugarcane productivity per unit area per unit time. To achieve this, sugarcane growing farmers are required to be ready to face new challenges, the global warming and aberrant weather situations etc. Thus, knowledge intensive technologies can sustain the modern sugarcane agriculture and sugar industry.

Uses

i) Sugar juice is used for making white sugar, brown sugar (khandsari) and jaggery (gur).

ii) Industrial by-product like Bagasse is used as fuel and also for production of compressed board paper, plastic and others and Molasses is used in distilleries for the manufacturing of ethyl alcohol, butyl alcohol, citric acid etc., and also used as an additive to feeds for livestock.

iii) Press mud can be used as soil amendment in saline and alkali soils.

iv) Green tops of cane are good source of fodder for cattle.

Global Scenario

- The total world acreage under sugarcane as recorded during 2017 is about 260 lakh ha with production at 18415 lakh tones and productivity 71 tonnes/ha. In the world, sugarcane is grown by 113 countries.
- India ranked second in area and production with 18% and 21% respectively of world area and production after brazil. Country's productivity at 80 tonnes/ha is higher than the world average productivity (71 tonnes/ha).

(Area-Lakh ha, Production-Lakh tonnes, Yield-tonnes/ha)

Country	Area		Production		Yield
Brazil	101.84	39.21	7585.48	41.19	74.48
India*	47.37	18.24	3799.05	20.63	80.20
China	13.77	5.30	1047.93	5.69	76.10
Thailand	13.68	5.27	1029.46	5.59	75.24
Pakistan	12.17	4.68	734.01	3.99	60.32
Mexico	7.72	2.97	569.55	3.09	73.78
Australia	4.53	1.75	365.61	1.99	80.63
Colombia	3.97	1.53	346.38	1.88	87.16
Guatemala	2.79	1.07	337.58	1.83	121.01
USA	3.66	1.41	301.53	1.64	82.41
Others	48.26	18.58	2298.69	12.48	47.64
World	**259.77**		**18415.28**		**70.89**

Source: FAO STAT and India*- DES, DAC&FW, New Delhi (2017)

National Scenario

- There are two distinct agro-climatic regions of sugarcane cultivation in India, viz., tropical and subtropical. Tropical region has about 41% area and contributes 47% of the total sugarcane production in the country. Thus, sub-tropical region accounts for 59% area and shares 53% of total production of sugarcane. Productivity of tropical region is higher than the sub-tropical region.
- In India, normal sugarcane area and production is 48 Lha and 3498 Lt respectively. Out of the total area, 21.86 lakh hectares is confined to Uttar Pradesh alone, earning a good sugarcane status and position contributing a remarkable >45% of the country's total area and a production of 1460.68 lakh tones (>41%) thereby ranking first both in area and production followed by Maharashtra both in area and production with 8.98 lakh hectares (18.58%) and 741.05 lakh tones (21.19%).While, Karnataka ranked third in area and production both with (>8% and >10%).

(Area-Lakh ha)

STATES / UT	Area						
	2013-14	2014-15	2015-16	2016-17	2017-18	Avg.	% Contri.
A. Tropical							
Andhra Pradesh	1.53	1.39	1.22	1.03	0.99	1.23	2.55
Gujarat	1.74	2.08	1.57	1.69	1.82	1.78	3.68
Karnataka	4.20	4.80	4.50	3.97	3.70	4.23	8.76
Madhya Pradesh	0.73	1.11	1.03	0.92	0.98	0.95	1.97
Maharashtra	9.37	10.30	9.87	6.33	9.02	8.98	18.58
Tamil Nadu	3.13	2.63	2.52	2.18	1.72	2.44	5.04
Telangana	0.39	0.38	0.35	0.29	0.35	0.35	0.73
B. Sub-Tropical							
Bihar	2.58	2.54	2.44	2.40	2.34	2.46	5.09
Haryana	1.02	0.97	0.93	1.02	1.14	1.02	2.10
Punjab	0.89	0.94	0.90	0.88	0.96	0.91	1.89
Uttar Pradesh	22.28	21.41	21.69	21.60	22.34	21.86	45.25
Uttarakhand	1.04	1.02	0.97	0.93	0.90	0.97	2.01
West Bengal	0.17	0.18	0.17	0.21	0.19	0.18	0.38
Other	0.86	0.92	1.11	0.91	0.92	0.94	1.95
All India	**49.93**	**50.67**	**49.27**	**44.36**	**47.37**	**48.32**	

Source: DES, DAC&FW,New Delhi

(Productivity-Tonnes/ha)

STATES / UT	Productivity						
	2013-14	2014-15	2015-16	2016-17	2017-18	Avg.	% Contri.
A. Tropical							
Andhra Pradesh	78.51	71.85	76.66	76.02	78.68	76.25	78.51
Gujarat	72.13	68.89	70.83	70.71	66.33	69.69	72.13
Karnataka	90.25	91.20	84.08	68.96	84.08	84.08	90.25
Madhya Pradesh	43.42	41.14	51.27	51.41	55.41	48.59	43.42
Maharashtra	82.07	82.23	74.65	82.52	92.00	82.54	82.07
Tamil Nadu	103.57	106.79	101.06	87.00	99.81	100.25	103.57
Telangana	86.48	87.97	68.71	71.07	74.41	78.33	86.48
B. Sub-Tropical							
Bihar	49.92	55.18	51.84	54.41	59.14	54.01	49.92
Haryana	73.52	73.91	71.96	80.62	84.50	77.20	73.52
Punjab	75.00	74.88	73.41	81.27	83.58	77.67	75.00
Uttar Pradesh	60.45	62.15	67.03	64.89	79.25	66.81	60.45
Uttarakhand	56.97	60.61	60.77	69.65	69.68	63.27	56.97
West Bengal	114.27	118.75	119.23	73.82	75.00	98.72	114.27
Other	48.43	43.03	36.06	47.07	49.06	44.33	48.43
All India	**70.52**	**71.51**	**70.72**	**69.00**	**80.20**	**72.39**	**70.52**

Source: DES, DAC&FW, New Delhi

Plan Performance (XIth to XIIth Plan)

- More than > 98 *per cent* of total sugarcane production has been contributed by 12 states of UP, MH, Karnataka, TN, Bihar, AP+Telangana, Gujarat, Haryana, Punjab, Uttaranchal, MP & WB.
- Plan analysis revealed that the national area and production increased by 4% & 5% respectively, but productivity is stagnant during XIIth plan over the previous plan. The area, production and yield increased significantly in the state of Bihar (55% & 72%) followed by MP (28% & 45%) and Karnataka (22 & 15%) during the same period. It is realized that the vertical expansion of sugarcane production in MP is existing which may be utilized through adopting improved technologies and intercropping with pulses.

(Area-Lakh ha, Production-Lakh tonnes, Yield-tonnes/ha)

S.No.	State	XIth Plan (2007-08 to 2011-12)			XIIth Plan (2012-13 to 2016-17)			% Increase over XIth Plan		
		Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield
1	Uttar Pradesh	21.05	1200.43	57.02	21.82	1371.46	62.85	**4**	**14**	**10**
2	Maharashtra	9.21	763.75	82.94	9.04	714.38	79.02			
3	Karnataka	3.55	316.95	89.18	4.34	365.25	84.08	22	15	
4	Tamil Nadu	3.24	346.90	107.16	2.79	277.90	99.66			
5	Bihar	1.61	75.80	47.22	2.49	130.69	52.43	55	72	11
6	AP + Telangana	1.99	158.07	79.27	1.71	131.86	77.20			
7	Gujarat	1.96	139.22	71.18	1.43	101.46	70.86			-0.4
8	Haryana	0.97	64.65	66.79	0.99	74.04	74.79	2	15	12
9	Punjab	0.80	49.77	62.05	0.89	66.78	75.21	11	34	21
10	Uttaranchal	1.08	63.85	58.94	1.01	62.50	61.80			5
11	Madhya Pradesh	0.68	28.07	41.02	0.88	40.79	46.50	28	45	13
12	West Bengal	0.16	13.45	84.74	0.18	18.58	104.12	12	38	23
13	Others	0.83	36.97	44.52	1.27	64.69	50.79	53	75	14
	All India	**47.14**	**3257.87**	**69.12**	**48.84**	**3420.38**	**70.03**	**4**	**5**	**1**

Source: DES, DAC&FW, New Delhi

State Scenario

- Madhya Pradesh rank 10th in area, 11th in production and productivity is far low (43 t/ha) among the all major sugarcane producing states as well as national avg. yield (71 t/ha).
- According to a survey by the Sugar Mills Association of Madhya Pradesh and the State Department of Agriculture, 15 sugar factories in the state have produced 35 lakh quintals of sugar from 34.8 lakh metric tonnes of sugarcane by the end of April, 2019. Another seven factories in Burhanpur and Narsingpur district are in the process.
- About 65% of the total sugarcane area of MP is in Narsinghpur district (approximately 75000 ha). It is termed as the sugar bowl of Madhya Pradesh. In this district, there are 09-10 sugar mills having 2500-3000 TCD capacity, but are not taking sugarcane development activities. In this situation, farmers are now very much eager to develop jaggery production

entrepreneurship and trying to install some improved plants for that. At present, there are around 3000 jaggery units and two automated khandsari plants in the area.

- Almost 35-40 per cent of the sugarcane grown in the state is used for production of jaggery and khandsari (another type of sugar). The sugar industry in Madhya Pradesh is gaining speed. The processing of sugar has increased five times in the last five years. Farmers are accepting this loss-less crop and this is leading to doubling of the output."
- Autumn planting is more common in in the state *i.e.* month of October. Good yield achieved planting upto 20th Oct. Delay in planting a reduction in yield observed as germination of sugarcane is reduced due to low temperature in late planting.
- Sugarcane farmers are totally dependent on cane varieties developed from other States of India as no sugarcane variety has been developed from research stations located in Madhya Pradesh. Sugarcane varieties viz., Co 0238, Co 86032, Co 92005, Co VSI 3102, Co VSI 8005, Co VSI 10001 and Co M 0265 are presently under cultivation, but with prevalence of various diseases particularly smut.
- Ridge & Furrows method is the most common planting method in the state. In this method, the ridge and furrows are opened with the help of redger by keeping 120cm distance between furrows in heavy soil and 105 cm distance in light and medium soil. Main and sub-irrigation channels are opened at an appropriate distance.
- Dry method is followed in heavy soil to avoid the pressing the sets deep into the soil. Sets are placed in furrow end to end by facing eye buds on sides and covered by giving a layer of soil. After completion of planting, irrigation is given to the field.
- District-wise area, production and yield of top ten districts in respect of production are presented below which together contribute to >88% and >93% of area and production of the State.
- District-wise analysis revealed that the highest area and production of sugarcane is in Narsinghpur, contributed >48 *per cent* and >60 *per cent* production of state's total sugarcane area and production. *The yield of Potential districts recorded higher than the State average yield (6.09 t/ha) in* Narsinghpur, Chhindwara, Burhanpur and Khargone *districts.*

(Area-000'ha, Production-000'tonnes, Yield-tonnes/ha)

District	Area	% Contri.	Production	% Contri.	Yield	Yield Index
Narsinghpur	65.00	48.93	486.77	60.16	7.49	123
Chhindwara	9.80	7.38	69.80	8.63	7.12	117
Betul	10.50	7.90	33.12	4.09	3.15	52
Dhar	5.40	4.07	32.47	4.01	6.01	99
Burhanpur	4.50	3.39	28.15	3.48	6.26	103
Datia	6.70	5.04	27.80	3.44	4.15	68
Barwani	4.40	3.31	26.03	3.22	5.92	97
Khargone	2.90	2.18	18.34	2.27	6.33	104
Balaghat	4.20	3.16	17.88	2.21	4.26	70
Hoshangabad	4.70	3.54	15.14	1.87	3.22	53
Total Above	**118.10**	**88.90**	**755.49**	**93.38**	**6.40**	**105**
State Total	**132.84**		**809.09**		**6.09**	

Source: State Govt. of MP.- 2018-19

Government Developmental Initiatives/Programmes in MP

NFSM- Commercial Crops (Sugarcane)

- Inception Year- 2012-13
- Budget Allocation (2019-20)- 59.44 Lakhs
- District Covered - 13
- Major Interventions and Assistance - i) Demonstration on intercropping & single bud chip technology with Sugarcane (Rs. 9000/ha – Rs. 8000/- for input & Rs. 1000/- for contingency); ii) Distribution of plant protection chemicals and Bioagents (Rs. Rs 500/ha or 50%); iii) State level training for 20 participants X 2 days (Rs. 40,000/Training).

Intercropping of Pulses with Sugarcane in M.P.

- Inception Year- 2018-19
- Budget Allocation (2019-20) - 8.78 Lakhs
- District Covered (Tot. 05) - Narsinghpur, Chhindwara, Betul, Barwani, Burahanpur
- Major Interventions and Assistance - i) Demonstration (Rs.9000/ha); ii) Distribution of seeds (Rs. 5000/qtls); iii) Distribution of PP Chemicals/Bio-agents (Rs. 500/ha); iv) Distribution of bio-fertilizer (Rs. 300/ha); State Level Training (Rs. 40,000/Training).

Major observations of monitoring/field visits (2018-19)

- The DPD visited 03 districts (Chhindwara, Betul, Narsinghpur) out of 05 districts covered under sugarcane intercropping programme during 2018-19. Out of 05 implementing districts, only one district (Chhindwara) has implemented the programme. The total 14 sugar mills are working in 5 districts.

On the basis of field visit, interactions with district officials, sugar factory's officials, beneficiaries, farmers and others stake holders are as under:

District wise intercropping area in MP

(Area 000 ha)

District	Area		Crops under existing intercropping
	Sugarcane	Intercropping	
Narsinghpur	65.00	9.85	Wheat, Gram, Lentil, Potato Onion , Coriander
Betul	12.88	0.11	Moong, Urd, Maize, Soybean, Gram
Chhindwara	9.80	0.90	Gram, Moong, Urd
Burhanpur	4.55	2.30	Gram, Moong, Coriander , Water melon
Barwani	6.00	0.10	Gram, Urd/ Moong
Grand Total	**98.23**	**13.26**	

Betul

- Inter-cropping of mung and maize with sugarcane, farmer's own programme (Shri Shyam Kishore Verma Vill.-Sinolwari Block-Betul) was excellent, and is already in practice.

- Had a meeting with "Shri Jee Sugar and Power Mill", village-Suhagpur, Block-Betul. Shri Ajay Kumar Tomar, Cane Manager briefed about the status of sugarcane and informed that this year less area under sugarcane coverage due to deficit rainfall. However, sustained efforts of this sugar mill were instrumental in increased area from 1200 ha during 2014-15 to 5000 ha at present. As an extension effort, the Mill provided technology and seed to about 3000 farmers.
- The Crushing capacity of the mill is about 2 lakh tons per season i.e. from Nov.15th to March 15th.
- Major varieties taken are CO 86032 (70% area), MS 1001, VSI 8005.
- Trash mulching is new technology, being propagated by the sugar factory among the farmers.
- Of the total area under sugarcane, about 20% is Arsali-sown in July; 10% area under Spring/summer-sown Jan. 15th to March 15th and remaining70% is major area under autumn (sharad), sown in Oct. to Nov.
- The average productivity is 250-300qtl./acre at present which earlier was 100-150qtl/acre., Maximum yield harvested is 800qtl/acre. The extension activities and hand holding by sugar factory has been a major boon to farmers.
- The single bud technology seed planting is in about 5% area in the district. In this technology, the required planting material is 5-6 qtl./ acre as against 25-30 qtl./acre. This technology saves ¾ the seed and Rs.10-12 thousands/ha as against the traditional system.
- Further, about 70% sugarcane area is under micro-irrigation due to deficit rainfall, exposure visit of the farmers arranged by the sugar factory on innovative famers' field has been highly useful in this adaption.
- Inter-cropping of soybean, gram, urd, mung with sugarcane is about 20-25% area.
- Trash-mulching technique conserves moisture for 1 to 1.5 months. Similarly, Kaoline is also used for moisture conservation @ 1 kg/acre using 200 ltr. Water.
- As regards the processing and value addition, more than 50% production of sugarcane goes to Gud ghani under preparation of gud.
- Review meetings with department, sugar factory and farmers have revealed that more subsidy and targets to sugarcane farmers and mill on MIS component could be a better strategy in coming year to sustain sugarcane production increase in cropping intensity and doubling farmers' income.

Chhindwara

- 45 demonstrations on intercropping with sugarcane (20 Urd + 25 Mung) have been conducted. Total sugarcane area coverage is 9000 ha in the district, area under intercropping is about 2000 ha during 2018-19.
- Visited/ interacted with the officials of "N. Punjab Sugar Mill, Chhindwara". Capacity 1200 tonnes, main sowing period is September to November, 5-10% planting is under single bud and remaining >80% under two bud system in the district.

- Visited field of Smt. Sanju Bai Raghuvanshi Vill. Tedni Block-Chouri where pulses inter-cropping with sugarcane has been taken. Seed of urd (Pratap Urd 1) 16kg, provided by SDA, other inputs arranged by farmer and submitted bill Rs 2480/- for claim of subsidy. Sowing 8th March, crop is at pod formation stage, irrigation provided 8-10 days interval, sprayed with Chlorpyriphos for control of white fly after 25 days of sowing. 19:19:19 spray at flowering stage, crop is in good condition.
- Based on the field visit, it is realized that the actual total cost of cafeteria which is being utilized by farmer is up to 5000/ha as against Rs.9000/ha in case of mung and urd, thereby poor fund utilization against the target.

Narsinghpur

- Narsinghpur mostly black cotton soils having clay content of 60-65 %, more water holding capacity and deficient in Mn and Fe, approximately 80% area is sprinkler irrigated and about 35% cane acreage is under intercropping with September-October planted sugarcane.
- Sugar mills produce press mud and sell to Nav Bharat Paper @ Rs.500/- per tones and provide subsidized to the farmers @Rs. 350/- per tones. It is suggested that DAC&FW may incorporate this component under PKVY assistance.
- Press mud compost is good option to enrichment of soil as it contains N-1.8%, P-2%, K- 1.4%, OC-15-20%, C:N ratio-10:1, moisture-20-25% and content enrich with ferrous sulphate, zinc sulphate, rock phosphate, humic acid, amino acid, EM solution, Azotobacter & PSB.
- Targeted productivity of sugarcane and package of practices for achieving target prepared by sugar millers in visited districts 1000qtl/acre.
- *Cost of production of sugarcane may be recovered within 3-4 month if proper intercropping with pulses in sugarcane field. The sugar factories and farmers have given this feedback.*
- Suitable time of sugarcane sowing is October-November; about 40% higher yield may be achieved through timely sowing.
- At least 4 fit row to row spacing required for use of sugarcane harvester.
- Also visited/ interacted with officials of Rewa Kripa Sugar Pvt. Ltd. Shahpura, Jabalpur. Area increased from 4000-12666 acre. Sowing period is October to December. Farmers are taking inter-cropping with sugarcane, peas, gram, coriander, potato, tur etc. Promising variety is CO 86032 and 2002. Average yield 200-250 qtls/ acre, maximum yield about 500qtls/acre. The sugar factories are involved in technology transfer.
- The sugar factories are ready to implement the intercropping component. These factories may also be provided funds for exposure visit of farmers on single bud technology planting, tissue culture and drip irrigation etc.

List of sugarcane factory in five implementing districts and varieties being taken

S.No.	Name of factory	Total Capacity (TCD)	Varieties
Narsinghpur			
1.	Kareli sugar mill Pvt. Ltd	4500	Co 86032 Co 9805 Co 238 CoM265 Co 94072 etc.,
2.	Mahakosal sugar and power industries Ltd Bachi . Narsinghpur	4000	
3.	Narmda sugar mill Salichouka, Teh. Gadarwara	4500	
4.	Aakrti sugar mill Pvt. Ltd Tumada, Teh. Gadarwara	1500	
5.	Sakti sugar mill Pvt. Ltd Kodiya, Teh. Gadarwara	4000	
6.	Vanshika sugar mill Pvt. Ltd Bilgua Teh. Gadarwara	2500	
7.	Rewa kripa sugar mill Pvt. Ltd Bhitoni District, Jabalpur	1600	
8.	Rajrajeshwari sugarmill Pvt. Ltd Mohpani, Teh. Gadarwara	1600	
Barwani			
9.	Shree Durga Khandsar(sugar) mills Mendrana Teh. Pansemal	2500	Co 86032 Co 265
10.	Olam Agro India Pvt. Ltd Gatwa Teh. Thikri	3500	Co- 0238, 86032, VSI -8005, CoJ 85
Chhindwara			
11.	N. Punjab Sugars Pvt. Ltd Harnakhedi Teh Chand	1200	Co 86032, 7318,CoM 265
Betul			
12.	Shrijee Sugar And Power Pvt Ltd, Sohagpur. Betul	2500	Co 86032 Co 62175
13.	Hanumant Sugar Pvt Ltd Danora Gene Joda Danora Dist. Betul	1500	
Burahanpur			
14.	Navalsingh Sahakari Sakkar Karkhana Maryadit, Naval naga, Burahanpur	2500	Co 86032 Co 419

Glimpses of field visit

Interaction with Sugarcane Mill Manger Rewa Kripa Sugar Pvt. Ltd. Shahpura, Jabalpur

Organic Farming (Intercropping with Mung-MH 421 District- Narsinghpur

Sugarcane Intercropping with Pulses (Mung) District-Betul

Best practices adopted by the farmers

- Farmers are taking utmost care to improve their soil fertility by adopting principles of organic farming in sugarcane based cropping systems viz., dhaincha/sunhemp green manuring, legume crops intercropping, application of decomposed organic manures, surface mulching of crops residues including sugarcane dry trash etc.
- Some sugarcane farmers have locally developed organic formulations involving Dhatura, Neem leaves etc. for the control of insect pests in field crops including sugarcane. They usually apply this formulation through sprinkler irrigation.
- Early planting of sugarcane in September-October and taking other popular crops as intercrops, namely potato, gram, pea, coriander, garlic, onion etc. with cane for higher production potentials and economic returns.
- Planting sugarcane at the row distance of 90:180 cm with the most popular intercrop of gram, and accordingly accruing higher monetary benefits.
- They have successfully addressed the constraints related to operational difficulties coming after trash mulching in between ratoon cane rows particularly during intercultural operations and fertilizer applications. For this purpose, they have locally fabricated an implement which performs shredding of cane trash residues and inter-culturing operations along cane rows in Narsinghpur district.
- To address the severe constraints of labour scarcity, the farmers have started adopting mechanization in sugarcane agriculture and accordingly, planting sugarcane in September/October at 4.5 to 5.0 feet apart to facilitate tractors running in between cane rows.
- The texture of black cotton soils is a problem for adopting mechanization in sugarcane cultivation. Some innovative farmers feed their crop with balanced application of nutrients particularly micronutrients after getting analyzed their soil samples. Foliar application of urea and other micronutrients is done by some of the farmers. But, in general, they need technologies for better crop management practices and balanced fertilization.

Major constraints

- The leading sugarcane production and marketing constraints identified by respondent farmers: included drought stress, fluctuating prices, low soil fertility, shortage of land, high cost of inorganic fertilizers, poor extension services, lack of improved varieties and pests and diseases.
- Drought stress: Drought stress has become a continued phenomenon in many parts of the region, limiting sugarcane production and productivity. Reduced and poor distribution of rainfall associated with climate change is heavily impacting on production and productivity.
- Fluctuating prices : The market challenges are worsened by lack of alterative market outlets.
- Transport Cost: Poor road system and networks is still a serious constraint to smallholder sugarcane farming, leaving some famers to depend on inefficient forms of transportation

including use of animals drawn carts. Further, high transport costs affect sugarcane marketing.

- Poor extension services: Poor extension service and lack of credit facilities to buy inputs as important constraints. Large quantities of agricultural produce perish before they are marketed, since smallholder farmers lack the technology for timely value addition and preservation. Therefore, there is a need to establish small and medium sugarcane enterprises and processing plants.
- Poor availability improved sugarcane varieties.
- Lack of awareness of improved methods of sugarcane cultivation and suitable implements for sugarcane cultivation.

Suggestion

- Sugarcane farmers of the district were suggested to develop sugarcane nursery using single bud sett (particularly cane node technology) in net houses in August and its transplantation in September as early autumn sugarcane crop, which will be useful in getting maximum survival of sugarcane plantlets in the field due to sufficient soil moisture after cessation of rains.
- Early establishment and growth with adequate root development help the cane crop to tolerate drought condition up to a certain extent. This practice of cane growing will offer an additional opportunity for intercropping of rabi/winter season crops.
- Most of the farmers are now switching over to jaggery production since sugar mills are of low crushing capacities, and also less developmental activities for the benefit of sugarcane farmers.
- The activities for scientific method of jaggery storage will be strengthened for a longer period. Tips for quality jaggery production with installation of improved pans for improvement in jaggery quality production were suggested. It was emphasized not to use chemicals during the process of clarification and tips for value addition were also given.
- The farmers were informed that the sugarcane requires more water and nutrients from soil to sustain higher productivity. There is a need to curtail the supply of irrigation water to sugarcane using micro-irrigation methods.
- Micro-irrigation saves at least 1/3rd of irrigation water (sustaining the same yield) and become more important in a situation of water scarcity or drought. In drip irrigation/ fertigation, both water and fertilizers are delivered to crop simultaneously through a drip irrigation system. Fertigation ensures that essential nutrients are supplied precisely at the area of most intensive root activity and according to the specific requirements of sugarcane crop. It results in higher cane yields and sugar recovery.
- Farmers were advised to remove and destroy the shoots infected with diseases like smut and GSD, and replacement of old varieties with new ones.
- Farmers were suggested to adopt integrated weed management practices for higher cane yield with better returns.
- Irrigation with held for about 10 to 15 days before harvesting.

- As informed by Reva Kripa Sugar mills Pvt. Ltd. (Shahpura, Bitoni, Jabalpur), the by-product of sugarcane i.e. press mud has been sell to Nav Bharat Paper @ Rs.500/- per tones and provide subsidized rate to the farmers @Rs. 350/- per tones. It is suggested that DAC&FW may incorporate this component under PKVY assistance.
- Press mud compost is good option to enrichment of soil as it contains N-1.8%, P-2%, K- 1.4%, OC-15-20%, C:N ratio-10:1, moisture-20-25% and content enrich with ferrous sulphate, zinc sulphate, rock phosphate, humic acid, amino acid, EM solution, Azotobacter & PSB.
- The sugar factories and farmers have given feedback, that the cost of production of sugarcane recovered within 3-4 month by taking proper intercropping with pulses in sugarcane field, this practices should be promoted for Doubling the Farmers' Income as well as Nutritional Security. Pulses are a Smart Food as these are critical for food basket, rich source of protein (20-25%) which is double of wheat and thrice of rice protein and help address obesity, diabetes, malnutrition etc.
- The sugar factories are ready to implement the intercropping component. Factories may also be involved/provided funds for exposure visit of farmers on single bud technology planting, tissue culture, drip irrigation/MIS component could be a better strategy in coming years to sustain sugarcane production increase in cropping intensity and doubling farmers' income with nutritional security.

Potential role of multiple cropping in doubling farmers' income and sustainable agriculture in India

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Multiple cropping is an agriculture system long adopted by marginalized small holder farmers, This practice was a meant to enhance farm productivity in limited farming area. In this paper, a brief review on the benefits of multiple cropping is discussed and the practices adopted by marginalized farmers, in general, are focussd. In multiple cropping, it is generally argued that the practices favour an efficient utilization of resources like air, water, light, space, and nutrients by companion crops in both temporal and spatial dimensions due to their differential growth habits and seasonality. Multiple cropping could be one of the viable alternatives to cope uncertainties and changes, where food and nutritional uncertainty looming large. The ultimate outcome of multiple cropping could be visualized in adverse or harsh environment for increasing agricultural production, ensuring livelihood and improving farm income. Various food products are obtained through multiple cropping. Farmers can overcome agrarian distress by adopting mixed/interpreting system. Multiple cropping helps in getting more than one crop simultaneously, so even if the selling price of one commodity is less, the other might compensate. By practicing these types of cropping patterns, farmers can produce more food, double their incomes and provide more support in the development of the nations. This clearly implies the importance of multiple cropping for small farmers who constitute majority in the developing countries like India.

Introduction

The growing world population needs an increase in food production, and therefore, it is needed to enhance crop yields to avoid famines and malnutrition. Past strategy was focused on the expansion of agriculture sectors for raising agricultural output in good turn of convalescing food security. The gross outcome has been a 45% augment in per head food production but this aggregate level has not been found sufficient for a country with a large population like India. Income earned by a farmer from agriculture is imperative to tackle agrarian trouble and encourage farmer's well being. The main aim of doubling farmers' income is central to promote farmers' welfare, diminish agrarian distress and convey uniformity among earnings of farmers and those working in non-agricultural professions. Doubling farmers' income by 2022 is quite challenging but it is needed and is attainable. Three pronged strategy focused on (i) development initiatives, (ii) technology and (iii) policy reforms in agriculture is needed to double farmers' income (http://vikaspedia.in/agriculture/policies-and-schemes). Multiple farming is a good approach of doubling income of farmers'. Multiple cropping is a type of mixed cropping and defined as the agricultural practice of cultivating two or more crops in the same space at the same time on the same field in a year (Andrews 1976). The component crops of a multiple cropping system neither necessarily has to be sown at the same time nor they have to be harvested at the same time, but they should be grown simultaneously for a great part of their growth periods. In intercropping, there is normally one main crop and one or more added crops, with the main crop being of primary importance for economic or food production purpose. This practice is an attractive strategy for small farmers to increase productivity and land labour utilization per unit of area of available land though intensification of land use (Seran and Brintha, 2010). Furthermore, intercropping of cereals with legumes have huge capacity to replenish soil mineral nitrogen through its ability to biologically fix atmospheric nitrogen. Therefore, this type of cropping patterns is very prominence for improving soil fertility. These types of cropping patterns is not a new form of agricultural technology, instead is an ancient means of intensive farming. These cropping patterns have been practiced in many parts of the world as a way to maximize land productivity in a small area in growing season by improving the intensity of land and labour use for better profit and stabilizing farm income (Joshi, 2007).

In these types of cropping systems, all the environmental resources utilized to maximize crop production per unit area per unit time. Biological efficiency of intercropping is improved due to exploration of large soil mass compared to monocropping (Francis, 1989). There are many socio-economic, biological and ecological advantages in these cropping patterns. This practice is an attractive strategy to smallholder farmers for increasing productivity and land labour utilization per unit of area of available land though intensification of land use (Seran and Brintha, 2010). Intercropping pattern is more common in tropical regions having more rainfall, higher temperatures, and longer growing seasons for continual crop production (Fininsa, 1996). The use of intercropping systems is more prevalent in developing countries, in general. The history of intercropping is old, however, the concept has received very little attention from agricultural scientists. Recently, some interest has been generated very recently as one of the climate change adaptation strategies (Degla *et al.*, 2016). Multiple cropping is a common practice in India, and it is mostly practiced by smallholder famers. The features of an intercropping system differ with soil, climatic conditions, economic situations and preferences of the local community. Several scientists have been working with intercropping systems and proved its success compared to the monocropping. One of the most important reasons for smallholder farmers to intercrop is to minimize the risk against total crop failures and to get different produces to take for his family's food and income (Steiner, 1982). Moreover, intercropping systems more efficiently used the growth factors because they capture more radiation and make better use of the available water and nutrients, reduce incidence of pests and diseases and suppress weeds and favour soil-physical conditions, particularly intercropping cereal and legume crops which also maintain and improve soil fertility (Ofori and Stern, 1987).

In orchard under tropics, intercrops such as legumes (soybean, groundnut, mungbean and seasonal vegetables such as brinjal, lady's finger, cucurbits including squash could be grown whereas in subtropics and temperate region, intercrops such as cole crops (cabbage, cauliflower, knoll-khol carrot, leaf mustard, turnip), radish, chayote, pea, kidney bean, parsley, onion, garlic, potato, and many locally available crops could be grown to provide healthy and nutritious food to the family, if not for commercial purpose. This will provide economic benefit to growers aside from controlling weeds in the orchards (Sanginga and Woomer, 2009).

Cropping system in India

The Indian agriculture is decided by the soil types and climatic parameters which determine overall agro-ecological setting for nourishment and appropriateness of a crop or set of crops for cultivation. There are three distinct crop seasons in India, namely *Kharif, Rabi* and *Zaid*. The *Kharif* season starts with South-West Monsoon under which the cultivation of tropical crops such as rice, cotton, jute, *jowar, bajra* and pigeonpea are cultivated. The *Rabi* season starts with the onset of winter in October-November and ends in March-April. *Zaid* is a short duration spring/summer cropping season beginning after harvesting of *Rabi* crops. There are four cropping systems in India such as (a) Rainy Season Cropping Systems: In this system of cropping, Rice, Sorghum, Pearl Millet (*Bajra*), Maize, Groundnut and Cotton are grown. (b) Winter Cropping Systems: In this system, wheat, barley and oats, sorghum and chickpea are grown. (c) Plantation and other commercial crops: Sugarcane, Tobacco, Potato, Jute, Tea, Coffee, Coconut, Rubber, Spices and condiments are important crops grown in this system. (d) Mixed Cropping: In this system, pulse and some oilseed crops are grown with maize, sorghum and pearl millet.

Multiple cropping in Indian farming systems

The farmers chose the crops for the cultivation on the basis of the factors like physical, social and economic. Sometimes, they cultivate a number of crops at their farms and rotate a particular crop combination over a period. But it is noteworthy that the best farming practices always followed by certain cropping patterns as well as cropping system for raising their productivity and also for maintaining the fertility of soil. Cropping pattern is a dynamic concept because it changes over space and time. It can be defined as the proportion of area under various crops at a point of time. In other words, it is a yearly sequence and spatial arrangement of sowing and fallow on a given area. In India, the cropping pattern is determined by rainfall, climate, temperature, soil type and technology. The cropping patterns in India can be presented by taking the major crops into consideration as the base crop and all other possible alternative crops. It is very important to identify crops and their showing agro-climatic condition so that they can be categorized. For example, wheat, barley and oats are taken as one category.

Potential of multiple cropping farming

Many techniques are available to enhance food production such as increasing cropping intensity, practicing multiple cropping, and using inputs in balanced amounts with effective plant protection measures. However, among those, multiple cropping is the most effective technique. Multiple cropping can be done in annual food crops, fodders, vegetables, fruit plants and perennial crops (Degla *et al.* 2016). Mixed cropping could enable the country to be self-sufficient in food production and export the surplus to generate revenue to finance the cost of other projects. Multiple cropping by definition makes effective use of inputs such as soil, water, fertilizer, land and labor, capital, the factors of production as a whole. Among the multiple cropping, both row or seed inter cropping, relay cropping and mixed cropping (Aiyer 1942) are important types practiced with main crops such as cereals, legumes, fruits, vegetables, forage and fodder and many other crops of economic importance. Examples of some crops which are frequently used in intercropping have been discussed below:

Sugarcane based cropping patterns

After Brazil, India ranked as a second sugar producer with an average productivity of 70–80 t/ha. In the world. Sugarcane being a significant cash crop, occupies about 5.00 million ha or 3.0% of the total cultivated area and approximately 7.5% of the gross value of the agricultural production in the country. Sugarcane industry is the second leading employment contributor after cotton and the textile industry, about 6 million farmers depends for their living on sugarcane cultivation and most of the agricultural labourers earn money by working on sugarcane. Farmers who are growing sugarcane crop can achieve higher income after adoption of advanced methods/practices of sugarcane cultivation. By using inter and multiple cropping systems, sugarcane growers not only get more income but also can enhance their income in different parts of the country. In intercropping, minor crops are planted in between rows or mixing of seeds in certain proportion with major crops. For instance, the crops like maize, mustard, garlic, onion, potato, okra, coriander, fenugreek, melons (watermelon, muskmelon) can be successfully intercropped with sugarcane crop in between the rows of sugarcane when establishment of major crop takes some time and competition between main crop and intercrops is minimum. The crops in intercropping may have a different sowing and harvesting time as well. Intercropping with sugarcane depends upon the season in which sugarcane is grown. Accordingly other companion crops within the main crop could be grown as bonus crops.

Rice based cropping patterns

Rice based cropping system is a major cropping system practicing in India. Rice based cropping system can be described as mix of farming practices that comprises of rice as the major crop followed by subsequent cultivation of other crops such as different cereals, pulses, oil seeds, vegetables and fibre crops. Intercropping of rice and other compatible crops is also widely practiced in many regions. In Kerala, rice intercropping with pigeonpea, finger millet, little millet, maize and cowpea is practiced.

Small scale farmers could enhance their productivity and cut costs by turning their plots into thriving ecosystems for instance, by using duck and fish in flooded rice fields to control pests and weeds and to nourish the plants with their droppings. Fish and ducks can provide protein supplement in farmer’s diet and even can increase the land productivity. In return, the duck and fish can control some of rice pest and weeds from the rice field (Mukerjee 2013).

Maize based cropping patterns

Legumes are not only important in rice based system, but equally important in maize based cropping systems. Maize based cropping systems in uplands, where legumes are incorporated include maize-lentil + mustard, maize-chickpea + mustard, maize-chickpea + barley or wheat, maize + cowpeas- mustard or wheat, maize + soybean- mustard or wheat- pigeonpea– fallow, maize + pigeonpea-fallow, maize +cowpea-mustard or wheat, maize +beans-mustard or barley, maize/black gram-mustard or wheat (Yadav 2003).

Intercropping with legumes

The morphological and physiological differences among intercrop components result in their ability to occupy different niches, (Keating and Carberry 1993). Thus, environmental resources could be more efficiently utilized and converted to biomass by mixed stands of crops than by pure stands. Intercropping of legumes with forage is done to improve quality of forage and maintain productivity of land. Mixtures of cereals and legumes are used extensively for forage production.

Intercropping with medicinal plants

Medicinal and aromatic plants (MAPs) plays an important role in uplifting rural economy and the demand is over increasing the world over (Rawat N. and Puni L., 2009). Intercropping of medicinal and aromatic plants with horticultural crops revealed that in general, medicinal and aromatic plants produce good vegetative growth (Ravitchandirane, V. and Haripriya, K., 2011). Stevia, Coleus, Ashwagandha, Khus, Aloe Vera, Gotu Kola, Calendula, Basil, Thyme, Rosemary and Kalmegh etc. are using frequently in daily kitchen, containing good health benefits and mostly used in pharmaceutical companies for medicinal purpose. Based on the present market prices of medicinal crops, it can be recommended to farmers for its large scale cultivation.

Fruit-cum-fodder-cum-crops-cum-animal production systems

Space available between the fruit tree (citrus: mandarin orange, sweet orange/naval orange, sour lemon, peach, plum, pear, banana, jack fruit, apple, guava), many locally available fodder trees are the best for the Intercropping. Many crops such as maize, millets (mainly finger millet and foxtail millet) and different legumes (cowpea, rice bean, green gram) can be utilized for inter and multiple cropping even in slopes and terrace riser of hills and mountains of India. Multiple cropping is especially important for fodder crops where it can provide enormous quantities of feedstuff for supporting sustainable livestock production. Thus, integration of fruit, fodder, animal and crops in the system is one of the most important subsystems of multiple cropping in India.

Role of multiple cropping in soil improvement

Multiple cropping could also help in maintaining soil fertility provided suitable crops such as legumes are included in the cropping system. For example, intercropping of legumes could increase the process of nitrogen fixation and enhance the nutrient status of the soil. An important aspect of multiple cropping is the utilization of nutrients more efficiently as the crops growing on the same piece of land simultaneously would have different nutritional requirements. Intercropping controls soil erosion by preventing rain drops from hitting the bare soil. In maize + cowpea intercropping, cowpea acts as the best cover crop and reduced soil erosion. It was reported that taller crops act as wind barrier for short crops. There are studies that intercropping are beneficial to conserve soil and it also improves soil condition in many ways. In brinjal+ groundnut intercropping, pod weight of brinjal in mono-cropping was low due to absence of intercrop which leads to high water evaporation in soil surface (Prashaanth *et al*. 2009). Complex diverse crop mixes, maintain or increase soil microbial diversity which is an indicator of good soil health. One gram of soil may contain over 1000 fungal hyphae and up to a million or more individual bacterial colonies which could help maintain soil health (Altieri, 1999).

Role of multiple cropping in plant protection

Mixed crops and cover crops can have some varying positive and some negative effects on soil pathogens such as *Brassica* species suppress plant parasitic nematodes and soil borne diseases like *Pythium* species by producing glucosinolate containing residues. Sudan grass is known for suppression of root-knot nematode (*Meloidogyne hapla*) in lettuce production, this may be caused by the release of cyanogenic compounds during decomposition of the Sudan grass residue (www.hort.cornell.edu/expo/proceedings/2012/)**.** There are instances that some repellent intercrops grown under sugarcane or fruit orchard as coriander, onion, garlic and fenugreek repel insect pests of the crops thereby increasing pollinators in the field have been reported.

Conclusion

Ecological agriculture has cited many social and economic advantages of multiple cropping such as avoidance of dependence on one crop, low requirement to import energy, and favouring the wildlife. Studies have shown that multiple cropping has number of advantages over mono-cropping. These include biological, physical, social and economic advantages for mobilizing resources in a sustainable manner, in general, and to small and marginal farmers in particular. In multiple cropping, better use of vertical space and time, efficient capture of solar energy and nutrients are utilized judiciously. It is a low input sustainable farming encompassing integrated farming system with respect to crop management, insect pest control, and efficient utilization of temporal and spatial relations, and crop mixtures better permit the functioning of complex mutualisms and beneficial interactions between organisms. Also, the multiple cropping might be useful in reducing hunger and food security to ever burgeoning population of developing countries. There are enough evidences that multiple cropping is beneficial over mono or sole cropping. Sole crops might be fully damaged by drought, floods, hailstorms, hurricanes and epidemics. As a result, farmers will lose the whole crop and investment, and this will be disastrous for poor farmers. However, multiple cropping provides insurance against crop failures, reduces incidence of pest and diseases and provides additional yield advantage from the intercrops as bonus yield. It is also necessary to empower farmers so that they can participate as equal partners in development. In the process of new technology generation and application, including its legal framework such as patent rights and access to genetic resources, care must be taken by the governments to discuss with farmers' representative organizations, the consequences for farmers both in the short and long term. There is a need to create awareness about the importance and usefulness of multiple cropping over mono or sole cropping. This can be done by involving active participation of both public and private institutions including farmers' organization in local, regional and global level.

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Maximising yield and profit through diversification in sugarcane: A farmer's perspective

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ABSTRACT

Field experiment were conducted in two consecutive years (2017 and 2018) in order to explore the effects of intercropping sugarcane with potato, onion in autumn and chilly in spring. This crisis demands alternate strategy to increase agricultural productivity and maximum economic returns per acre to feed the gigantic population. Intercropping in sugarcane has received much attention due to long duration and time to grow short duration crops and becoming popular among farmers, if it is properly managed. Intercropping has the potential to encourage the farmers to get maximum economic return per acre per annum. In the present study, an attempt was made to intercrop potato and onion, in autumn sowing and chilly in spring sown sugarcane plant. The experiment was made to evaluate the agronomic and economic performance of different intercrops with sugarcane in trench sowing system with distance of 13 cm row to row. Maximum return was achieved with sugarcane + potato as intercrop followed by onion and chilli in the study Maximum number of tiller, millable cane, and cane diameter and unit stalk weight were observed in the same crop combination. Brix (%) of cane juice did not varied significantly in different intercropping system studied. Hence, it is recommended to use these intercrop to increase the economic returns of sugarcane farmers in India.

Key words: Sugarcane, intercropping economic benefits, yield, intercrop of sugar beet

Introduction

India is the second largest producer of sugar after Brazil Over five million farmers are involved in the cultivation of sugarcane in tropical and subtropical India. The two distinct agro-climatic regions of the crop in the country subtropical region shares about45% and 55% of the total sugarcane area and production in country (Sundara 2011) Intercropping refers to growing two or more crops simultaneously on the same piece of land with a definite row-planting pattern to obtain higher productivity per unit area. Rapidly increasing population, increased demand for food, limited scope for extension of cultivation to new areas, diversified needs of small farmers for food and cash, etc. have necessitated the adoption of intercropping systems. In the case of sugarcane, much of the space between two rows of sugarcane remains unutilized for an initial period of 90-120 days, due to slow crop growth. Companion cropping offers an opportunity for profitable utilization of available space. Sugarcane growers take advantage of this and grow various short duration crops like cereals, pulses, vegetables and spices as intercrops to obtain interim return. Small sugarcane growers need not wait until the harvest of the sole crop to obtain financial returns. Intercropping of economically important short duration crops with sugarcane through utilization of the present limited land resources would help to sustain sugarcane cultivation and provide interim return to marginal and small farmers, besides meeting the ever-increasing demand for vegetables and pulses.

Potato has been reported to be promising intercropping autumn planted sugarcane in subtropical India. The results of the experiments carried out on the effect of intercropping of potato in sugarcane were reviewed by Rathi and Singh (1979). There have been several studies on intercropping of potato in sugarcane in Uttar Pradesh (Yadav and Prasad1991), Madhya Pradesh (Sharma and Dubey 1994) and north Karnataka (Roodagi et al. 2000)

Onion as a spice and vegetable was evaluated as intercrop by Kirtikar *et al.* (1972), Mathur (1980) and Singh and Rani (1996). The yield of onion could be increased under paired row system of cane plantation by accommodating higher intercrop population compared to the single row system. Intercropping onion with paired row cane showed the highest potential for increasing the net returns per unit area (US$ 562/ ha) under intercropped systems (Imam *et al.*1990). Higher yield of cane due to intercropping with onion was reported (Parashar *et al.* 1979). Onion was found to be a remunerative intercrop in studies at Sehore, Madhya Pradesh (Sharma and Dubey 1994; Sharma *et al.* 1986).

Great potential exists in India for increasing crop production and productivity through wider use of multiple cropping. In long duration crops like sugarcane, intercropping holds much promise. Due to slow establishment of sugarcane during the first 90-120days, the greatest scope for complementary effect lies in the addition of annual intercrops to the temporal system to improve resource use efficiency in the early crop growth period (Gopalasundaram and Kailasam 2003).

Legume intercrops in cropping systems enhance soil fertility through the excretion of amino acids into the rhizosphere. The nitrogen fixed by the legume intercrop may be available to the associated sugarcane in the current season itself, as sugarcane remains in the field for over nine months after the harvest of the legumes (Kailasam 1994). A further possibility of soil fertility improvement is through addition of crop residues, which on decomposition adds to the fertility of the soil. Since considerable addition of nutrient occurs through intercrop, there is a possibility of reducing N application through fertilizer. In general the optimum row spacing recommended for sugarcane is 90 cm which is widely followed in tropical India. Reduced row spacing is often preferred to accommodate higher cane population and increase cane yield in short duration and early maturing varieties (Sundara 1994). With the introduction of very high tillering and high yielding varieties of sugarcane, there is a possibility to adopt wider row spacing and still sustain cane productivity. Such wide row spacing permits intercropping without adversely affecting the cane yield and thus increases the overall productivity and profitability of the system. The present problem of labour shortage may worsen in future affecting the survival of sugar industry and cane growers. Wide row spacing becomes an important agronomic consideration in future in developing countries (For example, 150 cm row spacing was successfully attempted in the cane area of Uttar Pradesh state, India, which recorded higher yield than 90 cm row spacing (Nagendran and Palanisamy 1997)

High tillering and low tiller mortality in wide row spacing helped achieve such high yields in spite of the lower seed rate used. Wide row spacing of 150 cm is preferable for sugarcane based intercropping systems In the subtropical region, sugarcane is normally planted in autumn (September- October), i.e. before the onset of winter or during the spring season (February-April), i.e. after the cessation of winter. The cane planted in the autumn season germinates before the onset of winter and remains in the field without much growth until the spring sets in. During this period, the cane does not make much demand for the growth resources. This facilitates rising of any Rabi crop as intercrop with autumn planted sugarcane. Several studies demonstrated that the total productivity of crops in sugarcane + rabi crop intercropping system is substantially higher than the total productivity of crop in winter followed by sole sugarcane planted in spring season Keeping in view of additional advantage and income of intercropping, three different crops potato, onion and chilli were attempted in present study to see the performance of sugarcane and intercrop for better yields and better economic returns.

Materials and Methods

The experiment was conducted in Javandhia Group sugar industry research station field in 2018-2019 cropping season. The experiment comprised of three treatments viz., T1: solo sugarcane trench (control), T2: Sugarcane + potato followed by second intercrop sesame and T3: sugarcane+ onion T4 sugarcane + chilly. 2 plot size was 43560 square feet each. sugarcane variety Co0238 ,Co 86032 variety were used as test crop in the experiment. Row to row and plant to plant distance were 152.5cm and 45.72 cm, respectively with single bud sowing system. The spaces between two rows of sugarcane were 152.5 cm. Inter crops viz. onion and potatoes were planted between the vacant spaces of paired row sugarcane. Onion bulbs were planted in two rows with 20 cm row to row and 10 cm plant to plant spacing. Potato tubers were planted in one rows following the spacing row to row 152.5 cm and plant to plant 10 cm , chilly was planted one row to row 152.5 cm plant to plant 60.96cm. Fertilizer were applied @ N-130, P-35, K-60, S-20, Zn-3, N-50, P-20, K-30 and S-10, N-48.6, P-17.4, K-21, S-12.6 and Zn-2.4 Kg ha-1 for cane; potato; onion and chilly, respectively. Mustard oil cake @ 1 t ha-1 and cow dung 7 t ha-1 as organic manure (OM) were applied for potato and cow dung @ 3 t ha-1 were applied for onion. In sugarcane, full dose of P, S and Zn were applied in the trenches and thoroughly mixed with the soil by spade just prior to planting. Half of N and K were applied at 30 days after transplanting (DAT), remaining N and K were applied at 150 DAT. In potato, full dose of P, K and half of N were applied in the bottom of the furrow and was covered with 5 cm soil before planting. The rest amount of N was applied at the side of the row and covered with soil at 45 days after planting. In onion, full doses of P, K, S , one-third of N were applied at the time of land preparation; half of remaining N were applied at 21 and rest amount of N at 42 days after plantation. In chilly, full dose of P, K, S and Zn, half of N were applied at the time of final land preparation and rest amount of N were applied after 30 days of sowing. All cultural and pest control measures were done when required. Data on yield and yield attributing parameters of cane and Brix (%) of sugarcane and yield of intercrops were recorded and analyzed statistically at 5% level of probability using LSD test. Cost of production was calculated on the basis of the cost of land preparation, seed cost, fertilizer cost, pesticide cost, labour cost and interest on current capital. The crop should put forth its biomass early and cover the land surface so that weed growth is minimised and essentially it should come to harvest within 75-80 days of sugarcane planting. Most important is that at which time which crop is favourable for intercrop.

The different treatments were:

T1 Sole sugarcane

T2 Sugarcane+Potato second week October autumn sowing

T3 Sugarcane+Onion second week of October autumn sowing

T4 Sugarcane+Chilly February spring sowing

Treatments comprised of three cropping systems viz. sole sugarcane, sugarcane + potato, sugarcane + onion, and were tested in randomized block design with three replications. Autumn cane was planted in second week of October and two rows of onion and one row of potato were sown in between two rows of sugarcane on second week of October. Sugarcane was fertilized with 200:80:80 kg of NPK. Whereas, intercrops were fertilized on the basis of their population ratio in sole and intercropping situations with RDF. Other operations were done as per recommended package of practices for the respective intercrops. Sugarcane was given with full phosphorus and potassium and half nitrogen as basal and remaining half nitrogen top dressed in four three splits after harvest of intercrop.

1) Intercrop Sugarcane + potato

Intercrop of potato + sugarcane is quite profitable, if we plant sugarcane with a distance of 152.5 cm row to row it's easy to take one row of potato as intercrop both crops dose not disturbed each other in yield. Both the corporate sector and small growers are involved in potato production,

Sugarcane with potato

the former accounting for about 52% of production. About 42% of the potato is produced by small growers who do not have land and who rent interrows of sugarcane from sugar estates.

Potato is planted in every interrow of plant cane, and in alternate interrows of ratoon cane, and is harvested before the cane canopy closes. The potato does not reduce cane yields, nor does cane reduce potato yields. A package of husbandry practices has been developed and has been widely and rapidly adopted. The system is easy to manage, and most cultural practices can be, mechanized.

Harvesting of potato take place after 80 days of sowing. After harvesting of potato all sugarcane operations are easy to be done.

2) Sugarcane + Onion

Onion as a spice and vegetable was evaluated as intercrop with cane row of 152.5 cm row to row. The yield of onion could be increased under paired row system of cane plantation by accommodating higher intercrop population compared to the single row system. The yield of onion under paired row systems was 4.4 t/awhile it was 2.25 t/ha under single row system. Intercropping onion with paired row cane showed the highest potential for increasing the net returns per unit area. Compared to other crops, onion exerted least detrimental effect on the emergence, tiller, millable cane and yield of sugarcane.

Intercropping in spring

1) Sugarcane + Chilly

Sugarcane with chilly

Chilly: It is known as the most valuable crop of India.

It is used as a principle ingredient of various curries and chutneys, also used in vegetables, spices, condiments, sauces and pickles.

Sugarcane practice with intercrop chilly was been practiced in spring season and got great results as chilly crop is harvested in 110-120 days.

Intercrop of chilly + sugarcane is quite profitable.

If we plant sugarcane with a distance of 150 cm row to row its easy to take one row of chilly as intercrop both crops dose not disturbed each other in yield.

Both the corporate sector and small growers are involved in chilly production, the former accounting for about 38% of production. About 20% of the chilly is produced by small growers who do not have land and who rent interrows of sugar cane from sugar estates.

Expanded trial programme

After the initial trials had indicated that there were indeed potential benefits to be gained from intercropping cane with food crops, the trial programme was expanded considerably to investigate these benefits under a number of different climatic conditions. Specific trial sites were chosen in areas where large numbers of small scale growers were based.

A small experimental trial under IISR guidelines was been followed results are yet to come.

Sugarcane with sugarbeet

Table 1. Economic analysis of intercropping with sugarcane with varity Co 0238 and Co 86032

Cropping system	Yield (t ha)		Return (₹/ha)		Net profit (₹/ha)
	Cane	Intercrop	Cane	Intercrop	
T1) Sole sugarcane	77	-	242550	-	177560
T2) Sugarcane +potato	85	29.0	267750	232000	350500
T3) Sugarcane+ onion	83	1.60	261450	60800	226500
T4) Sugarcane +chilly	84	1.5	264600	72000	220600

Sugarcane yield increase by 17-24 t/ha, whereas farmer earned additional profit ranging between 103000 to 233000(table 1)

Results and Discussion

The economics of different intercrops with sugarcane were worked out and are presented in the data revealed. Higher yield of cane due to intercropping with potato was reported. Therefore, cultivation of short duration spices and vegetables like onion, garlic and coriander as intercrops in sugarcane can be a successful package as it provides the needed income during the early stages and increases the total productivity without affecting the cane yield in the system proved to be best combination, found similar results with sugarcane + onion

Potato has been reported to be promising intercropping autumn planted sugarcane in subtropical India with row spacing of 152.5 cm row to row in sugarcane crop. The results of the experiments carried out on the effect of intercropping of potato in sugarcane were reviewed by Rathi and Singh (1979). There have been several studies on intercropping of potato in sugarcane in Uttar Pradesh (Yadav and Prasad 1991, Karanjeet Singh Dhaliwal 2016), Punjab (Kanwar *et al.* 1990), Maharashtra (Nankar, 1990; Solanke *et al.* 1990), Madhya Pradesh (Sharma and Dubey 1994). sugarcane + potato and many other crop combination. Maximum income increased 38% in Madhya Pradesh, Uttar Pradesh respectively under sugarcane + onion intercropping system and the second highest income was 26.73% under sugarcane + potato intercropping revealed that the highest adjusted cane yield of 96.20 t ha-1 at observation .From the above discussion it is inferred that cultivation of short duration intercrops like onion and potato followed by sesame with sugarcane in paired row system were found profitable over sole planted sugarcane. Hence, both crop combinations may be suggested for achieving higher cane yield as well as to get interim benefit from a same piece of land.

Sugarcane crop after taking Intercrop at Karanjeet Singh Dhaliwal's farm in Palia Kalan Kheri, Uttar Pradesh

Conclusion

The review clearly brings out the positive effects of combining crops in sugarcane based cropping systems. Though there are overall biological advantages in intercropping system, most of the studies have indicated depressing effect of intercrops on the base crop of sugarcane. Although intercropping has been practiced traditionally for thousands of years and is widespread in many parts of the world, it is still poorly understood from an agronomic perspective and research in this area is far less advanced than comparable work in monoculture. This is due in part to the wide use of pure crop cultures in the developed world, in part to the relative lack of resources in the developing world, but not least to the complexity of the problems involved. Thus, more research is needed to better understand how intercrops function and to develop intercropping systems that are compatible with current farming systems. For an intercrop combination to be biologically advantageous, agro-techniques such as fertilizer application, seed rate of intercrop and base crop, and selection of suitable genotypes must be taken care of to reduce the depressing effect of intercrops on sugarcane and to increase the productivity and profitability of the intercropping system.

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Climate-smart agriculture and artificial Intelligence : Future strategies for doubling the sugarcane farmer's income

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ABSTRACT

Challenges for Doubling of Sugarcane Farmer's Income in India can be overcome by the future strategies involving, Climate-smart agriculture (CSA) and Artificial Intelligence (AI). Sustainably increase in agricultural productivity and incomes from crops including sugarcane, livestock and fish, without having a negative impact on the environment is an approach *i.e.* CSA, its adaptation are essential for maintaining productivity and our ability to adapt to climate changes and for mitigation, must avoid deforestation, manage soils and trees in ways that maximizes their potential to acts as carbon sinks and absorb CO_2 from the atmosphere, development of conventional agriculture, integrates multiple goals and manages trade-offs. Use of the modern/advance smart agricultural technologies and AI are giving accurate and timely information regarding crops, weather and insect-pests infestation *etc.*, to the farmers on mobile app may improve the crop productivity, reduce the risk and resulting more income of the farmers. Owing to long duration crop, sugarcane does not fit well in crop rotation along with important food crop like wheat, rice and maize. A number of important crops like potato, rajmah, wheat, garlic, cauliflower, lentil, coriander and black cumin have been identified as intercrop with autumn planted sugarcane but planting of crop in this season is hardly 20% while autumn planting gives 25% more yield and 0.5 to 1.0% additional recovery because it attains age of more than 12 months at the time of harvesting next year in comparison to spring planted crop which is about 9 months old. The cost of cultivation of sugarcane as main crop is realized from the produce of intercrops there by increasing the net profit per unit area of land. Ratoon crop cover 50% of total sugarcane cropped area of country every year with no proper ratoon managemnt resulted in low yield (loss of 35%). It needed climate smart ratoon crop and its management in term of scientific knowledge and technologies through artificial intelligence. Being a commercial crop, sugarcane plays an important role in the rural economy of the country. A novel variety of sugarcane in favourable climate under suitable fertilizer and water management can produce up to 474.24 t/ha Yield. The Government has set a target of doubling of farmers' income by the year 2022 the farmers will be able to enable their income by sugarcane cultivation with intercropping, *gur* preparation, other related entrepreneurship, livestock and fish cultivation using climate smart agriculture and artificial intelligence..

Key words : Sugarcane, Climate-smart agriculture (CSA) and Artificial Intelligence (AI), Doubling the Farmer's Income (DFI)

Introduction

Sugarcane provides useful raw material to over 25 types of Industries which utilizes its different components to produce Sugar and *Khandsari*, *Gur* and range of agro-industrial co-products like alcohol and its derivatives, fuel, chemicals, paper based news print, antibiotics, cattle feed and now bagasse based paper making is better option against its use as fuel for co-generation (electricity). Small scale industry for juice preparation/*Gur* making from which the bye product bagasse will be used for hand making paper which create additional employment opportunity and prosperity to the young and women workers. Doubling Farmers' Income is frequent distress, despite higher productivity and production. The demand for income growth from farming activity, has also translated into demand for the Government to procure and provide suitable returns. In a reorientation of the approach, this Committee suggests self-sustainable models empowered with improved market linkage as the basis for income growth of farmers. India today is not only self-sufficient in respect of demand for food, but is also a net exporter of agri-products occupying seventh position globally. It is one of the top producers of cereals (wheat & rice), pulses, fruits, vegetables, milk, meat and marine fish. However, there remain some chinks in the production armoury, when evaluated against nutritional security that is so important from the perspective of harvesting the demographic dividend of the country. The country faces deficit of pulses and oilseeds. The availability of fruits & vegetables and milk & meat & fish has increased, thanks to production gains over the decades, but affordability to a vast majority, including large number of farmers too, remains a question mark? The average income of an agricultural household during July 2012 to June 2013 was as low as ₹6,426, as against its average monthly consumption expenditure of ₹6,223. As many as 22.50 per cent of the farmers live below official poverty line. Large tracts of arable land have turned problem soils, becoming acidic, alkaline & saline physico-chemically. Another primary factor of production, namely, water is also under stress. Climate change is beginning to challenge the farmer's ability to adopt coping and adaptation measures that are warranted. Technology fatigue is manifesting in the form of yield plateaus. India's yield averages for most of the crops at global level do not compare favourably. The costs of cultivation are rising. The magnitude of food loss and food waste is alarming. The markets do not assure the farmers of remunerative returns on their produce. In short, sustainability of agricultural growth faces serious doubt, and agrarian challenge even in the midst of surpluses has emerged as a core concern. Farmers own land. Which is a powerful asset. and, that such an asset owing class of citizens has remained poor is a paradox. They face the twin vulnerabilities of risks & uncertainties of production environment and unpredictability of market forces, tackling above said points in view agriculture as a whole with sugarcane cultivation a future strategies for doubling of the sugarcane farmer's income which will be achieved after involvement of Climate-Smart Agriculture and Artificial Intelligence.

Challenges and opportunities for DFI

At present, the agricultural and allied sectors are facing several new challenges like reducing availability of quality water, nutrient deficiency in soils, climate change, farm energy availability, loss of bio-diversity, emergence of new pests and diseases, fragmentation of farms, rural-urban migration, besides globalisation of agri-food markets and trade regulations and those need to be addressed during the years to come. The farm sector stress and non-realisation of the desired/

accelerated growth rate are attributable to several factors, some of which are as follows:

Stagnant yields in last 20 years except in cotton–importing edible oils and yet to reach pulse–self sufficiency. Depletion of critical resources–water & soil, climate change–rising temperature and frequency of extreme weather events, infrastructure constraints–power, roads, storage (cold & dry) and other agri-logistics, low risk bearing capacity of farmers– poor farm returns. Low profitability in many crops / due to high vulnerability geographies – high cost of production; and less than remunerative returns. High market risks – information asymmetry and market inefficiency. Inadequate financial services– credit and insuranceg price & demand forecasts (useful in decision making) difficult. Poor use of technology and modern science–as reflected in wide yield gaps between FLDs (frontline demonstrations) and farmers' fields. In India, subsidies and increased awareness about fertilizers have led to a significant increase in fertilizer consumption. Importantly, while fertilizer consumption has continued to rise substantially, the elasticity of output with respect to fertilizer use has dropped sharply. During the period of 1970-71 to 2010-11, while food grain production grew by about 2.3 times, the increase in fertilizer (NPK) consumption was about 13 times (GoI, 2014). In the year 2013-14 food production was 264.8 million tonne with use of 24.5 million tonne of NPK fertilizers. The average crop response which was about 50 kg of food grain per kg of NPK fertilizer during the year 1970-71, fell to about 18.70 kg during 2010-11 and further down to about 10.8 during 2013-14. It also needs to be noted that the increase in fertilizer use has come at significant cost. The fiscal burden of fertilizer subsidy which was just ₹ 60 crore in 1976- 77, shot up to over ₹ 70,000 crore in 2012-13. It was as high as ₹ 72,437.58 crore in the year 2016-17). There are other important costs in the form of long-term soil degradation, degradation of water resources (in both quantity and quality), and general stagnation of yields due to application of sub-optimal nutrient ratios. Thus, disproportionate NPK fertilizer application, multi-nutrient deficiencies, and lack of organic manure application has led to reduction in the carbon content of the soil and contributed to stagnating agricultural productivity. This is turn has been getting reflected in high cost of production over the years.

Sugarcane itself known as cash crop, hence, doubling income will be easily achieved with respect to other crops after overcoming the few additional challenges related to this crop viz, cultivation of non recommended varieties creating disease (red rot) load, poor ratoon management, Cultivation of sugarcane in marginal land prone to abiotic stress such as water logging, drought and salinity, lack of proper irrigation, lack of proper farm mechanization, low input application, lack of harvesting schedule for early and midlate varieties, absence of plant protection umbrella against diseases (red rot, Smut and wilt) and insects (root borer, shoot borer and plassey borer) and lack of quality seed finally construction of industrial infrastructure and its proper regulations suitable for farmers as well as sugar mills. Owing to long duration crop, sugarcane does not fit well in crop rotation along with important crops like wheat, rice and maize but most of the crops, *viz*, potato, *rajmah*, wheat, garlic, onion, cauliflower, lentil, coriander, mustard, maize have been identified as intercrop with autumn planted sugarcane but planting of crop in this season is hardly 20 % while autumn plant gives 25% more yield and 0.5 to 1.0 % additional recovery. The cost of cultivation of sugarcane as main crop is realized from the produce of intercrops thereby increasing the net profit per unit area of land. Ratoon crop cover 50% of total sugarcane cropped area of country every year with no proper ratoon managent resulted as low yield (loss 30-40%) which needs climate smart ratoon crop and its management in term of scientific knowledge and technologies through artificial intelligence. In India. during the last 65 years, sugarcane production increased from 69.2 million tonnes (1950-51) to 350.00 million tonnes (2015-16). Being a commercial crop sugarcane plays an important role in the rural economy of the country. It has been estimated theoretically that a novel variety of sugarcane in favourable climate under suitable fertilizer and water management can produce up to 474.24 t/ha. In comparison to this, 464.03 t/ha and 335.42 t/ha have already been produced in progressive farmers field of Maharastra and U.P respectively (Yadav, 2007).

Average size of land holdings of Indian farmers is decreasing day by day owing to constant increase in human population. Presently, the proportions of marginal, small and big farmers in the country is 58.0, 18.0 and 24.0 per cent, respectively. Therefore, to meet the demand of food viz; cereals, pulses, oilseeds, vegetables, sugar, *etc.*, for the ever increasing population, raising production of these crops is of utmost importance. Since increasing the area under these crops is not possible due to limited availability of agricultural land, the only option is to increase the crop productivity on the available land. The productivity of land could be enhanced substantially by growing intercrops in the space left between sugarcane rows. Sugarcane crop remains in the field for a year or more and the space between sugarcane rows range from 70 to 90 cm providing ample chance for profuse weed growth which draws huge amount of nutrients and moisture from the soil. Hence, besides suppressing weeds in the inter-row spaces, additional production could be taken by growing suitable intercrops in between the cane rows. Some of the intercrops have been found to have no/negligible adverse effect on sugarcane yield. It has been proved by the results obtained at the different research stations that Sugarcane + maize intercropping system may fetch a profit of ₹ 93,457/ha., Sugarcane + *rajmash* and sugarcane + potato system are equally profitable. Sugarcane + potato system ₹ 321282 receiving 75% NPK produces cane yield similar to sugarcane + *rajmash* with 100% NPK. sugarcane + cauliflower ₹ 2,26,547 sugarcane + cabbage ₹ 2,37,525.

Intercroping of sugarcane with wheat additional income

Intercroping of sugarcane with coriander (₹ 10000) and Maize (₹ 13000) in 0.5 acre at farmers field in Samastipur Bihar

Fig.1. Photographic indication just for artificial intelligence related to Intercroping of sugarcane with wheat, coriander and mize at farmers field Samastipur Bihar and its cultivation for doubling the farmes income.

Sugarcane characteristically widely spaced, initially slow growing, long duration and one time income generating crop, lends ample scope for intercropping with short duration, high value and mid-season income generating crops for nutrition and economic security especially of small and marginal cane growers. Moreover, intercropping is a tool to promote autumn planting giving 15-20 per cent higher cane yield and 0.5 unit more sugar recovery than spring planted cane. The autumn sugarcane based intercropping systems involving pulses, oilseeds, cereals and vegetables with their productivity levels have been identified. Challenges related to cultivation of sugarcane varieties that must be recommended one, either by CVRC or SVRC for its commercial cultivation. Farmers have a better opportunity to cultivate sugarcane as intercrop, as photograph of Fig.1 indicated the farmers are getting double income with sugarcane crop, in another Fig.2 most of the photograph of intercrop are the pictorial view of farmers field while Fig.3 gives the importance of traditional cultivation in comparison of CSA & AI based Agriculture.

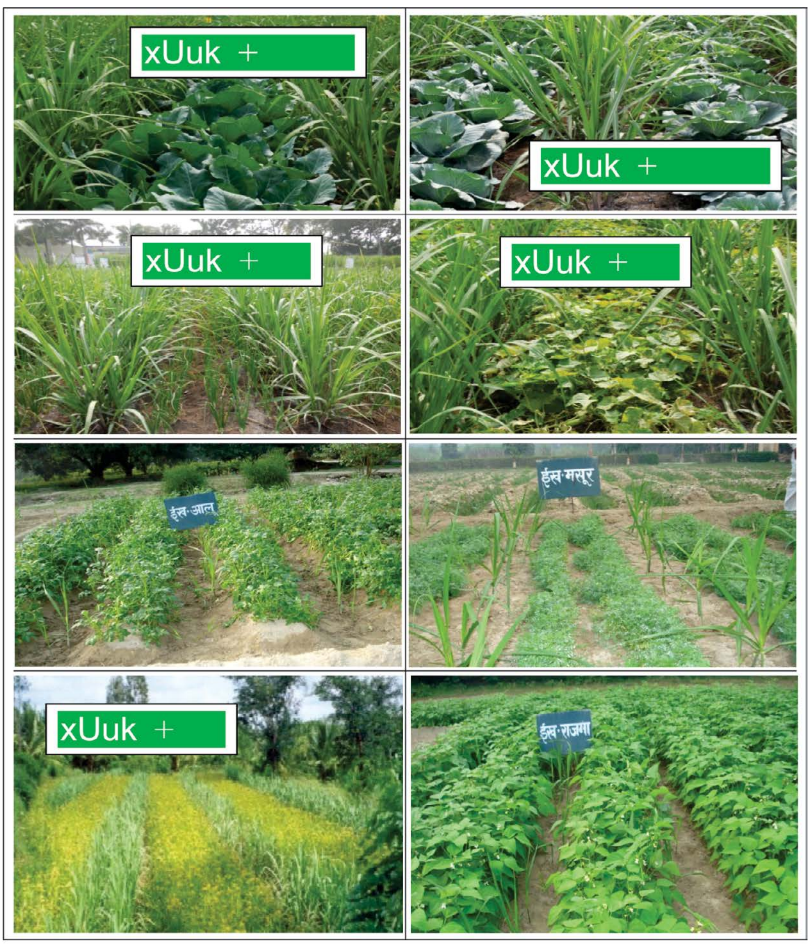

Fig. 2. Photograph of intercrop with sugarcane indication for artificial intelligence related to intercroping of sugarcane with cauliflower, cabbage, onion and maize for doubling the farmes income

Recommended varieties adapted to specific climate, smart ratoon management, specific recommendation and technologies for cultivation of sugarcane in marginal land, water logging, drought and salinity climate, proper drip irrigation or as per need solar operated timely irrigation, proper farm mechanization, proper input application, well prepared harvesting schedule for early and mid-late varieties, all information related to appear diseases and special control measure for plant protection Umbrella against diseases (red rot, smut and wilt) and insects (root borer, shoot borer and plassey borer), quality seed production follow participatory, its distribution and timely payment of cane price to the farmers through proper regulations as per suitable for farmers as well as sugar mills if needed than construction of industrial infrastructure. All the technologies related to DFI must be uploaded so that as per question in his mind they will get their answer immediately.

Traditional cultivation **Cultivation with CSA & AI**

Fig. 3. Photographic indication to show artificial intelligence related to sugarcane and its cultivation

CSA & AI : Future strategies for doubling the farmer's income(DFI)

Lipper *et al.* 2014 pointed out climate-smart agriculture as an approach for transforming and reorienting agricultural development under the new realities of climate change while as per Food and Agricultural Organisation of the United Nations(FOA), CSA has been defined as "agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes GHGs (mitigation) where possible, and enhances achievement of national food security and development goals". Here productivity, adaptation, and mitigation are identified as the three interlinked pillars necessary for achieving this goal. Digital Technology, which can play a transformational role in modernizing and organizing how rural India performs its agricultural activities to CSA. The technologies include Artificial Intelligence, Big Data Analytics, Block chain Technology, Internet of Things *etc*. By use of the modern/advance technologies and Artificial Intelligence (AI) and giving accurate and timely information regarding crops, weather and insects *etc.* to the farmers, may improve the crop productivity, reduce the risk and improve the income of the farmers

Artificial intelligences involved in sugarcane cultivation harvesting and transportation accounts for one third of the total production costs of sugar from sugar cane. To be more efficient, Bevap brought artificial intelligence and the Internet of Things into this process. This resulted in 8% increased efficiency representing € 150 million. Sugar cane production in Brazil amounts to 769 million tonnes per year while a typical factory processes 2 million tonnes. Companies are challenged every day to reduce costs, with harvest and transport being responsible for more than 30% of the total. Bevap understood that it could reduce costs by optimising the harvest. It identified points that could be automated to reach the expected return. To be even more efficient, Bevap brought artificial intelligence (AI) and the Internet of Things (IoT) into the process. In USA, the National Science and Technology Development Agency (NSTDA) has announced a two-year research collaboration with

Fig. 4. Photograph representing artificial intelligence related to sugarcane and its cultivation

IBM to improve the yield of sugarcane in Thailand. NSTDA and IBM, with domain knowledge support from Mitr Phol, the world's third largest sugar producer and the largest in Asia, will pilot an intelligent dashboard and mobile application to enable experts to access insights on crop health, soil moisture, pest and disease infestation risk, expected yield, and commercial cane sugar (CCS) index by leveraging the world's most accurate weather data from The Weather Company and industry-leading AI, Internet of Things (IoT) and analytics capabilities.

The Agronomic Insights Assistant is being developed by IBM researchers and is based on the IBM Watson Decision Platform for Agriculture and the IBM PAIRS Geoscope. These technologies integrate intelligent geospatial-temporal data (such as multispectral crop images captured by multiple satellites, soil data and digital elevation) and agronomic data (crop health, soil moisture level, pest/disease risk forecast, yield and commercial cane sugar index) with precise forecasts models from The Weather Company. This data is then combined with local sensing technology customized and enhanced for sugarcane farming in Thailand by NSTDA, and rich agronomic domain knowledge from Mitr Phol to provide actionable insights on water and nutrient stress, pest and disease risk, and agriculture production yield and crop quality index.

Major technology interventions

Kisan Suvidha mobile application to facilitate dissemination of information to farmers on the critical parameters viz., extreme weather alerts, Market Prices, Plant Protection; input Dealers (Seed, Pesticide, Fertilizer) Farm Machinery; Soil Health Card, Cold Storages & Godowns, Veterinary Centres and Diagnostic Labs., Farm Machinery package for Different Agro-Climatic Zones in India' mobile application, which gives information on farm machinery package available for state-wise, agro-climatic zone wise, district-wise, cropping pattern wise and power source wise., 'My Ciphet' mobile application to help farmers to get precise information regarding the ICAR developed post-harvest technologies, products and machineries. ICAR has also compiled more than 100 mobile apps developed by ICAR, State Agricultural Universities and Krishi Vigyan Kendras and uploaded on its website. These mobile apps developed in the areas of crops, horticulture, veterinary, dairy, poultry, fisheries, natural resources management and integrated subjects, offer valuable information to the farmers, including package of practices, market prices of various commodities, weather related information, advisory services, etc. Development of mKisan Portal (www.mkisan.gov.in) for sending advisories on various crop related matter to the registered farmers through SMSs**.** Launching of e-National Agriculture Market initiative to provide farmers an electronic online trading platform. Introduction of Soil Health Card Scheme to assist State Governments in providing Soil Health Cards to all farmers across the country once in a cycle of two years. Soil health card provides information to the farmers on nutrient status of their soil along with recommendations on appropriate dosage of nutrients to be applied for improving crop productivity and soil fertility. Using machine learning process along with different computer algorithm for crop classification and area estimation. The Government has also set up 713 Krishi Vigyan Kendras and 684 Agricultural Technology Management Agencies at district level for dissemination of technologies among farm community. In addition, farmers are provided information through Focused Publicity Campaigns, Kisan Call Centres, Agri-Clinics and Agri-Business Centres of entrepreneurs, Agri Fairs .

Conclusion

Doubling farmers income by 2022 is quite challenging but it is needed and is attainable. Three pronged strategy focused on (i) development initiatives, (ii) technology and (iii) policy reforms in agriculture is needed to double farmers income. To boost income of sugarcane farmers, intercropping of pulses, oilseeds or potatoes along with sugarcane is recommended. The country need to increase use of quality seed, fertiliser and power supply to agriculture purpose, irrigation has to be expanded by 1.78 million hectare and area under double cropping should be increased by 1.85 million hectare every year. Besides, area under fruits and vegetables is required to increase by 5 per cent each year. In the case of livestock, improvement in herd quality, better feed, increase in artificial insemination, reduction in calving interval and lowering age at first calving are the potential sources of growth. Research institutes should come with technological breakthroughs for shifting production frontiers and raising efficiency in use of inputs. Evidence is growing about scope of agronomic practices like, precision farming to raise production and income of farmers substantially. Similarly, modern machinery such as laser land leveller, precision seeder and planter, and practices like SRI (system of rice intensification), direct seeded rice, zero tillage, raised bed plantation and ridge plantation allow technically highly efficient farming. However, these technologies developed by the public sector have very poor marketability. They require strong extension for the adoption by farmers. R&D institutions should also include in their packages grassroots level innovations and traditional practices which are resilient, Sustainable and income enhancing. ICAR and SAUs should develop models of farming system for different types of socioeconomic and bio physical settings combining all their technologies in a package with focus on farm income. This would involve combining technology and best practices covering production, protection and post-harvest value addition for each sub systems with other sub systems like crop sequences, crop mix, livestock, horticulture, forestry. Such shift requires interdisciplinary approach to develop on knowledge of all disciplines.About one third of the increase in farmers' income is easily attainable through better price realization, efficient post-harvest management, competitive value chains and adoption of allied activities. This requires comprehensive reforms in market, land lease and raising of trees on private land. Agriculture has suffered due to absence of modern capital and modern knowledge. There is a need to liberalise agriculture to attract responsible private investments in production and market. Similarly, FPOs and FPCs can play big role in promoting small farm business. Ensuring MSP alone for farm produce through competitive market or Government intervention will result in sizeable increase in farmers' income in many states. Most of the development initiatives and policies for agriculture are implemented by the States and invest much more than the outlay by the Centre on many development activities, like irrigation. Progress of various reforms related to market and land lease are also State subjects. Therefore, it is essential to mobilise States and UTs to own and achieve the goal of doubling farmers' income. If concerted and well-coordinated efforts are made by the Centre and all the States and UTs, the country can achieve the goal of doubling farmers' income by the year 2022.

Ecofriendly management of sugarcane top borer, *Scripophaga excerptalis walker* with an egg parasitoid, *Trichogramma japonicum* in western Uttar Pradesh

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ABSTRACT

Trichogramma japonicum against sugarcane top borer, *Scirpophaga excerptalis wlk*. was studied specially top borer 3rd brood in the experimental plot of Sugarcane Research Centre Farm, Muzaffarnagar during crop season 2017-19 with Co 0118 variety. Among six treatments, *T. japonicum* @ 50,000 parasitized egg/ha showed superior result causing significantly reduction in infestation of target pest in top borer 3rd brood infestation, respectively as compared to control pot, other treatments of *T. japonicum* also gave significant result over control, Per cent incidence of *S. excerptalis* showed negative correlation with increase in number of *T. japonicum*, which indicates that it may be successfully utilized for the suppression of top borer under western Uttar Pradesh condition.

Key words: Scirpophaga excerptalis, Trichogramma japonicum, Variety Co 0118 and sugarcane

Introduction

Sugarcane top borer (*Scirpophaga excerptalis wlk*) is unique among the moth borer it infects sugarcane during all the stages of crop growth. The damage and losses caused by top borer are due to the mortality of shoots and canes and also due to the arrest in growth of the latter. In Uttar Pradesh, the yield losses assessed is 18.8 tonnes/ha at 55% incidence (Gupta and Mukunthan,1959) and 30% losses when the incidence is heavy (Rajani,1960). The losses in sugar recovery due to top borer infestation varies from 0.2-4.1 units (Raja Rao,1953; Rajani,1960). Loss due to top borer was recorded 22.4% in yield and 1.04% units in recovery at mid season and 11.3% in yield and 0.6% units in recovery at late stage of cane maturity (Pandey *et al*, 2016). The tunneling of the first instar larva in to the midrib causes a white streak that turns reddish brown subsequentlly and become visible from the ventral surface of the midrib forming an unique symptoms of attack (Huque and Agarwala,1955). The larvae bores it way to the central core of the spindle through the unfurled leaves, and a result rows of the shot holes become visible when the leaves unfold (Gupta1959; Mukunthan, 1985). As a larva feed by boring in to the narrow central core towards the growing point, it also nibbles the inner half of the leaf immediately surrounding the feeding region. This leaf dries up, become atrophid and turns dark brown forming the dead heart, when the fourth instar larva cuts the growing points,the leaf forming the deadhear is never served off transversely in the course of feeding by the larvae (Mukunthan 1985).

In the tillering phase of the crop the attack shoot die resulting in the formation of side tillers, while in the grand phase, the crop growth is arrested and the crown with the dead heart completely dries and may be blown off leaving only a stamp. In grown up canes, the infestation results in dead heart formation, which induces spourting of the lateral buds giving a "Bunchy Top" appearenc. Occasionally, top borer infestation induces aerial root formation (Singh *et al*,1980).

Sugarcane borers become a challenging pest of cane, due to its feeding inside the plant parts, where insecticidal sprayes are difficult to reach indiscriminate use of pesticide kill the natural enemies resulting in flare up to pest population (Yousaf, 1996). Incorporation of biocontrol as component of integrated pest management of top borer acquires immense prominence in recent days. Among different biocontrol, agents the egg parasitoid, *T. japonicum* proved to be effective in regulating the pest populationat egg stage (B. Bhavani, CH.V. Narsimsiha Rao, 2011). Management of top borer with egg parasitoid, *T. iaponicum* seems to have economic proposition because of the low cost production. Whenever the present study was designed to evaluate the relative efficacy of different dose of egg parasitoid of *T. japonicum* against 3rd brood infestation of sugarcane top borer.

Material and methods

Field experiment was conducted at Sugarcane Research Center at Muzaffarnagar during crop season 2017-19 to evaluate the relative efficacy of *T. japonicum* against sugarcane top borer in variety Co 0118 (early variety) planted during autumn season 2017-19. The experiment was laid out in RBD with six treatments including control in three replication as follows:

T_1: 20,000 parasitized eggs /ha

T_2: 30,000 parasitized eggs /ha

T_3: 40,000 parasitized eggs /ha

T_4: 50,000 parasitized eggs /ha

T_5: 75,000 parasitized eggs /ha

T_6: Control

The plot size was 10*5.4 meter^2 with recommended dose of fertilizer for sugarcane cultivation in the western Uttar Pradesh were followed without application of insecticides.

The numbers of paracitized eggs were released by stapling *T. japonicum* cards on fortnight basis in each treatment as per need. These cards were stapled on lower (ventral) side of sugarcane leaves, due to direct exposure of sunlight. Infestation of sugarcane top borer was monitored fortnightly on the basis of randomly selected canes from each treatment which consisted 25 canes from each replication. Damaged plants from these selected samples by *S. excerptalis* were counted and per cent infestation was calculated on this way:-

Per cent infestation=Damaged tillers*100/Total tillers

The per cent reduction in infestation over control was calculated as follows:

Per cent reduction=Damaged tillers in control plots-no.of tillers in treatment plots*100/ Damaged tillers in control plots

First installation of cards with paracitized eggs for 3rd brood infestati on , oriented doses were done on 15th June,2018 and last installation on 30Th October 2018. To evaluate the performance of the *T. japonicum,* and means infestation of top borer under study was compared in treatment plots with the control plots. Obtained data were stastically analysed by using analysis of variance.

Results and discussion

Perusal of data embodied in Table 1 revealed a significant reduction in percentage infestation of sugarcane top borer which ranged from 2.46 to 3.83% when 20,000 *Trichogramma* paracitized eggs were released, and 1.80 to 2.38% when 30,000 paracitized eggs were applied,when 40,000 paracitized eggs/ha were released 1.50 to 2.23%,when 75,000 *Trichogramm*a paracitized eggs were released, 2.34 to 3.08% maximum reduction 1.16 to 1.78% of sugarcane top borer was observed, when 50,000 *Trichogramma* paracitized eggs were applied per hectare in the experimental plots. Other doses of *Trichogramma* paracitized eggs showed significant differences over control or untreated. The result showed that maximum (3.83%) infestation of *S. excerptalis* present in the experiment was on 15.10.2018 followed by 1.65% and 0.70% on 30.09.2018 and 15.09.2018, respectively, when 20,000 paracitized eggs/ha were applied. The minimum 1.78% was observed on 15.10.2018 followed by 1.16% and 0.76% on 30.06.2018 and 15.07.2018, respectively, when 50,000 *Trichogramma* paracitized eggs were applied against 3rd brood infestation of top borer.

Table: Utilization of *T. japonicum* against sugarcane top borer (3rd brood) infestation

S. N.	Incidence per cent (Date wise)								
	Date-----	**30.6.2018**	**15.7.2018**	**30.7.2018**	**15.8.2018**	**30.8.2018**	**15.9.2018**	**30.9.2018**	**15.10.2018**
T_1	20,000,PE	2.46	1.78	1.37	0.98	0.36	0.70	1.65	3.83
T_2	30,000,PE	1.80	1.24	0.97	0.23	0.33	0.59	1.48	2.38
T_3	40,000,PE	1.50	1.08	0.93	0.23	0.14	0.49	1.40	2.23
T_4	50,000,PE	1.16	0.76	0.761	0.22	0.21	0.40	0.44	1.78
T_5	75,000,PE	2.34	1.76	1.31	0.16	0.08	0.69	1.00	3.01
T_6	Control	3.33	2.11	1.64	1.31	1.13	1.18	3.89	4.90
	CV	13.964	15.6356	19.9901	80.6921	162.29	53.1616	54.8783	
	SE	0.2074	0.1612	0.1648	0.2988	0.4055	0.2548	0.6388	
	CD	0.4418	0.3436	0.3513	0.6368	Nil	Nil	1.3613	

Tabulated data indicate, mean of three replication; P.E.=Paracitized eggs
Figures in parenthesis are presented per cent reduction in incidence over control.

The data clearly indicate that when the population of *Trichogramma japonicum* increased in the field due to successive releases, the infestation of top borer (*S.exceraptalis*) decreased in experimental plots,where 50,000 and 75,000 *Trichogramma* paracitized eggs were released, whereas in plots where 30,000 and 40,000 paracitized eggs were applied, infestation increased gradually. The maximum 1.78% reduction percentage was observed on 15.10.2018 when 50,000 *Trichogramma* paracitized eggs were applied and minimum reduction percentage was 2.46% on 30.06.2018 when 20,000 *Trichogramma* paracitized eggs were applied, similar trends was also observed on in 3rd brood infestation of S.exceraptalis in the released plots.

Thus, it may be concluded from the data that the population of *Trichogramma japonicum* directly proportional to the reduction percentage of *S.excerptalis;* when the population of *Trichogramma japonicum* was low, infestation of *S. excerptalis* remained high in 3rd brood infestation but as the concentration of *T. japonicum* paracitized eggs increased gradually the population of S.excerptalis also decreased that indicated the superior performance of *T. japonicum* against top borer in case of 3rd broods infestation in the sugarcane crop. The present finding of the study indicated that the release of 50,000 *T. japonicum* paracitized eggs/ha at an interwal of 15 days that is 30th June to 15th October is effective against under the western Uttar Pradesh agroclimatic condition.

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Strategies to improve cane area, production and productivity in Andhra Pradesh

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Sugarcane is one of the important commercial crops of Andhra Pradesh. There is a sharp decline in cane area and production in the state. Cane farmers are in desperate mood with sugarcane cultivation and are switching over to other more remunerative crops like maize, paddy, groundnut and pulses. Increased cost of cane production , in-ordinate delay in the payment of cane price by the sugar factory managements, non availability of labour, stagnation in cane yields, high requirement of irrigation water for the crop, stiff competition from other crops have led to reduction in cane area, production and productivity. Thus, cultivation of sugarcane has became non remunerative in the state.

Most of the sugar units in Co-operative sector have either closed or temporarily suspended cane crushing activities. Even the sugar units functioning in private sector are also contemplating to shut down the cane crushing activities to overcome the huge financial losses. Presently all the sugar units operating either in the Co-operative or in the private sector are not achieving the full installed capacity utilisation due to non availability of the raw material for crushing. They are not in a position to dispose sugar and pay the cane price timely to the farmers. Thus, the sugar industry and cane cultivation is in disaster stage in the state of Andhra Pradesh. Cane productivity also remained stagnant for five decades around 72-74 t/ha. However, there is no dearth in the availability of proven sugarcane production technologies in terms of varieties, crop production and protection.

Some of the promising clones developed by ANGRAU are not only under cultivation in A.P. but also in other states. They include Co A 92081 (87A 298), 83 V 15. 86V 96, 2003V 46, 91V83 and 84 A 125. Short cropping, sett treatment, trash mulching, pre- harvest maturity survey, varietal mix, ratoon cane management practices, micro nutrient deficiency correction, soil health management, crop geometry, crop residue utilisation, foliar nutrition, biopesticides, biofertilizers, balanced nutrition, remunerative inter crops, good cultural practices, integrated insect pest and disease management and management of crop under abiotic and biotic conditions developed by the Agricultural university are very well accepted by the cane farmers. On the back drop of the present status of cane cultivation / sugar industry, there is an urgent need to take immediate steps by all the four stakeholders to protect the rural based agro- industry in the state.

All the four players *viz*; the researchers, extension workers, cane farmers and policy makers should work jointly so as to overcome the present crisis in sugar industry in state of Andhra Pradesh.

Research scientists should evolve high cane yielding clones rich juice sucrose, resistance to biotic and abiotic stresses, climate resilient varieties, clones with good ratoonability, suitable for mechanical harvesting, diversified uses (ethanol, paper industry, Co-generation), high input use efficiency and clones suitable for different growing situations superior to the presently commercially grown clones adopting wide/ distant hybridization.

Emphasis on popularisation of low cost technologies (crop rotation, poly bag single node seedlings, suitable inter crops under irrigated conditions, trash mulching, production and supply of biofertilizers, biopesticides and usage of PMC & Distillery effluents to reduce raw material production cost, design and fabrication of location/region/site specific implements through PPP mode and production and supply of quality planting material for commercial cultivation.

The cane development/extension staff either in the sugar industry or in the Department of Agriculture should play active role in the production and supply of quality planting material adopting three tier system of seed production to achieve desired seed and varietal replacement ratio, maintenance of liaison farms, transfer of improved technologies through training programmes, demonstrations, print and electronic media.

The sugar factory managements on their part should make arrangements in bringing their client *i.e,* the farmer to their folds by clearing the long pending cane price dues, promoting implementable technologies, improving/augmenting irrigation facilities, timely supply of critical inputs, transport and harvesting system, soil health management, crop residue utilization, intercropping, biofertilizers, biopesticides promotion of fertigation so as to ensure sufficient raw material production and to extend crushing duration.

The policy makers should also take necessary steps for timely announcement of fair and remunerative cane price to the farmers at least one year in advance, liberal allotment/ release of SDF towards infrastructure development, diversification of products production in sugar units; establishment of soil testing labs, bio-pesticide labs, bio-fertilizer production & tissue culture units, augmentation of irrigation facilities , mechanization (location specific implements including cane harvesters); water saving technologies (fertigation, wide row planting), seed multiplication, varietal replacement, seed replacement; modernization of sugar units (minimum 2500 TCD), popularization of good agronomic practices for plant and ratoon crops, low cost technologies to reduce cost of cultivation (trash mulching & ratoon cane management), establishment of ancillary units (Ethanol production, Co-generation, Distillery units), reasonable price for green power and ethanol, leverage to sugar factory managements to produce products based on market trends ,bringing down the basic recovery linked to cane price from 10 to 9.5, incentives to renewable energy production and promotion of inter cropping under irrigated conditions, Industry- Institute linkage, favourable policies for blending ethanol in petrol/diesel.

ABSTRACTS

Sugarcane Farming: Future Strategy to Doubling the Farmers Income

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History of farming in India is known back since 9,000 BC. from NorthWest India. Farming means the method of crop cultivation gradually changed and refined over time, but the soil component remained as integral part for commercial agricultural production. Soil is the basis of life for flora as well fauna existing in nature and the humus content of soil is the main source of nutrients for plants life.

Our ancestor's foresightedness toward the importance of soil for crop production was very good they were aware for soil enrichment with organic manure and resultantly, the organic matter in the soil remained around 1 per cent till the time of Green Revolution, but as a result of the chemical based farming during last 50 years the average organic content of the soil has presently reduced been between 0.3 and 0.6 per cent. Today, our attention is only toward quantitative production with increasing use of chemicals and ignoring its effect on soil health & environment which leads to air, water, earth and environment pollution. We are getting high production from chemical farming but due to lack of quality production and residual effects of chemicals used for production, the outbreak of new diseases is increasing. If this indiscriminate use of chemicals continues and soil health is ignored, the crop production cannot be sustained for a long time as well as a serious threat to soil, crop and human health may arise in the future.

The major challenges in sugarcane farming are decreasing soil fertility and organic content of soil, depletion of ground water level, lack of water recharge system and increasing environmental pollution. The most suitable solution to all these problems is the natural farming which is also highlighted by Subhash Palekar in the name of S.P.N.F. The perspective of natural farming can be adopted by the farmers in the following way for doubling farmers' income by reducing cost of cultivation and increasing qualitative produce:

1. Due to the cost imposed by buying most of the inputs from the market, the farmer is trapped in a vicious cycle of self-murder. By SPNF method, the cost of cultivation is almost zero due to the maximum use of home made indigenous produce and that is why it is also called as "zero budget natural farming". The house litters like vegetable wastes, food remains *etc.* could be utilized properly.
2. Normally, an average of 60 to 70 quintals per hectare cane seed is required for planting whereas in natural method of planting (distance 8 X 2 ft) it requires only 2.5 to 3.0 quintals per hectare. Due to which the cost of seed worth ₹ 30000 per ha could be saved.
3. Taking of intercrops like onion, chilli, cowpea and chickpea *etc.* in between 8 feet rows of sugarcane not only give additional income of about ₹ 1.0 to 1.5 lacs per ha. but due to covering of soil and releasing antagonistic substances, disease / pest and weed infestation is also controlled which leads to the saving of at least ₹ 4,000 per ha. Secondly, the left over material of intercrops also add organic content to the soil, which ultimately reduces water demand of

sugarcane atleast 70 to 80 per cent and provide suitable environment for soil fauna & flora. It leads to saving of ₹ 22,000 to 23,000 per ha.

4. The chemical fertilizers can be replaced from *Jeevamrut* & *Ghanjeevamrut* prepared at home from dung and urine of *desi* cows. It will save about ₹ 20,000 per ha, and equally effective for plant nutrient as chemical fertilizers.
5. Use of the home made plant protection solutions like *Neemastra*, *Agneyasthtra*, *Brahmastra* and *Dasparni* Ark for controlling insect-pest & diseases instead of expensive and harmful chemical pesticides, makes possible the saving of about ₹ 8000 per hectare as well as reduces environmental and human health hazards.
6. According to the UPCSR, the cost of cultivation for the year 2018-19 of sugarcane crop in Uttar Pradesh, is estimated to about ₹ 1.99 lakh per ha. On the basis of this cost of cultivation the saving of farmer is about ₹ 60,000 rupees per ha. on average yield of 80 t/ha. In case of natural farming, the cost of cultivation is reduced by about ₹ 80,000 rupees per ha, and the total income / saving of the farmer increased to ₹ 1.40 lakh per ha. It means by the natural farming farmer can get 2.25 times more income over than chemical based farming. In addition to above, by adopting natural farming method, farmers can easily take 4 to 5 sugarcane ratoon crops, so that the additional saving of 23.50 per cent of the expenditure on field preparation, seed and sowing of plant crop could be saved in every ratoon and the a farmer can earn up to 3 times income. Due to regular use of organic compounds, soil health is also maintained sustainably.

Therefore, it is the need of the hour to shift from chemical based farming to natural farming which is sustainable, eco-friendly, cheep and to obtain produce, free from hazardous chemical residues.

Integrated nutrient management for sugarcane plant–ratoon system

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Continuous use of high analysis fertilizers has resulted in imbalance of nutrients in soil, poor growth and decline in sugarcane productivity. In view of the increasing cost of fertilizers and the need to improve and sustain soil health, integrated nutrient management (INM) involving a judicious combination of organic, inorganic and biofertilizers is essential for sustainable sugarcane production. The efficiency of applied nutrients could be raised by the combined use of organic manures, inorganic fertilizers and biofertilizers. The present investigation was carried out to determine the effect of integrated nutrient management (INM) for sugarcane plant –ratoon system. In this context field experiments were conducted to study the effect of INM for sustainable sugarcane plant-ratoon system at Sugarcane Breeding Institute, Coimbatore (11^{o}N latitude and 77^{o}E longitude at an altitude of 427m MSL) during the year 2007-11. The experiment was laid out in Factorial RBD with 18 treatment combinations involving 3 levels of Nitrogen (140, 210 and 280 kg/ha), 3 levels of Farm yard manure (no FYM, 6.25 t/ha and 12.5 t/ha) and 2 levels of liquid biofertilizer mixture (no biofertilizer, biofertilizer @ 6 litre/ha) with three replications. The sugarcane variety was Co 86032. In first plant crop, higher NMC of 124.8 thousands/ha was produced with 6.25 t/ha FYM closely followed by 124.3 thousands/ha at 280kg N /ha. Similarly, in second plant crop significantly higher NMC of 111.3 thousands/ha was produced with 12.5 t/ha FYM. It was observed the addition of organics and biofertilizer has a tendency to increase cane yields in plant as well as ratoon crops, even though the effects were non-significant. In first plant crop, N level (280 kg/ha) has responded to cane yield (200.6 t/ha). At lower levels of N (140 and 210 kg N /ha), there was increase in trend of cane yield (191.3 t/ha at 140 kg N /ha and 199.3 t/ha at 210 kg N /ha). While in second plant crop, higher cane yield of 138.9 t/ha with 12.5 t/ha FYM and 137.6 t/ha at 280 kg N /ha were recorded, however non-significant. Similarly, both the years of ratoon crop, N levels (280 kg/ha), there was significant response to cane yield (170.3 t/ha in 2008-09 and 135.4 t/ha in 2009-10). Similar increase in trend of cane yield was recorded with application of FYM levels.

The mean cane and sugar yields of plant and ratoon crops of two crop cycles obtained from the integrated application, showed that application of 140 kg N along with 12.5 t of FYM and 6.0 litre/ha biofertilizer produced the highest cane (154.74 t/ha) and sugar yields (19.71 t/ha) as compared to their individual application. It is concluded that integrated nutrient management recorded saving 50% N fertilizers due to application of FYM (12.5 t/ha) along with liquid bio-fertilizers (6 litre/ha). This will not only enhance growth, yield and quality of sugarcane plant -ratoon system but also conserve agro-ecosystem for higher sugarcane productivity, sustaining soil health and enhancing the farmers' income.

Agronomic approaches for doubling sugarcane farmer's income

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Sugarcane is as multi-purpose crop and have economic values. In the present era of energy crises, it is also coming up as a biofuel crop as mixing of ethanol by 10-15 per cent has already been recommended. It requires higher levels of nutrients and water for better growth and development. India's 54.6 per cent of the population is engaged in agriculture and allied activities (Census 2011). The programme of doubling farmer income was announced by the finance minister during his budget speech on February 29, 2016. Doubling real income of farmers till 2022-23 over the base year of 2015-16, requires annual growth of 10.41 per cent. Doubling sugarcane farmer income in nominal terms is possible by increasing sugarcane crop output, SAP and FRP, which in real terms would be a daunting task but there is every possibility not only to double the income of farmers through enhancement in productivity changes in cropping pattern, inspiring additional income through many supplementary activities but also provide stability in farmers income. Major sources for enhancing farmers income through agronomic interventions should address the challenges of reducing the cost of cultivation as well as increasing the productivity of the farm through subsoliling, soil test based nutrient application-soil health card distribution, adoption of modified paired trench planting method, intercropping, mechanization, avoidance of burning sugarcane trash and modern ratoon management system. Subsoiling by Pant ICAR subsoiler cum differential rate fertilizers applicator improved cane yield by 16.2 and 26.6% over no subsoiling in plant and ratoon crop, respectively. Cross subsoiling at 1.0 m distance should be done to ameliorate soil physical conditions and to improve sugarcane productivity. Two harrowing or rotavator once have been good enough to achieve desired soil tilth. Hard pan could be alleviated with the help of deep soil loosening subsoiler equipment. This equipment improves soil structure by establishing a system of deep cracks and or fissures in the subsoil, facilitating the downward movement of water, air and roots enabling plants to withstand better against short term anaerobic conditions, enhances or re-establishes the soil profile structure allowing rapid infiltration. Soil health cards are helpful to farmers because of soil nutrients status based fertilizer use in crops. The soil health card evaluates the health or quality of a soil as a function of its characteristics, plant and other biological properties. The soil card is a tool to help the farmer to monitor and improve soil health based on their own field experience and working knowledge of their soils. Paired row trench planting method is done at 30:120 cm in subtropical India. In this method, trenches are opened at centre to centre distance 150 cm with the help of tractor drawn trench opener machine with 25-30 cm trench depth. The bavistin treated sugarcane setts are placed along the walls of the trench. The mixture of fertilizers should be uniformly spread in the trenches. Trenches are filled upto 2.5cm above the setts with loose soil after planting. Trench planting method avoids lodging of cane in plant and ratoon crop. Paired row planting is the best practice for surface drip irrigation system and involving maximum resource use efficiency and cane productivity. This is urgently needed for improving productivity of sugarcane crop through energy efficient water saving irrigation system i.e. per drop more crops – drip irrigation system. Intercropping generates mid-season income for sugarcane farmers to meet the expenses for sugarcane cultivation and also fulfils the household requirement of food, fibre and oilseeds. The inclusion of short duration, high value crops in sugarcane-based production system as inter-and/or sequential crops holds great promise in increasing the land utilization efficiency, reducing the production cost, economizing the use of market purchased costly inputs and making the system sustainable. Suitable crop for intercropping with sugarcane is potato, onion, garlic, wheat, pea, coriander and other vegetables crops. Doubling the sugarcane farmers income woild increase the interest of farmers to modern management system of ratoon canes. Ratoons are economical by about 25 – 30 per cent in the operational cost because of saving in the cost of setts and initial preparatory cultivation. Ratoons save time as they early establish and mature, therefore can be harvested early. Farmers will get time to grow other crops or have enterprises in the farm. We can say that income of sugarcane farmers can be doubled by adopting new modified agronomic techniques and practices.

Doubling the income of cane growers by increasing cane productivity with reduced cost through various sustainable agro-techniques and intercrops

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It is well known that sugarcane (*Saccharum* species complex), is one of the most important cash crops of India, provides livelihood to about 34 lakh farmers' families in Uttar Pradesh. The problem of shrinking agriculture lands and increasing demand of sugar have made the agricultural scientists anxious for increasing the cane and sugar productivity through rapid spread of newly developed varieties with high yield potential and suitable agro-techniques. Since the central Government has fixed the target to double the farmers' income by 2022-23. In this ambitious target, sugarcane crop can play vital role. In India, this crop is grown in about 5.00 million hectare area and occupying 3% of gross cropped area. In recent years, sugarcane improvement and management programmes have contributed to substantial increase in sugarcane yield within the country but for doubling farmers income, it is imperative that the quality, productivity of cane and sugar and energy, value added product have to need more technological importance.

Keeping in view the above points, so many experiments have been conducted at U.P Council of Sugarcane Research, Shahjahanpur, (U.P). One experiment among those revealed that modified trench method of planting gave 118.70 and 121.66 t/ha cane yield during 2007-09 and 2008-10, respectively compared to conventional flat method (93.91 and 95.83 t/ha). Since U.P. C.S.R, Shahjahanpur is a premier sugarcane research organization at not only the state level but has also released more than 200 varieties. Among them, 32 are in cultivation at present. Soil fertility and productivity is an alarming situation in the state. To achieve double income without impairing the soil fertility, an experiment was conducted by modified trench method of sugarcane planting during autumn season in 2016-2018 (two years) in paired row with wider spacing (30:120 cm) with medicinal and aromatic plants *viz;* peppermint, marigold and chamomile as intercrops. Among intercrops, peppermint gave better result and net profit simultaneously with maximum cane yield. Also the soil fertility status was improved and there was no any infestation of pests and diseases.

Onion and potatoes as an intercrop augments productivity of autumn sugarcane

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Sugarcane crop remains in the field for a year or more and the space between sugarcane rows range from 70 to 90 cm providing ample chance for profuse weed growth which draws huge amount of nutrients and moisture from the soil. Hence, besides suppressing weeds in the inter-row spaces, additional production could be taken by growing suitable intercrops in between the cane rows. An experiment was conducted to evaluate the agronomic performance of different intercrops *viz.,* Onion (*Allium cepa*), Potato (*Solanum tuberosum*) with sugarcane in paired row system. The experiment comprised three treatments *viz.*, T1: sole paired row sugarcane (control); T2: Sugarcane + onion; T3: sugarcane + potato .The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 6x3 m^2. Forty five days old two eyed soil bed settling of variety CoS 687 were used as test crop in the experiment. Row to row and plant to plant distance were 55 and 40 cm, respectively. The spaces between two rows of sugarcane were 90 cm. Onion bulbs were planted in 3 rows with 20 cm row to row and 10 cm plant to plant spacing. Potato tubers were planted in two rows following the spacing row to row 15 cm and plant to plant 15 cm. All cultural and pest control measures were done when required. Data on agronomic parameters of cane and brix (%) of sugarcane and yield of intercrops were recorded and analyzed statistically at 5% level of probability using LSD test. The highest number of tiller was found from T1 (sugarcane) followed by T3 (with potato) and least number of tiller was found from T2 (with onion). Maximum cane height was found from T3 (3.20 m) followed by T2 (2.97 m) and the maximum diameter of cane was found from T3 (5.01 cm), followed by T2 (4.97 cm) at harvest. These might be possible due to non-exhaustive and dwarf nature of the intercrops and residual effect of the additional fertilizers as well as cultural practices and irrigation applied to companion crops on sugarcane. The highest brix per cent was obtained from T3 (18.95%) followed by T2 (16.99). It was observed that potato as intercrop did not show any antagonistic effect on yield and yield attributing parameters of sugarcane and gave second highest tiller, maximum height, diameter, and unit stalk weight. Onion as intercrop also did not show any adverse effect on sugarcane growth but it produced minimum number of tiller it might be due to more competition of the crop for nutrient and water than that of potato.

Intercropping in sugarcane: A major tool for enhancing farmers' income

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Sugarcane is characteristically widely spaced, initially slow growing, long duration and one time income generating crop which lends ample scope for intercropping with short duration, high value and mid-season income generating crops for household nutrition and economic security, especially of small and marginal sugarcane farmers. Intercropping of pulse crops in the sugarcane provides ample scope of increase in area under pulse crops under irrigated agro ecosystem. Moreover, intercropping is a tool to promote spring planting of sugarcane which gives 15-20 per cent higher cane yield and 0.5 unit higher sugar recovery than spring planted cane. To achieve higher productivity, harness positive associative complimentarily of intercrops and make the system economically more viable, the choice of compatible crops and suitable genotypes and development of appropriate management strategies are the key factors. Studies conducted at various locations have established profitable sugarcane based intercropping systems involving pulses, oilseeds, cereals, vegetables, spices and fodder crops at their higher productivity levels. Moreover, intercropped pulses improved soil fertility through entire leaf fall at pod maturity besides root mass addition. Considerable improvement in physical, chemical and microbial properties of soil takes place. The crop diversification option through prominent intercropping systems generates ample employment opportunities in sugarcane farming. Intercropping of rajmash, mustard, potato and maize (cobs) in autumn planted cane has been found quite remunerative. Similarly, intercropping of dual purpose grains legumes (cowpea and green gram) in spring planted cane is able to provide higher monetary benefit. Intercropping of high density forage legumes, viz. berseem and shaftal in winter initiated ratoon is also found beneficial. The adoption of intercropping of other crops with sugarcane will provide additional income to the sugarcane farmers.

Soil health and nutrient management approaches for sustainable sugarcane production

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Sugarcane is the second most important industrial crop in India after cotton¸ occupying about 5 million hectares of area with a production of more than 375 mt which support the production of more than 32 mt of sugar. Sugarcane is the major sugar-producing crop that contributes about 78% to the total global sugar production. It is a long duration (10-18 month) nutrient exhaustive crop. An integrated approach of nutrient management using chemical fertilizers in conjunction with sugar factory wastes (filter cake, effluents), bulky organic manures, crop residues, green manures and bio-fertilizers has been found effective in maintaining soil fertility, sustaining crop productivity and improving quality of sugarcane products. Generally, heavy doses of fertilizers (NPK-150:60:60 kg/ha) is recommended for sugarcane cultivation, but a saving of 25 to 50 kg of chemical N/ ha is achieved through the application of *Gluconacetobacter diazotrophicus* based bio-fertilizer. The phosphorus use efficiency was as high as 28.5%, if sprayed on foliage as 0.5 to 1.0% solution of di-ammonium phosphate. Application of potassium @ 60 kg K_2O/ha with irrigation water in standing plant cane one month prior to harvesting improves bud sprouting, number of millable canes and yield of succeeding ratoon crop. Sulphitation press mud cake proves as an effective source of sulphur for the crop. Application of $ZnSO_4$ (@ 25 kg/ha after harvest of plant crop, significantly improves stubble sprouting and number of tillers in winter initiated sugarcane ratoon. After germination of sugarcane (30-40 days after planting), 45 cm wide and 15 cm deep furrows made in alternative rows saves irrigation water by 36.5% and improves water use efficiency by 64%. At initiation dismantling of ridges, stubble shaving and off barring is recommended for good ratoon yield**.** Trash mulching (8-10 cm thick) in alternate rows for conserving soil moisture, minimizing weed infestation, maintaining soil organic carbon and increasing cane yield. Skip furrow method of irrigation is water saving sugarcane production technology. Intercropping of crops like potato, mustard, wheat, *berseem*, coriander, lentil, garlic and winter vegetables with autumn sugarcane has been found more remunerative with respect to land use efficiency and monetary returns.

The study concludes that sugarcane cultivation is feasible under organic farming by providing nutrients through organic sources involving manures like FYM and sulphitated press mud and microbes like *Gluconacetobacter diazotrophcus* and *A. chroocoum.* It is recommended to cultivate sugarcane under organic farming conditions by using 20 t FYM/ha + *Trichoderma viride* + intercropping with lentil in plant crop and 10 t SPM/ha + 10 t FYM/ha in subsequent ratoon crop. Apart from it, multi-ratooning improves the rhizospheric micro-climate and structure in comparison to chemical fertilizers and promotes the restoration of return of easily decomposable organic compounds in the soil rhizosphere with increase in organic carbon content and improving microbial activities and physio-chemical properties of the soil. Use of biomanures also helps in successfully raising more number of ratoon crops leading to enhanced overall productivity and profitability of the sugarcane cropping system.

Current status of sugarcane insect pests in western Uttar Pradesh

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The aim of this publication is to provide an overview on the white grub, root borer, shoot borer, top borer, wooly aphid, white grub, mite, hispa and other insect pests specially in the western Uttar Pradesh surveyed area. During last decade 2005 to 2015, survey was conducted at various sugar factories area of western Uttar Pradesh. The moto against insect pest survey was to adjudge the behaviour of different sugarcane cultivars against the major insect pests. The inference drawn from the result of insect pest survey in western Uttar Pradesh was that shoot borer, top borer, stalk borer, Gurdaspur borer, *Pyrilla*, hispa, mealy bug, mite, army insects, grasshopper as well as white grub and wooly aphid *etc.*In 2005 to 2011, *Pyrilla* (4-150/clump), black bug (2-14/clump), mite (15-300/leaf) as well as white grub (2-5/clump) ,was also reported in Muzaffarnagar, Meerut, Bulandsahar, Khurza, Ghaziabad, Amroha, Shamli and Shahranpur on varieties namely Co 1148 CoJ 64, CoS 767, 8436, 8432, 88230, 94257, 92423, 95255 and 96268 as well as CoJ 85, 88 and BO 54. But in 2012, top borer and mealy bug were also reported in all surveyed factories on varieties Co 0238, CoS 767, CoS 97261, 07250, CoSe 01434, 03234 and UP 0097. In 2013-14, top borer heavy incidence was reported in Muzaffarnagar, Saharanpur as well as Bijnore districts. Its incidence varied from one to fourty per cent. The scenario is change in 2014-15, the incidence of root borer, wolly aphid and white grub is found in several factories such as Shamali, Saharanpur, Muzaffarnagar, Meerut and Bagpat. Moradabad's Khaddar area also affected with Gurdaspur borer in patches form in CoS 0238, 1148, CoJ 85 as well as 88.

Scenario of sugarcane borers incidence in a decade at Khatauli sugar factory area of Muzaffarnagar-A case study

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The aim of this study was to provide an overview on the stalk borer, top borer as well as shoot borer especially in Muzaffarnagar Khatauli sugar factory area in Western Uttar Pradesh. During last decade 2009-10 to 2018-19, a survey was conducted at Khatauli sugar factory area of Muzaffarnagar in Western Uttar Pradesh. The moto against sugarcane borer survey was to adjudge the behaviour of different sugarcane cultivars against it. The inference drawn from the result of borers survey in khatauli sugar factory area in western Uttar Pradesh was that shoot borer (*Chilo infuscatellus)* in hot weather, as well as top borer (*Scirpophaga excerptalis Wlk*) and stalk borer (*Diatraea saccharalis, Fabricus*) at the time of post monsoon.

During 2009-10 to 2018-19, the shoot borer per cent incidence was found 3.0% to 11.0%. Minimum 3.0% in 2011-12 and maximum 11% incidence was reported in 2012-13 followed by 7.5% in 2018-19. The top borer percent incidence was fluctulate frequently, in 2010-11 and 2011-12, it was same (3.5% in this sugar factory area) while the scenario is changed during 2012-13. The incidence was mild (below 2%), but between 2013-14 and 2017-18, it was 3.5% to 14% but the trend also changed during 2018-19, the per cent incidence of top borer only 5% in this zone. As well as per cent incidence of stalk borer (on cane basis) was reported very high to medium and then low, in last decade *i.e*. in 2013-14, it was maximum 19.0% and minimum 5.0% in 2017-18 followed by 6.5% in 2015-16.

Record of aphidophagous predators of *Aphis craccivora* (Hemiptera: Aphididae) in sugarcane lentil intercropping system in Uttar Pradesh

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The aphid, *Aphis craccivora* (Hemiptera: Aphididae) is a polyphagous, occasional insect of lentil crop. It feeds by sucking sap from lentil plants. The undersides of leaves are preferred, other leaf surfaces and flower buds are its next choice, but the entire host may be covered when populations are large. Infested leaves often become cupped downwards and may appear wrinkled. Heavy infestations may result in wilting of plant. Young plants may have reduced or stunted growth. *Aphis craccivora* can curl, yellow, or stunt leaves and can reduce flower production and stem growth. Like other aphids, *Aphis craccivora* secrete copious amounts of honeydew, a sweet and watery anal excrement that serves as a medium on which black sooty mould grows. Sooty mould blackens the leaf and decreases photosynthetic activity. When found on the pod, honeydew and sooty mould reduces their marketability. Aphis craccivora (both apterous and alate morphs) transmit different virus disease, which cause substantially greater losses than damage caused by direct feeding injury.

A field survey was conducted from 2018 in sugarcane lentil cropping system to record the incidence of aphid and its predators. Periodical sampling revealed, the occurrence of five species of aphidophagous ladybird predators (Coleoptera: *Coccinellidae*), *viz.*, *Coccinella septempunctata,Cheilomenes sexmaculata*, *Coccinella transversalis Propylea* dissecta, *Anegleis cardoni* and one species of syrphids fly an one species of Neuropteran predator were found predating on *A. craccivora in sugarcane lentil intercropping system*. All the immature stages and adult is dominant predator of *A*. *craccivora*. In the above intercropping system, dobling farmers income can be increased by controlling the aphids through predators.

Current status of sugarcane production in Uttar Pradesh

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Uttar Pradesh has the distinction of being the largest sugarcane and sugar producing state of the country. Sugar industry of the state play an important role in the revenue generation of the state. The sugarcane is produced in 44 districts of the states and of these districts, 28 districts are the major sugarcane producing districts. Area under sugarcane in the state which was 798,000 ha during 1953-54 has increased to 2794,000 ha during 2018-19. Similarly, the production during the same period has increased from 38,989 thousand tonnes to 22,4,900 thousand tonnes. The productivity has also reached to 80.5 t/ha from 35.82 t/ha. Out of 43 main cane growing districts, 13 districts have the average cane yield in the range of 60-70 tonne per ha, 14 districts in the range of 70-80 t/ha and 13 districts with the above 80 tonne per hectare cane yield, out of which two districts have achieved more that 90 t/ ha yield level in 2017-18. The quantity of cane crushed which was 6134 thousand tonnes during 1950-51 has increased to 103167 thousand tonnes during 2018-19. Similarly, the sugar production which was 6,02,000 t during 1950-51 has increased to 11822,000 tonnes during 2018-19. There are 116 operational sugar mills in the state. Out of these, 92 sugar mills are in the private sector. Out of 489 sugar mills located in India, 116 sugar mills are located in the state only, during 2016-17. Similarly, out of 3532.26 lakh MT of sugarcane produced in the country, 1623.38 is produced in the state. The 116 mills located in the state crushed 827.17 lakh MT sugarcane out of 1934.34 lakh MT and produced 87.78 lakh MT sugar out of 202.62 lakh MT. Uttar Pradesh surpassed Maharashtra in sugar production and became the largest sugar producing state of the country in 2016-17 and maintained its position in 2017-18 and 2018-19. This is primarily due to the spread of improved sugarcane variety which has resulted in significant increase in cane yield and sugar recovery in the State, and lowered the per unit cost of sugar production in the state. The state also has witnessed higher sugar recovery of 10.62%, 10.61%, 10.84% and 11.46% during the period of last four years. During 2017-18, the payments made by the sugar mills located in Uttar Pradesh to the sugarcane farmers for purchasing their sugarcane produce has increased to ₹ 35,423 Crore in comparison to just ₹ 2871.80 Crores in 2006-07.

Sugarcane production could be increased substantially as there exists the large potential to increase the productivity of cane. Two types of yield gaps in sugarcane have been identified. There exists a huge Yield Gap-I (the difference of the highest yield level obtained in a cane growing district and the state average level) of 17 to 50 t/ha in tropical states compared to sub-tropical states where it ranged from 4 to 15 t/ha. Yield Gap-II (the difference between state average yield level and the lowest yield obtained in its cane growing district) exhibits more or less the same magnitude and pattern. A multi-pronged strategy is needed to revisit and analyze the constraints in yield enhancement and in reducing the yield gaps at state, regional, district, and local level by considering the sugar mill at the focal point. The strategy to bridge the Yield Gap-I would be to better dissemination of the proved technology in resource rich districts. To bridge Yield Gap-II, the development strategy needs to be oriented towards better resource management and resource augmentation. The ratoon crop needs special treatment right from the planning, as a separate crop if the yield levels are to be improved significantly. The mechanization of sugarcane cultivation needs to be encouraged to lower the cost of cultivation. Also, adequate incentives to farmers need to be generated for improving the yield levels.

Economics of sugarcane cultivation in Uttar Pradesh

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Sugarcane occupies a very prominent position on the agricultural map of India covering large areas in sub-tropics and tropics. It is the sole raw material for the largest agro-processing industry in the rural sector, involving about 6.0 million growers. Besides, the industry also provides employment to half a million unskilled and skilled workers in the rural areas. Besides sugar, the production of ethanol for partial substitution of fossil fuel and use of bagasse in co-generation of electricity has great potential in future and thus, requirement of cane will increase further. Uttar Pradesh has the distinction of being the largest sugarcane and sugar producing state of the country. Despite the increasing cost of cultivation and stagnant yields, sugarcane is still the most profitable crop in the country *vis-à-vis* its competing crops like wheat, paddy and cotton. Net returns as per cent of cost C2 are more than 50 percent in sugarcane at all India level compared with paddy (12 per cent), cotton (15 per cent) and wheat (27 per cent).

In terms of cost of production (₹/quintal), the projected cost of production A2, A2 +FL and C2 as estimated by CACP for the year 2017-18 in the state of Uttar Pradesh were ₹ 115, ₹ 160 and ₹ 232 per quintal, respectively. The recovery rate was 9.44 and using this value, the projected costs (A2 and A2+FL) adjusted for 9.5 per cent recovery were worked out to ₹ 161 and ₹ 234 per quintal, respectively. The all-India weighted average projected cost C2, adjusted at 9.5 per cent recovery was estimated at ₹ 202/qtl. The modified C2 cost inclusive of costs of transportation and insurance premium of sugarcane for the season was estimated at Rs. 227/qtl. The FRP of sugarcane for 2017-18 sugar season recommended at ₹ 255/qtl. was linked to basic recovery of 9.5 per cent. It was only 26% higher over Cost C2. For UP, TN and Haryana states, the price was less than 50% over Cost C2 at this recovery rate. As the All India average recovery rate was at 10.60 per cent, the FRP was worked out at ₹ 284.48/qtl. At this price too, the sugarcane growers at all India level and in states of UP, AP and TN could not get at least 50% returns per unit over Cost C2. Hence, under new budgetary provisions, if at least 50% increase over per quintal C2 cost of sugarcane production is ensured, the farmers in these states will get benefitted.

UP, the largest cane growing state in India would get a fair deal, as per ha net returns over Cost C2 were higher compared to other states even when the FRP was just 22% over Cost C2.

As per the CACP Report on Price Policy for Sugarcane for 2019-20 sugar season, was the component of human labour was around 62 per cent of the operational cost, and around 50% of the total cost.

The gross value of output (GVO) was ₹ 1.70 lakh per ha. Further analysis of rate of return over COC A2 and A2 + FL for sugarcane during TE 2016-17 clearly revealed that the average gross returns over A2 was 329 per cent in Uttar Pradesh while average gross returns over A2 + FL was 211 per cent. Share of inputs in total cost of production (A2 + FL) during TE 2016-17 was the highest (56.4%) for human labour. The next in rank were fertilizer and manure (16.9%), irrigation (8.7%), seed (6.5%) and machine labour (4.7%). The share of others including bullock labour, insecticides, interest on working capital, rent paid for leased-in-land, land revenue, cesses and taxes, depreciation on implements and farm buildings and miscellaneous expenses was 10.2%. Hence, it is clear that the component of human labour needs to be reduced by increasing the extent of mechanization by promoting the use of planting and harvesting machines. In this way, quite low component of machine labour will also get increased which in turn will reduce the component of human labour.

Sugarcane plant residues (trash) as bio fuel resource

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Sugarcane is the major crop in the world that is most efficient at converting solar radiation into plant biomass. Unfortunately, this scientific fact is not being fully harnessed in India. The sugarcane is an industrial cash crop of India, cultivated in about 5 million hectare with average productivity of about 280 million tons per year Sugarcane is a giant perennial grass of the genus *Saccharum* that can be found in wet and dry tropical and partially sub-tropical regions. It consists of an above-ground bamboo-like stalk with trash, cane tops and leaves and underground rhizomes and roots. 30 tonnes per hectare of fiber and sugarcane juice are sent to factories for sugar production, which leaves 24 tonnes per hectare of waste biomass. Currently, sugarcane bagasse is burnt for onsite heat and electricity production at sugar factories and surplus electricity is exported to the grid. That still leaves 24 tonnes per hectare of waste in the fields. The leafy trash contributes about 14 to 15 per cent *i.e.*, equivalent to 350 kg (140 to 150 kg + 60% moisture) with every 650 kg cane produced (75 % moisture). Approximately 42 million tonnes of trash is produced annually in India. In Madhya Pradesh, sugarcane is cultivated in 70,000 to 80,000 hectare. The farmer harvests the crop manually and burns the trash to avoid difficulty in further agronomical operations. This not only leads to environmental pollution but also creates problem in conservation of soil microbes and natural enemies of the pest viz., *Epiricania malanoleuca*.

Energy is a pre-requisite for the proper functioning of nearly all sub-sectors of any economy. It is an essential service whose availability and quality can determine the success or failure of development endeavours.

The combustion of sugarcane biomass for the production of electricity is technically and economically feasible and creates opportunities for increasing the renewable energy share in sugarcane-producing part of India.

Objective

a) Gasification of biomass (trash) to produce clean energy (electricity)

b) Conversion of sugarcane trash to generate bio fuel through Bio Gas Plant

i. Gasification of sugarcane trash to generate electricity

ii. Fuel candies for rural domestic fuel requirement

iii Fuel bricks for industrial boilers *etc*.

Beautifully Harnessing Action and Interest to Create Harmony for Augmenting Resilience in Agriculture : A concept for sustainable agriculture in distress farming situation

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Two third of the India's population derives sustenance of livelihood from agriculture which is dominated by small and marginal farmers. Indian farmers confronted with severe distressful circumstances and found themselves unable to cop up with the changes in the economic environment. The cross section analysis involving problems of farmer's distress culminating in suicide. The agrarian distress, therefore not only impacts on the livelihood system of the large share, but finally bringing down the growth of the economy. The emancipation of farmers can be tackled through an empathetic approach blended with Beautifully Harnessing Action and Interest to Create Harmony for Augmenting Resilience in Agriculture (BHAICHARA). The agriculture includes all allied aspects of rural development. BHAICHARA approach was coined by Dwivedi *et al.* (2019) for Peer communication. This approach is based on brotherhood and interested in agriculture and allied sector development. It was coined by six brothers of extension fraternity having specialization in dissemination of ago-forestry gender & dairying, jute & allied fibers and sweetness of sugarcane

In present situation, farming enterprise has become a deal with the changing and unpredictable environment. In fact, distress situation is a cumulative effect of depleting production resources, perils in production due to unpredictable change in environments like low and erratic rainfalls, raising temperature, smog owing to burning of crop residue, fuel emissions, constructions work for infrastructure, buildings, houses, roads, sand storm *etc.,* making further misery for agriculture production system.

Sugarcane is one of the important commercial crops which provide ample opportunities for economical emancipation to overcome distress situation. To make the sugarcane crop more economically viable, there is need to focus upon technological backstopping and extension delivery with immense full means based on "Experiential Learning" and "Seeing and Believing". The Technology Park developed at ICAR-Indian Institute of Sugarcane Research, Lucknow is the treasure best collection of live piece of technology modules such as improved varieties of sugarcane attributed in high yield and sugar recovery, resistance to diseases and pests, suitable for varied agro-ecological zones, sugarcane planting method, modules intercropping with sugarcane for enhanced income helps the visitors to assess and evaluate interventions to apply in their own situation. It also facilitates decision support to the cane growers/entrepreneurs on spot through interaction with sugarcane production experts. The technologies demonstrated through the Technology Park Beautifully Harnessing the Action and Interest of large number of farmers, entrepreneurs, sugarcane development department officials, sugarcane researchers, extension workers and the students.

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