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Sugarcane in India

(Package of Practices for Different Agro-climatic Zones)

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The world population is increasing day by day and would demand more food besides the natural resources like land and water. Keeping in view the need of 7 billion world population, agriculture will need more land and water to produce enough food grains. Availability of natural resources is depleting at faster rate. Thus, to fulfill the needs of future population would be more challenging task for farming communities. Sugarcane is one of the multi-product main cash crop of India, and its use for sugar and renewable energy (production of ethanol), the task has become more challenging than ever before to cope-up the demand of adequate sugarcane production in spite of the shrinking available natural resources.

Moreover, choice of sugarcane varieties, planting methods and distance, time of planting, methods of irrigation and frequency of irrigations required, fertilizer management and integrated weed, insect-pest and disease management are critical practices to increase sugarcane productivity *vis-a-vis* reducing the cost of production and improving farmers income. Number of sugarcane production technologies has been developed at various sugarcane research stations, ICAR Institutes and SAUs. Exploitation of the potential of advanced sugarcane production technologies and proper dissemination of technologies at national level is required. Agriculture is the state subject and it has been observed that various technologies developed by state universities can bring improvement in other states also due to similar agro-climatic zone condition. Thus, need was felt to compile the advanced technologies developed by various AICRP(S) centres for effective transmission at national level. Thus, present technical bulletin on **Sugarcane in India: Package of Practices for Different Agro-climatic Zones** has been developed for sugarcane growers, research workers and state development personnel working in sugarcane sector.

I express my heartfelt gratitude to Dr. T. Mohapatra, Secretary (DARE) & Director General, Indian Council of Agricultural Research, New Delhi for providing all kinds of support to AICRP on Sugarcane. I profusely thank Dr. J.S. Sandhu, Deputy Director General (Crop Science), ICAR, New Delhi for technical guidance and support to us. I thank Dr. R.K. Singh, Asstt. Director General (Commercial Crops), ICAR, New Delhi for encouragement and guidance.

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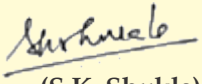


(S.K. Shukla)

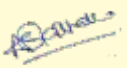
Project Coordinator (Sugarcane)

FOREWARD

Sugarcane is one of the important commercial led industrial crop in India. It has contributed significantly to the growth of Indian Agriculture and National Gross Domestic Products (GDP). The rural economy in traditional sugarcane growing area is primarily linked with sugarcane crop and sugar or allied industries. Since early 20th century, a lot of emphasis has been laid on the research and development (R&D) associated with sugarcane crop, which enabled the sugar industry to progress through years.

Sugarcane (*Saccharum* spp. hybrid) is the prime source of sugar in India. It occupies a prominent position in the Indian Agricultural scenario on account of its wider adoption in different agro-climatic conditions of the country. It has significant role in national economy and provides raw material to sugar and over 25 other major industries viz. producing alcohol, papers, chemicals, and cattle feed. It also finds place in pharmaceutical industry, next to textiles, is entirely based on cane production as raw material. The industry has enabled the country to be self reliant in this highly sensitive essential commodity of mass consumption. Ethanol production and co-generation of electricity in sugar factories are yet other utilities that enhance the importance of sugarcane in national economy. Besides the sugar factories and other industries based on its by-products, sugarcane also supports rural and cottage industry of gur (jaggery) and *khandsari* which together produce about 7-10 million tonnes of sweeteners. Due to its multi-purpose uses in different industries, the demand is increasing for the increased production of sugarcane and its sustainability in the country.

It has been observed that in south India, sugarcane growers have achieved cane yield around 175 t/ha per hectare by adopting good agronomic practices, whereas in subtropical India it is about 100 to 125t/ha. So, there are still opportunities to increase sugarcane productivity in both the regions also. Several technologies have been developed for increasing productivity and sustainability of the sugarcane based cropping system. However, effective utilization and dissemination of technologies is still required to harvest the fruits of innovations by end user. It is urgent need to disseminate farmer's friendly production technologies generated through various research organizations/institutions/SAUs/state departments in the country. In this direction, the efforts of AICRP(S) Coordination Unit, ICAR-IISR, Lucknow, in a shape of technical bulletin on **"Sugarcane in India (Package of Practices for Different Sugarcane Growing Zones)"** are appreciable and would serve the purpose of sugarcane growers and fulfilling the objective of doubling the farmer's income in the country by 2022. I also hope that technical bulletin will be useful to researcher and extension personnel as well as policy makers in India.



(A D Pathak)

Director, ICAR-IISR, Lucknow

PREFACE

India is a land of high species richness as well as agro-biodiversity with only 2.4% of the land biomass and supports 17% world's human population. Agriculture plays a vital role in India's economy and 58.6% of the population is engaged in agriculture and allied activities. Sugarcane is the main cash crop and grown in both tropical and sub-tropical regions of the country. It is main source of sugar, gur and *khandsari* and also provides raw material for manufacturing alcohol. It is also an efficient substitute for petroleum products and other chemical products. It is a long duration crop and requires 10 to 15 months and even 18 months to mature depending upon the geographical conditions. At present, sugarcane is commercially cultivated on 4.91 mha of area with a productivity of 69.5 tonnes/ha in India.

All India Coordinated Research Project on Sugarcane is coordinating research work in the country since 1970 through a network of sugarcane research stations of ICAR, State Agricultural Universities, State Govt. Departments and Non-Government Organizations. At present there are 22 regular centers and 14 voluntary centers for conducting research and multilocation testing of technology for wider adoption.

So far, 119 varieties have been identified in AICRP on Sugarcane still now and out of these, 55 varieties have been released and notified for cultivation in different parts of the country. Few sugarcane varieties have been widely adopted and occupied larger share in sugarcane area viz., (Co 86032 (70%) in Pennisular zone, Co 0238 (35%) 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 country. These varieties have shown larger impact on economic status of sugarcane growers.

Present technical bulletin has been prepared keeping in view the recommendations made by QRT during 2016. It was recommended that a technical bulletin on sugarcane package of practices for different agro-climatic zones has to be prepared by AICRP(S) unit. The details of latest sugarcane varieties recommended and top five varieties of the sugarcane growing states with their occupied area, management practices for crop planted in different seasons, plant cane vs ratoon cane, crop diversification of sugarcane based system for maximizing farmers income, mechanization of sugarcane have been given more emphasis. Besides, detailed information on cost of production of sugarcane in various states, has also been given for the benefit of scientists and development personnel.

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BRIEF ABOUT ALL INDIA COORDINATED RESEARCH PROJECT ON SUGARCANE AICRP (S)

All India Coordinated Research Project on Sugarcane is coordinating research work in the country since 1970 through a network of sugarcane research stations of ICAR, State Agricultural Universities, State Govt. Departments and Non-Government Organizations. At present, there are 22 regular centres and 14 voluntary centres for conducting research and multi-location testing of technology for wider adoption. As per the mandate, main emphasis is laid on the development of improved sugarcane varieties, crop production and protection technologies suited to commercial cultivation under different agro-climatic conditions of the country. Few sugar factories are also voluntarily involved in the AICRP programme for conducting on-farm trials to evaluate performance of new clones/genotypes of sugarcane.

Mandate:

- Evaluation of locally adapted sugarcane varieties with improved yield and quality as well as resistance to biotic and abiotic stresses.
- Development of package of practices for higher sugarcane production.
- Development of low cost technologies for sugarcane production.
- Intensifying and extending the networking facility and information generation for transfer of technology to the farmers and sugar industry.

Objectives:

- To coordinate multilocation testing of germplasm and advance breeding materials for evaluating appropriate region/location specific improved varieties.
- To organize and conduct strategic and applied research of inter-disciplinary nature for evolving appropriate region/location specific package of practices for crop production.
- To develop region or location specific strategies for integrated disease and pest management.
- Enhancement and maintenance of disease free nucleus seed material for distribution to the cooperating organizations.
- To disseminate generated information and technology.

So far, 120 sugarcane varieties have been developed through AICRP on Sugarcane and out of these, 56 varieties have been released and notified by Central Varietal Release Committee (CVRC) after 2000 for cultivation in different parts of the country. These sugarcane varieties are known for better performance in terms of cane yield, juice quality, sugar recovery and are showing resistance against major

insect- pests and diseases. Many of these varieties are also recommended for various adverse climatic conditions in India. These varieties can be grouped in to the category of high sugar (early group), mid-late group and tolerant to biotic and abiotic stresses conditions. Besides these, few sugarcane varieties like Co 419, Co 527 and Co 6806 are also very much popular in African and South-East Asian countries.

Major production technologies developed under AICRP (S) included reduction of seed cane requirement through cane node technology, optimized crop geometry, integrated weed management schedule, integrated nutrients management schedule for plant and ratoon crops, economizing water and nutrient use through micro-irrigation technique, FIRB method for wheat + sugarcane system, evaluation of various intercrops for doubling farmers income, agro-techniques for multiple ratooning and played pivotal role in increasing productivity and sustainability.

Among protection technologies, identification of varieties resistant to red rot smut and wilt, is the useful programme running with the association of plant pathologists and sugarcane breeders. Chemical control of brown rust of sugarcane has also been advocated. Chemical control of mealy bug and bio-control of woolly aphid have also been developed AICRP on Sugarcane is the nodal agency for conducting DUS Testing Programme under Protection of Plant Variety and Farmers Rights Authority (PVFRA) at its two cooperating centres – Indian Institute of Sugarcane Research, Lucknow and Sugarcane Breeding Institute, Coimbatore.

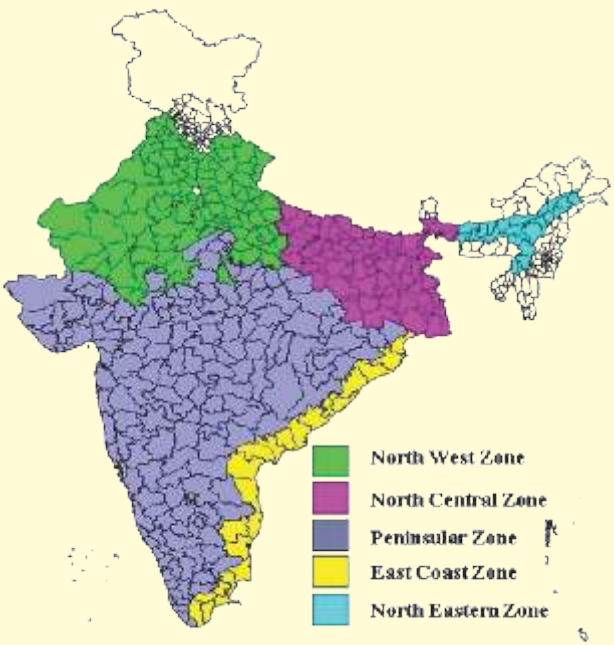

Fig 1: Sugarcane producing zones in India

Fig 2: Regular centres of AICRP (S)

Fig 3: Voluntary centres of AICRP(S)

INTRODUCTION

Sugarcane is a tropical plant and grown as cash crop in the world . It is grown over 49.18 lakh hectares in India. India is the fourth largest growing economy in the world, next to US, China and Japan. Contribution of these countries to the world Gross Domestic Products (GDP) are - US - 21.1%, China - 12.1%, Japan - 7% and India - 5.7%. In India, sugar industry is the second largest after cotton textiles which contributes around 6% of the agricultural GDP (http://eagri.tnau.ac.in/eagri50/AGRO301).

Sugarcane is the main source of sugar (80%) globally and holds a prominent position as a cash crop. It is one of the main crops of earning foreign exchange. The sugar juice is used for making white sugar, brown sugar (*khandsari*) and jaggery (*gur*). The main by-products of sugarcane industry are bagasse and molasses. Bagasse is mainly used as fuel. It is also used for production of compressed fibre board paper, plastic and others. Molasses is used in distilleries for the manufacturing of ethyl alcohol, butyl alcohol, citric acid etc. Rum is the best potable spirit made from molasses. Molasses is also used as an additive to feeds for livestock. Press mud can be used as soil amendment in saline and alkali soils. Green tops of cane are good source of fodder for cattle.

There are two distinct agro-climatic regions of sugarcane cultivation in India, viz., tropical and subtropical. Tropical region has about 45% area and contributes 55% of the total sugarcane production in the country. Thus, sub-tropical region accounts for 55% area and shares 45% of total production of sugarcane. The average sugarcane yield in the country is about 69.4 t/ha. 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 a large number of agricultural labours are involved in sugarcane cultivation, harvesting and ancillary activities (http://shodhganga.inflibnet.ac.in).

The country had produced 28.1 mt of sugar in the 2014-15 marketing year (October-September). India is the world's second biggest sugar producer. There is consistently increase in sugarcane area, production and productivity after independence. However, during 2015-16, the Maharashtra state witnessed the severe drought which affected sugarcane and sugar production adversely and national sugar production declined to the level of about 25.1 million tonnes. There are 716 installed sugar factories (Co-operative-326, Private-347 & Public-43) in the country as on 31.01.2016, with crushing capacity to produce about 33 million tonnes sugar. Thus fluctuating trends in sugar production requires main focus on 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. Here the involvement of scientists, sugar mill officials, State Cane Deptt. personnel and other marketing and finance agencies focusing on key issues and increasing the farmers income are becoming important.

In world, sugarcane is grown, between the latitude 36.7° N and 31.0° S of the equator extending from tropical to subtropical zones. There is no country where sugar is not being used and produced by sugarcane or sugar beet crops only. About 80% of sugar is obtained from sugarcane and the remaining 20% is produced through sugar beet. An average person consumes about 24 kg of sugar every year. According to a report, there are more than 120 countries producing sugarcane on large scale to meet their own needs and for export(http://www.beeculture.com/catch). Details of few some sugarcane growing countries are given below.

Table 1: Top ten Sugarcane growing countries in world

Country	Sugarcane area (mha)	Sugarcane production (million tonnes)	Yield (t/ha)
Brazil	10.41	736.10	70.64
India	5.01	352.14	70.25
China	1.76	126.15	71.33
Thailand	1.35	103.69	76.64
Pakistan	1.14	62.82	55.08
Mexico	0.76	56.67	74.39
Indonesia	0.47	28.60	60.50
Philippines	0.43	25.02	57.93
Australia	0.37	30.51	81.33
Argentina	0.36	24.50	66.54

Source: FAO statistics, 2014

Sugarcane producing regions in India

The consolidated efforts of the research network of AICRP on Sugarcane have resulted in vertical growth in sugarcane productivity and production in the country. India is the second largest producer of sugarcane (18.18%) and sugar (15.81%) in the world, next to Brazil. However, the country is also largest consumer of sugar (15.93%) of the world and 7th larger exporter of sugar (2.80%) to 113 countries of the world (2015-16 - April to January). The sugarcane productivity has increased from 48.0 t/ha (1970-71) to about 70 t/ha (2015-16). Whereas, total cane production has gone up from 126 million tonnes in year 1970-71 to 341 million tonnes (2015-16).

Tropical region

Sugarcane productivity is the tropical states is higher (80 t/ha) than subtropical states (60 t/ha). Sugarcane gets more or less ideal climatic conditions for its growth and development throughout year in the tropical region. Maharashtra and the adjoining areas of Karnataka, Gujarat and Andhra Pradesh record higher sugar recovery due to long sunshine hours, cool nights with clear sky and the latitudinal position of the area favourable for sugar accumulation. Although sometimes biotic and abiotic stresses faced by sugarcane crop during tillering and grand growth phases become critical to sugarcane crop and affect growth and yield adversely.

Sub-tropical region

The subtropical region is divided in to three sugarcane agro-climatic zones like North-West Zone, North-Central Zone and North-Eest Zone. In North Central Zone, Uttar Pradesh (U.P), Bihar, Haryana and Punjab states face the extremes of climate viz., high and low temperatures, relative humidity, sunshine hours and wind velocity etc. The main characteristic features of the region. Sugarcane production and productivity in this region is very much influenced by the climatic conditions throughout the year. Uttar Pradesh is having maximum area under sugarcane cultivation. However, the highest sugar recovery can be obtained in the Maharashtra. Climatic conditions are generally variable depending upon the seasons and sometimes within the season also. Sugarcane crop faces all the seasons in a year. During April to June, the weather is very hot and dry. July to October is rainy season accounting for most of the rainfall from south -west monsoon rains. December and January months are very cold and temperature touches subzero levels in many places. November to March is cool months with clear sky. The North West Zone comprising the areas of Haryana, Punjab, Western Rajasthan and Western U.P. has very low temperature in December-January which often causes frost. During May and June, the temperatures are extremely high. Because of extremes of weather, the active sugarcane growth is restricted to 4-5 months only. In North East Zone, Eastern U.P, Bihar, and West Bengal, sugarcane suffers due to floods and water logging during monsoon months. The high incidence of pests and diseases is major bottleneck in achieving higher sugarcane production. The cane yields are lower in the subtropics due to short growing season, moisture stress, more pest and disease problems, floods and water logging and very poor ratoons. The average yield of this region is around 60 tons per hectare.

Table 2: Area, Production and Productivity of sugarcane growing states of tropical and subtropical in India

S. No.	States	During 1970-71			During 2015-16		
		Area (Lakh tonnes)	Production (Lakh tonnes)	Productivity (Tonnes per hectare)	Area (Lakh hectares)	Production (Lakh tonnes)	Productivity (Tonnes per hectare)
A – Tropical region							
1	Maharashtra	2.17	147.70	68.06	9.87	750.87	76.1
2	Karnataka	0.97	84.83	87.45	4.00	342.00	85.5
3	Tamil Nadu	1.35	104.43	77.35	2.63	276.15	105.0
4	Andhra Pradesh	1.20	91.22	76.01	1.57	124.60	79.4
5.	Gujarat	0.37	19.37	52.35	1.85	130.40	70.5
6.	Madhya Pradesh	0.61	16.13	31.75	0.73	33.43	45.8
7.	Kerala	0.08	3.76	47.00	0.02	1.37	91.5
B – Sub tropical region							
1.	Uttar Pradesh	13.45	546.72	40.64	21.60	1332.03	61.7
2.	Bihar	1.62	62.09	38.32	2.58	142.40	55.2
3.	Uttarakhand	-	-	-	0.98	60.47	61.7
4.	Haryana	1.55	69.80	45.03	1.13	85.88	76.0
5.	Punjab	1.28	52.70	41.27	0.99	71.31	72.0
6.	West Bengal	0.38	20.75	54.68	0.20	23.00	115.0
7.	Assam	0.32	12.00	37.5	0.29	10.48	36.1
8.	Chhatishgarh	-	-	-	0.29	0.79	27.0
9.	Jharkhand	-	-	-	0.10	7.05	69.1
	Odisha	0.30	16.27	54.23	0.13	8.80	67.7
	Rajasthan	0.37	12.15	32.83	0.04	2.82	67.4
Others		0.11	2.38	21.63	0.18	10.40	57.5
All India		26.10	1263.60	48.30	49.18	3414.25	69.4

Source: *Indian Sugar 2015-16*
Cooperative Sugar 1975-76

Climatic requirements

Sugarcane is a tropical plant. It grows well in those regions where the climate is more or less tropical. Under warm humid conditions, it can continue its growth unless terminated by flowering. A mean temperature of 28-32°C is best suited for the growth of sugarcane. Higher temperature above 45°C reduces tillering and arrests its growth, whereas temperatures below 20°C may slow down the growth. The areas with a minimum temperature <5°C are not suitable for sugarcane cultivation. The crop does well in tropical regions receiving an annual rainfall of 75-120 cm. It requires a long growing season of 10-18 months. A relative humidity of 70-85% during growth and 55-75% during ripening phase is ideal. Relative humidity < 50% during growing season is not suitable for sugarcane cultivation.

Table 3: Temperature and Humidity requirement for sugarcane cultivation in India

S. No.	Sugarcane crop stages	Growth stages duration (days)	Temperature requirement (°C)	Humidity requirement (%)	Sunshine (hrs)		
			Max.	Min.	Max.	Min	
1.	Germination and emergence phase	15 to 30 days after planting	30	15	70	50	10
2.	Tillering and Stem elongation phase	31 to 120	30	15	70	50	10
3.	Grand growth phase	121 to 210	30	20	85	80	11
4.	Ripening phase	211 to 365	15	12	65	45	10

Planting Seasons

The sugarcane crop requires 10-18 months for its maturity in India. Generally 12 month crop duration is most common. Time of planting is governed by the weather conditions. In India, sugarcane planting is done during different months, called planting seasons. In subtropical India, planting seasons are autumn (October), spring (February–March), and summer (April-May). In Peninsular India, planting is done in the months of January-February. Spring planted crop is also known as ***Suru*** in Maharashtra and ***Eksali*** in Gujarat and Andhra Pradesh. Autumn Planting in Peninsular zone is done during October-November. Autumn planting is also known as **Pre-seasonal** planting in Maharashtra and Gujarat. The pre-seasonal crop matures in 13-15 months and sugarcane is supplied during early crushing period. ***Adsali*** planting is preferred in Maharashtra and Karnataka and done during July-August and the crop matures after 16-18 months. There is an increase in yield as well as sugar recovery because of extended growing season. The biggest advantage of ***Adsali*** is that it passes through only one summer season. In the present scenario, the area under ***Adsali*** planting is declining because of less availability of irrigation water. Late planting is common in western Uttar Pradesh where sugarcane is planted after wheat harvest. It has been observed that autumn planting covers only 10-12% area of sugarcane in north India. Larger share lies in spring/summer depending upon the cropping systems followed.

Table 4: Sugarcane Planting Seasons in India

S. No.	Sugarcane agro-climatic zones	Planting Seasons				
		Autumn/ Pre-seasonal	Spring season/ Seasonal/ *Suru*	Late spring /early summer	Early spring planting	Adsali planting
1.	North West Zone	September to October	February to March	March to April	-	-
2.	North Central Zone	October to November	February to March	March to April	-	-
3.	North Eastern Zone	October to November	February to March	March to April	Late January to February	-
4.	Peninsular Zone	October-November	January-February	-	-	July to August
5.	East Coast Zone	October to November	2nd fortnight of December to end of February	-	-	2nd fortnight of June to end of July

Sugarcane varieties

Sugarcane varieties are mainly classified in three groups - 1. Early varieties, 2. Mid-late varieties, 3. Late varieties. The varieties attend 16.5% sucrose, and 85% purity in 10 months are kept in early category. The varieties acaumulate above 16% sucrose level and 85% purity in 12 months are grouped in mid-late category. Those varieties, attend the similar 16% sucrose level and 85% purity in more than 12 months and maintain up to 14 months stage are grouped in late maturing varieties. Normally, two groups i.e early and mid-late/late are observed. Farmers prefer the varieties of high tonnage and sugar mills prefer the higher sucrose

content. So, it is the job of scientists to make the balance between two i.e., cane yield and sucrose content. Nowadays early maturing, high sucrose and higher tonnage varieties are also available and are in higher demand by the sugarcane growers as well as sugar mill owners. These varieties are performing well in the country and accounts for higher sugar production.

Table 5: Recommended sugarcane varieties and their acreage in different states

State	Recommended sugarcane varieties in the state by AICRP(S)/State Depts.	Top five sugarcane varieties of the state	Share in percentage (approx.)
Punjab	Early varieties - Co 118, CoJ 85, CoJ 64, Mid-late varieties - Co 0238, CoPb 91, CoJ 88 Other varieties – Co 89003, CoH119, CoJ 83	Co 0238	62.77
		Co 89003	12.82
		CoJ 85	10.40
		Co 118	5.54
		CoJ 88	5.36
Haryana	Early varieties - Co.J.64, Co.H.56, Co.H.92 Mid-late varieties - Co.7717, Co.S.8436, Co.H.99, Co. H. 119 Late varieties - Co.S.767, Co.1148, Co.H.35, Co.H.110.	Co0238	35
		Co 89003	30
		CoS 8436,	12
		CoH 119	8
		CoH 128	5
Uttar Pradesh (West, Central, East)	Early varieties - Co. 88216, Co. 88230, Co. 95255, Co. 94257, Co. 94270 Mid-late varieties - CoS 767, BO 91, CoJ 20193, CoS 96275	Co 0238	20.5
		CoS 767	12
		CoS 8436	7
		CoJ 64	3
Rajasthan	Early varieties – Co 29, Co 997, Co 527, Co 6617, CoS 96268 Midlate varieties - Co 1253, Co 419, Co 1007, CoJ 111, Co 449, Co 527, CoJ 20193, CoH 119	CoS 767	18
		CoS 8436	7
		CoJ 64	5
		Co 527	1
		CoH 119	1

Bihar	Early varieties - Bo 99, CoP 9301, CoSe 98231, CoS 8436, Cos 95255, Bo 102, Midlate varieties - Bo 91, Bo 110, CoP 9206, CoSe 95422, CoSe 92423, UP 9530	BO 91	20
		BO 110	12
		CoP 9301	10
		CoP 2061	5
		BO 153	3
Assam	Early varieties – Co 997, CoBln 9103(Barak), CoBln 9102 (Kalong), CoBln 9101(Doria), CoBln 94063 (Nambar) Midlate varieties- CoBln9605(Dhansiri), CoBln9104(Lohit), Co740, CoBln 90006(Kapilipar), CoBln 02173(Doiyang)	CoBln 9104 (Lohit)	18
		CoBln 9605 (Dhansiri)	17
		Co997	16
		CoBln 9103 (Barak)	15
		CoBln 9102 (Kalong)	10
Tamil Nadu	Early varieties – CoC 671, CoC 8001, Coc 85061, Co 7704, Co 8208, CoC 92061, CoC 90063 Midlate varieties - Co 6304, CoSi 776, CoSi 86071, Co 8021, Co 85019, Co 86032, Co 86010, Co 86249, CoSi 95071, CoSi 96071, CoSi 98071, CoG 93076	Co 86032	70
		CoC (Sc) 24	16
		CoV 09356	2
		TNAU Si (Sc) 7	1
		CoSi 6	1
Karnataka	Early varieties - CoC 671, Co 94012, Co 92005, CoSnk 05103, SNK 09211 Midlate varieties - Co 86032, CoM 0265, CoSnk 03632, CoSnk 05104, SNK 07680	Co 86032	53
		CoM 0265	18
		CoSnk 03632	9
		SNK 07680	9
		CoC 671	4

Maharashtra (South, Central & North East)	Early varieties - Co 419, Co 7219, Co 8014, CoC 671, Co 94012 Midlate varieties - Co 86032, CoM 0265, Co 92005, CoVSI 9805	Co 86032	35
		CoM 0265	25
		Co 92005	15
		CoC 671	10
		Co 94012	5
Gujarat	Early varieties – CoN 95132 (GS-3), CoN 03131 (GS-4), CoN 05071 (GS-5), CoN 07072 (GNS-8), CoN 09072 (GNS-9) Midlate varieties - CoN 91132 (GS-1), CoN 85134 (GS-2), CoN 05072 (GS-6), CoN 04131 (GNS-7)	Co 86032	20.06
		CoM 0265	18.99
		CoN 05071 (GS-5)	18.73
		Co 86002	16.12
		Co 97009	8.16
Odisha	Early varieties - CoOr 03151, CoOr 03152, Co 6907, CoOr 05346, CoA 92081 Mid-late varieties - CoOr 04152, Co 86249, Co 87044, CoV 92102, Co 7508	Co 6907	20
		Co 86249	16.25
		Sabita (CoOr 03151)	13.75
		Co 87044	13.50
		Raghunath (CoOr 04152)	12.00
Andhra Pradesh	Early varieties - Viswamithra (87A298) (CoA92081), Bharani (2003 V 46) (CoV09356), Simhadri (2003A255) (CoA08323), Swathi (2000V 59) (CoV06356), Co 8013 Mid-late Varieties - CoT 8201, Kanaka Durga (83V15) (CoV92102), 87A380 (CoA90081), Revathi (2000A225) (CoA05323)	Viswamithra (87A298) (CoA92081)	45
		Bharani (2003 V 46) (CoV09356)	21
		Krishna (91V83) (CoV95101)	4
		93V297	4
		Co86032	3

West Bengal	Early varieties – CoB 99161, CoLk 94184, Co 0232, CoJ 64, CoSe 95422 Mid-late Varieties – CoB 94164, Co 0233, BO 91, CoSe 92423, CoSe 96436	BO 91	70.5
		CoB 99161	48.25
		CoLk 94184	28.25
		CoSe 95422	16.00
		CoB 94164	15.5

Table 6: Salient features of prominent sugarcane varieties in India

Co 86032 (Nayana): The wonder variety, Co 86032 developed at the Sugarcane Breeding Institute, Coimbatore and recommended for the peninsular zone. It spread fast and occupied sizeable area in Tamil Nadu (80%) and Andhra Pradesh, Karnataka, Gujarat and Maharashtra around 40% in each state. This is a high yielding (120 t/ha), high sucrose mid-late variety with good ratooning ability. This can be cultivated in drought and saline affected areas also.

Co 0238 (Karan 4): This variety was developed at the ICAR-Sugarcane Breeding Institute Research Centre, Karnal for cultivation in North West Zone. Co 0238 is early maturing and good ratooner. Due to its wider adaptability, the variety has fast spread in Haryana (19,517 ha), Punjab (26,683 ha), Uttarakhand (2,950 ha), UP (72,628 ha) and Bihar (91,795). Presently Co 0238 is going like wild fire in U.P. and occupied more than 30% acreage under early group.

CoLk 94184 (Birendra): This variety is early maturing high yielding variety with a rare combination of two attributes early maturity and good ratoonability. It gives cane yield of 75-80 t/ha in plant crop and more than 70 t/ha in ratoon crop. The variety withstands both moisture stress and water logging and therefore is replacing the existing varieties that do not perform well under water logged conditions in eastern U. P. and Bihar. The average sugar recovery is about from 10-11% which is 1.13 to 1.23 units higher than existing varieties.

CoOr 03151 (Sabita): This gives average cane yield 105.28 t/ha and 11.13 t/ha of sugar. It is moderately resistant to red rot and well suited to irrigated upland and could be grown in rice land with standing water of about 1-2 ft during rainy season. It is tolerant to water logging and drought. This variety has good ratooning ability and is a non-flowering.	
CoPb 08212: This is sugarcane early maturing variety, moderately resistant to red rot, smut & wilt and less susceptible to early shoot borer and top borer. At 10 month stage, sucrose content (18.03%) and sugarcane yield level (79.07 t/ha) can be achieved.	
CoP 09437: Mid-late maturing variety, moderately resistant to red rot, smut & wilt and less susceptible to early shoot borer and stalk borer & moderately resistant to top borer. At 12 month stage, sucrose content (17.60%) and sugarcane yield level (76.85 t/ha) can be achieved.	

Field preparation

As sugarcane crop stands in field for more than a year, it is necessary to give deep ploughing by mould board plough drawn by tractor. The proper time for ploughing is immediately after the preceding crop is harvested or just after a good shower of rain received. The land is then exposed to atmosphere for a month. The harrowing is done 3 to 4 times to break clods and to make the land smooth and even to facilitate uniform irrigation. Four to Six ploughings to produce good tilth is recommended. Each ploughing should be followed by planking.


Tractor operated subsoiler for sugarcane field preparation

Cross Sub Soiling

Cross Sub Soiling is an advanced method of field preparation for sugarcane cultivation. The cross sub soiling at 1.0 m spacing should be done once in three to four years before preparing the field. This is done by tractor drawn sub-soiler to the depth of 45-50 cm. Do planking to break the clods and then prepare seed bed. This will help in breaking the hard pan, help in increasing water infiltration rate and better penetration of sugarcane roots. It is recommended for enhancing plant as well as ratoon cane yields.

Planting techniques

Sugarcane requires about 25-32°C temperature for germination. This temperature requirement is met twice in north Indian conditions, i.e., in October and February-March. Autumn planting of sugarcane is done in October. For higher yields, autumn planting should be completed in the month of October. Delay in planting may cause reduction in germination of sugarcane due to low temperatures during winter season.

Spring cane is planted in the month of February-March. March is the best time for cane planting in Punjab and Haryana, February-March in Uttar Pradesh and January-February in Bihar. The planting time is advanced as we move towards east. In Tamil Nadu, Andhra Pradesh, Maharashtra and Karnataka, sugarcane planting is done in December-February. *Adsali* planting in Maharashtra is done during July-August months and crop duration is about 15-18 months. *Eksali* planting is common in south India. The crop is planted during January-February and harvested after one year. Normally following sugarcane planting methods are adopted in India,

1. Planting on flat beds

This is the simplest and cheapest of all the methods of planting. This method is usually adopted in low rainfall areas of India (in most parts of northern India and some parts of Maharashtra). In this method shallow furrows (8-10 cm deep) are opened with a country plough or tractor operated furrow opener at a distance of 75-90 cm. The setts are planted end-to-end taking care that on 3-budded sett falls in each running 30 cm length of furrow. After planting, the furrows are covered with 5-7 cm soil and the field is levelled by heavy planking. It is essential that there should be adequate moisture in the field at the time of planting. After germination. Three to four inter-cultures are recommended at a proper interval to control the weeds and facilitate the tillering.

Flat bed planted sugarcane crop

2. Ridge and furrow method

This method is usually adopted in areas of moderate rainfall having drainage problems. In this method, the furrows are made in 'V' shape about 90 cm apart and 20-25 cm deep. The setts are placed in horizontal position, usually with end-to-end system. If the seed stalk is not healthy and internodes are longer, eye-to-eye system of planting may be adopted. As soon as the canes start growing, the furrows are partly filled with soil and inter-row cultivation is carried out. This repeated row cultivation of cane results in levelling of the land by end of May or mid of June, which is known as first earthing-up. Furthe,r repetition of inter-row cultivation transforms the furrow into ridges by putting soil around the plants and inter-row space becomes furrow automatically, through which irrigation or drainage is provided for the growth and development of crop. The transformation of furrow into ridges is known as second earthing-up.

Ridge and Furrow method

Ridge and Furrow planted sugarcane crop

3. Trench method

This method is usually adopted in coastal areas as well as other areas, where the crop grows very tall and the strong winds during rainy season cause lodging of cane. Trenches are dug at a distance of 75-90 cm, with the help of ridger or by manual labour. The trenches should be about 30 cm deep. The mixture of fertilizers (NPK) should be spread uniformly in the trenches and mixed thoroughly in the soil. The setts are planted end to end in trenches. Drenching of setts with chlorpyriphos 20 EC (1 kg ai/ha or 5 litres/ha) to protect from the soil borne insects is required. The trenches are filled up with loosened soil after planting. The sugarcane Cutter and Planter developed by Indian Institute of Sugarcane Research (IISR), Lucknow (U.P.) can be used for combining the operations of opening the furrows, placement of fertilizers and then planting setts in the rows.

Placing of setts (Two rows in one trench)

Sugarcane crop in Trench method

Double row planted crop with surface drip

4. Furrow Irrigated Raised Bed (FIRB) technique

In this system, three rows of wheat in the month of November are sown on raised beds. Sugarcane is planted at 80-85 cm apart furrows in February in furrow. 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, requires lower volume of water, and provides about 20% water saving.

5. Ring Pit planting

Pit planting is also done by some progressive farmers. In pit planting, pit dimensions of 2.25 feet diameter and 1.25 deep depth and seed rate of 21, two-budded setts per pit were found most economical with cane yield of 1.5 to 2.0 times higher than conventional planting method. For higher germination and cane yield in pit planting i.e. placing the setts in pits followed by light irrigation in individual pit and then covering with 2-3 inch loose dry sol when water disappears in pit planting is the best practice. New planting technique i.e. wide bed & furrow method (trench method) found suitable for mechanization, saving of water and seed in sugarcane with comparable yields.

Sugarcane planting in Ring Pit Technique

Advanced seed multiplication or nursery raising techniques

1. Tissue Culture Technique

Tissue cultured sugarcane plantlets

The tissue culture technique in sugarcane can be used for rapid multiplication of newly developed high yielding, high sugar, disease resistant varieties and rejuvenation of outstanding varieties under cultivation. The vegetative propagation of sugarcane through seed cane cuttings is cumbersome requiring larger quantities of vegetative seed material and seed multiplication rate is too low. About 10-12 years are required in release of a sugarcane variety. Further more than five years are required for its coverage on farmers' fields in sizeable area. With tissue culture technique, it is possible to multiply a variety within five years and propagate it quickly in the field conditions. The productivity of the important varieties can also be maintained and improved for their longer life span in the field. The micro propagation technique has the advantages like production of true to type plantlets, rapid multiplication, independent of seasonal constraints, maintaining and improving the productivity of outstanding varieties in the field and production of disease free planting material from apical meristem.

2. Spaced Transplanting (STP) Technique

Planting of one bud sett in nursery

In STP method, raised nursery beds of 3 feet width and convenient length are prepared. FYM is applied on nursery bed and mixed with soil. An area of 100 sq. m is required to raise nursery for planting one hectare sugarcane. Disease free setts are selected from nursery crop. Single bud setts are prepared, dipped in 0.2% Carbendazim for 5 minutes and then planted vertically on the raised bed facing the budup. Apply Chlorpyriphos or Imidacloprid (1 ml/litre of water) on nursery beds. The setts are covered with loose soil and watered using Rose Can or irrigated immediately. Regular weeding and watering is essential to obtain good germination and weed free nursery. After 6-7 weeks, the settlings are uprooted

from the nursery with spade and transplanted after flooding main field. A part of settlings are retained in the nursery itself for gap filling. Transplanting should be done preferably in evening. With careful management of the transplanted field, the settling survival can be increased to 90-95%. STP method facilitates planting sugarcane after wheat harvest. Seed cane requirement is lesser (20 q/ha as against 60 q/ha used in normal planting method) hence saving of seed cost.

Table 7: Settlings requirement in STP technique (number of settlings/hec)

Planting season	Recommended planting spacing (cm)	Spacing of settlings (cm)	No. of settlings required/ha
Autumn	90	90 x 30	37,037
Spring	75	75 x 30	44, 444
Late planting	60	60 x 30	55,550

3. Cane Node/Poly Bag Technique

Disease free setts are selected from the seed nursery. Single bud setts are cut manually, dipped in 0.1% Carbendazim for 5 minutes and then planted in perforated poly bags (12 x 8 cm) filled with 1:2:5 mixture of sand, soil and FYM. The settlings can be used for gap filling in ratoon and plant crop. As there is no damage to the root system, field mortality of settlings is very low (5%).

Cane Node technology

Bud Chip Technique

In this method nursery is prepared using bud chips and settlings are transplanted in the main field. Select disease free canes from seed nursery. Take out the bud along with a portion of the nodal region using the bud chipping machine. SBI Coimbatore has designed and developed a bud chipping machine designed at SBI Coimbatore. Only 15 quintals of bud chips are required for planting in one hectare. The remaining portion of the stalk can be sent for milling. Treat the bud chips in chlorpyriphos (2 ml/litres of water) + Carbendazim (2 g/litres of water) for 5 minutes and incubate in a moist gunny bag for overnight (priming). Prepare a homogenous mixture with equal quantity of soil, sand and FYM, fill in perforated polythene bags or cavity trays, plant the bud chips in upright position facing the bud up, cover it with soil mixture. Provide regular watering with Rose Can and spray 1% urea solution at 15th and 25th day after planting. The seedlings are ready for transplanting at 6-8 weeks. The survival rate of settling in the field would be high

as it is transplanted along with ball of earth. Bud chips are easy to transport for long distance. There is saving of seed cane (quantity and cost) and 6-8 weeks time. The higher survival rate after transplanting, uniform tillering and higher yields are achieved through planting of bud chips.

Bud Chip technique

Sprouted Sugarcane Buds

Germinated Sugarcane Bud Chip

Agro techniques for late planting in subtropical India

In sub-tropical India, large area is under late planting particularly in western U.P. In summer planting, farmers grow wheat in the winter and sugarcane is planted after wheat harvest in the months of April/May. This delayed planting reduces tillering span and restricts cane crop maturity to 9-10 months resulted into lower cane yield. The yield of late planted cane is low because of unsatisfactory plant stands and lowers individual cane weight. Agronomical requirements of late planted sugarcane differs entirely as compared to spring and autumn planted sugarcane. To minimize crop yield loss, following measures should be adopted-

- Planting should be done only by half ridge irrigation method of planting for better germination. Farmers should adopt space transplanting method (STP) method of planting for good crop stand, higher cane length and cane weight.

- Due to short formative phase as compared to spring planted cane, it is considered necessary to optimise dose of N and its time of application. Since there are recommendations to apply N during at formative phase. A dose of 150 kg N/ha applied ½ at planting and ½ at 60 days after planting (end June) gives better cane yield in late planted conditions.
- Weed management is very crucial during late planting as the period for tillering and grand growth phase is restricted. Integrated weed management involving application of atrazin @ 2 kg ai/ha (pre-emergence) followed by 2,4-D @ 1kg ai/ha(post emergence) at 60 and 90 days after planting (DAP) is found effective.

Seed Rate and Spacing

Seed rate in sugarcane varies from region to region and spacing required. In subtropical India, generally 60 cm spacing is used in less fertile soil, late planting and under drought condition, 75 cm in fertile soil and under spring season and 90 cm during autumn season along with intercrops. Seed rate requirement is higher in North Western Zone (Punjab, Haryana and Rajasthan) because of the lower germination percent and also adverse climatic conditions (very hot weather with desiccating winds during summer season) in tillering phase. In North Central and North East Zone, seed rate generally varies from 40,000 to 60,000 setts/ha while in Peninsular and East Coast Zone it range between 25,000 to 40,000 three bud setts per hectare.

Cane setts

Seed Spacing

Table 8: Optimum seed rate and row spacing for sugarcane in different states in India

S. No.	States	Seed rate (3-bud setts/ha	Row spacing (cm)
Sub-tropical region			
1.	Uttar Pradesh		
	Timely planting	35,000	90
	Late Planting	56,000	60
2.	Bihar	37,000	75-90
3.	Punjab	50,000	60-75
4.	Haryana	75,000 (2 budded)	60-75
5.	Rajasthan	40,000-45,000	75-90
6.	Madhya Pradesh	25,000-30,000	90
7.	Assam	37,000-42,000	90
8.	West Bengal	25,000-30,000	90
Tropical region			
1.	Maharashtra	30,000	90-100
2.	Andhra Pradesh	30,000	80-90
3.	Karnataka	25,000-30,000	90
4.	Gujarat	25,000-30,000	90
5.	Tamil Nadu	42,000 – 45,000	80
6.	Odisha	37,000-40,000	90
7.	Kerala	35,000-40,000	90

Seed treatment

Since sugarcane is vegetative propagated crop, it is more prone to attack by insect-pests and diseases resulting in poor germination. It has been observed that even under satisfactory condition hardly 40-45% buds germinate. So improvement in germination can improve growth and yields.

Recommendations

1. Always use disease free quality setts for planting.
2. To save the setts from the attack of termites and ants, chlorpyriphos 1.0 kg ai/ha on seed cane/ stalk is recommended.
3. To reduce the incidence of soil-borne diseases, setts must be treated with fungicides. Setts are first given heat treatment (50°C for 2 hours) and then treated with fungicides like 0.2% solution of Bavistin have been found effective.
4. If setts are infested with scale insect or wooly aphids, setts should be dipped in Chlorpyripos 20 EC solution (2ml/lit) before planting.
5. To enhance higher germination percentage, soaking of seed cane in normal water for a period of 12-18 hours improves germination by 12-20% particularly under late planting condition in sub-tropical India. Soaking of whole cane has been found to be more beneficial than soaking the setts or storing the canes in mud or cow dung for 12-24 hours reduces the water loss during cutting, planting and even later, which helps in higher germination or sett treatment with 10% solution of $KMnO_4$, $MgSO_4$ or potassium ferrocyanide accelerates the bud sprouting.
6. To increase biological nitrogen fixation and solubility of phosphatic fertilizers, setts should be treated with N supplying bio-fertilizers or phosphate solubilising inoculants. For one hectare area, dissolve 10 kg of microbial inoculants (CFU > 10^{7-8} per ml) in 200-250 litres of water and dip sets for 10-15 minutes before planting.

Irrigation water management

Sugarcane is a long duration and irrigated crop. The plant crop season is being 12-18 months in India, 13-14 months in Iran, 16 months in Mauritius, 13-19 months in Jamaica, 15 months in Queensland (Australia) and 20 - 24 months in Hawaii. Depending on climate, water requirements of sugarcane are 1500 to 2500 mm evenly distributed over the growing season.

In India, farmers must plan their acreage to be planted under cane crop according to the available water at their farm. Irrigation water depth of 7-8 cm is recommended. Irrigate the crop depending upon the need during different phases of the crop. For example, in tropical area, irrigations are to be given once in 7 days during germination phase (1 –35 days after planting), once in 10 days during

tillering phase (36 – 100 days after planting), again once in 7 days during grand growth phase (101-270 days after planting) and once in 15 days during maturity phase (271 days after planting up to harvest) adjusting it to the rain fall pattern of the area. Generally, sugarcane crop requires 6-8 irrigations in subtropical region whereas in tropical region number of irrigation may range from 20-36 because of climatic conditions, annual rainfall of that region, planting season, and crop duration, soil type etc.

Table 9: State-wise irrigation requirement in sugarcane cultivation

State	No. of irrigations required	Average Sugarcane Yield (t/ha)	Amount of irrigation water required to produce 1.0 kg sugarcane (kg)
Punjab	13	72.0	135
Haryana	13	76.0	133
Rajasthan	16	67.4	174
Uttar Pradesh	8	61.7	99
Bihar	7	55.2	95
West Bengal	7	115.0	48
Assam	6	36.1	122
Gujarat	25	70.5	260
Madhya Pradesh	16	45.8	276
Maharashtra	32	76.1	292
Karnataka	32	85.5	266
Andhra Pradesh	28	79.4	262
Kerala	9	91.5	67
Tamil Nadu	25	105.0	181

Sugarcane, an important cash crop of the country, requires considerable quantity of water during its entire crop cycle of 12-18 months, depending upon agro-climatic regions varying from sub tropical to tropical. The annual water requirement of this crop in sub tropical states like Uttar Pradesh, Punjab, Haryana and Bihar is 1400- 1500 mm. Majority of sugarcane farmers in these states irrigate sugarcane with only 35-45% irrigation water use efficiency, leading to great loss of irrigation water. Irrigation water use efficiency in sugarcane depends upon the different irrigation methods. Net irrigation water requirement (mm/year) by different irrigation techniques is given below.

Table 10: Net irrigation water requirement (mm/year) by different irrigation techniques in India

Sugarcane producing regions	Sugarcane Water requirement (mm/year)	Rain (mm/year)	Rain efficiency (%)	Available rain water (mm/year)	Net sugarcane crop water requirement (mm/year)	Irrigation techniques			
						Furrow	Skip Furrow	Sprinkler	Drip
						Irrigation efficiency (%)			
						60	80	85	95
						Net irrigation water requirement in the state (mm/year)			
Sub tropical India									
Bihar	2000	1210	70	847	1153	1921	441	1356	13
Uttar Pradesh	2000	1025	70	717	1283	2138	1603	1509	350
Punjab	2000	636	70	445	1555	2591	1943	1829	1636
Haryana	2000	355	70	248	1752	2920	2190	2061	1844
Rajashthan	2000	400	70	280	1720	2866	2150	2023	1810
Uttarakhand	2000	370	70	259	1741	2901	2176	2048	1832
West Bengal	2000	250	70	175	1825	3041	2281	2147	1921
Odisha	2000	1451	70	1015	985	1641	1231	1158	1036
Tropical India									
Andhra Pradesh	2000	940	70	658	1342	2236	1677	1578	1412
Tamil Nadu	2000	945	70	661	1339	2231	1673	1575	1409
Karnataka	2000	1248	70	873	1127	1878	1408	1325	1186
Maharash tra	2000	1007	70	704	1296	2160	1620	1524	1364
Madhya Pradesh	2000	1172	70	820	1180	1966	1475	1388	1242
Gujarat	2000	1107	70	774	1226	2043	1532	1442	1290

Economizing irrigation methods

In depleting water resources, economizing irrigation water requirement can increase the quantity of cane produced per unit amount of water. Besides, irrigated area can also be increased through similar quantity of water available for irrigation. Methods are given below-

1. Skip-furrow/alternate furrow irrigation

In this method, instead of irrigating all the rows and inter-row spaces, one row is skipped (left out) and irrigation water is applied in alternate furrows. This method saves 30–40% water without impairing cane productivity.

Skip furrow irrigation method adopted at IISR, Lucknow

2. Sprinkler Irrigation

Sprinkler system in sugarcane cultivation

This is most useful for irrigating just after in plant crop of sugarcane. Sprouting of bud increases and may be up to 90%. It is most suitable for decomposing sugarcane trash. It creates healthy and congenial environment to the microbes, provides better aeration and thus enhances crop growth. This method is conveniently used for irrigating sugarcane up to 5 months from the planting date or from harvesting date (in case of ratoon). This method is most suitable for undulating and steep topography (land forming is not required). About 50-60% water economy is observed through adoption of sprinkler system of irrigation. Soil compaction caused due to heavy application of water is also avoided in this method. Installation cost may vary with sprinkler unit and ranges from Rs. 75 thousands to 1.5 Lakhs which may be recovered in subsequent cropping and economizing water use through higher area covered under irrigation with similar quantity of water.

3. Drip irrigation

Drip irrigation system in sugarcane crop

Micro-irrigation is the frequent application of small quantities of water on, above or below the soil surface, by surface drip, subsurface drip, micro sprayers or micro sprinklers. Water is applied as discrete or continuous drops, tiny streams or miniature sprays through emitters or applicators placed along a water delivery line

near the plant. Micro-irrigation is characterized by low rate, frequent irrigation; water being applied near or into the root zone of plants and low-pressure delivery systems. In drip irrigation, water is supplied directly to the root zone using a network of tubes and dippers/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.

Table 11: Contingent measures suggested under different monsoon conditions during sugarcane cultivation

A.	**Normal monsoon**	**All the recommended varieties with normal package and practices**
B.	**Delayed onset of monsoon**	
	(a) 2 weeks delay	1. Trash mulching (ratoon) 2. Apply water in alternate furrows 3. Keep the crop weed free 4. Continue irrigation as per pre-monsoon (8-10 days) followed by inter-culture 5. Precautions against white fly, mite, root borer and pyrilla
	(b) 3-5 weeks	1. Trash mulching in ratoon 2. Apply water in alternate furrows 3. Keep the crop weed free 4. Continue irrigation as per pre-monsoon (8-10 days) followed by inter-culture 5. Precautions against white fly, webbing mite, root borer and pyrilla
	(c) 6-8 weeks	1. Protective irrigation at 10 days interval 2. Insect pest control as in case of 3-5 weeks 3. Iron deficiency expected. Spray 1% of $FeSO_4$+0.5 % $ZnSO_4$+ 2% urea
C.	**Long dry spell after onset of monsoon**	
	(a) 2-3 weeks delay	Normal package
	(b) 4-6 weeks	1. Irrigation interval at 10-15 days 2. Apply water in alternate furrows 3. Control of white fly, webbing mite, pyrilla and root borer 4. Iron deficiency expected. Spray 1% of $FeSO_4$+0.5 % $ZnSO_4$+ 2% urea

D.	**Early withdrawal of monsoon**	1. Irrigate at 15-20 days interval 2. Protection against white fly, webbing mite, root borer and pyrilla
E.	**Heavy monsoon causing floods**	
	(a) At initial stage	1. Avoid long stagnation of water 2. After drainage, apply urea @ 60 kg/ha at working condition or if possible spray of 3% urea 3. Control sucking pest and stalk and top borer.
	(b) At mid stage of the crop growth	1. Avoid long stagnation 2. After drainage apply urea 60 kg/ha at working condition or if possible spray of 3% urea 3. Control sucking pest and stalk and top borer.

Drainage is also equally important in waterlogged areas. Waterlogged conditions may deteriorate the quality of cane. Drainage greatly helps not only in higher yields, but also sucrose content of the cane.

Nutrient management:

An average crop of sugarcane yielding 100 t/ha removes 208 kg of N, 53kg of P, 280 kg of K, 30 kg of Sulphur, 3.4kg of iron, 1.2 kg of manganese and 0.6 kg of copper from the soil. Hence, soil has to be replenished to sustain the productivity of sugarcane with the said quantities of nutrients and maintain availability of micronutrients in soil before there critical limit like Fe (non-calcareous soil) 4.2 ppm, Fe (calcareous soil) 6.3 ppm, Zn (Loamy soils) 1.2 ppm, Zn (Clay soils) 2.0 ppm, Mn 2.0 ppm, Cu 1.2 ppm and Hot water soluble-B 0.44 ppm.

In northern India, the N requirement of sugarcane is about 150-180 kg N/ha, whereas in southern India, it is 250-350 kg/ha. If soil test values are not available, apply 60-80 kg P_2O_5 and 60 kg K_2O/ha in north India and 100 kg P_2O_5/ha and 80-120 kg K_2O/ha in southern parts of the country.

1. Application of well decomposed FYM/compost @ 10-15 t/ha or composted press mud @ 5 t/ha is recommended.

2. Sugarcane did not respond to potassium application under terai soils, where soils are rich in available potassium, containing more than 300 kg K_2O /ha. At Padegaon, the maximum yield of cane and CCS were obtained under soil moisture stress condition during summer for spring planted sugarcane with conventional planting, application of 150 kg K_2O /ha (at planting) and trash mulching @ 5 t/ha immediately after germination. It has been recorded that crop

significantly responded to potassium application up to 60 kg K_2O / ha.

3. Soil application of *Azotobactor* or *Azospirillum* @ 10 kg/ha cfu 10^7 -10^9 in two equal splits at 30 and 60 days after planting gave 25% saving in nitrogenous fertilizers.

4. Trash mulching in ratoon crop increased sugarcane yield significantly over no mulching at a number of locations in the country. Trash mulching conserves the soil moisture, controls weeds and creates favourable rhizo-microbiome environment for optimizing nutrients availability and crop growth.

5. Application of recommended dose of nitrogen in three to four splits resulted in increased number of milliable canes, seed cane yield and quality. In certain soils, application of 25% additional nitrogen and 25 kg K_2O/ha as an extra dose produced significantly higher seed cane yield.

6. Incorporation of sulphitated press mud at the rate of 4 tonnes/ha + 75% of recommended dose of N resulted in cane yield equal to that obtained with recommended nitrogen dose alone, thereby saving of 25% of nitrogen.

7. Sulphur may be applied @ 40-60 kg/ha in sugarcane plant crop in sulphur deficient soils. As regards source of sulphur, gypsum has been found more effective and economical.

8. The cane growth and development has also been found to be affected by B, Cu, Fe, S, Mg, Mn, Mo and Zn. Most of these are needed in small amounts, but necessary in case of their deficiencies in the soil. The calcareous soils require Zn and S for better growth and development of canes. An application of 25 kg Ferrous Sulphate, 20 kg Zinc Sulphate, 10 kg Manganese Sulphate, 10 kg Copper Sulphate 2.5 kg. Sodium Molybdate and 5 kg Borax per hectare is advocated if deficiencies exist. Micro nutrient fertilizers should be mixed with well decomposed dung manure or compost and applied as basal dose.

Table 12: Recommended fertilizer doses in different sugarcane growing zones of India

S. N.	Sugarcane producing agro-climatic zone	Season of planting	Kg/ha		
			Nitrogen	P_2O_5	K_2O
1.	North West Zone	Autumn planting	150	60	60
		Spring planting	150	60	60
		Late planting	150	60	60
		Ratoon Crop	200	60	60

2.	North Central Zone	Plant crop	150	85	60
		Ratoon crop	200	60	60
3.	North Eastern Zone	Plant crop	135	70	60
		Ratoon crop	200	60	60
4.	Peninsular Zone	Plant crop	250	100	125
		Ratoon Crop	200	60	60
5.	East Coast Zone	Plant crop	250	100	60
		Ratoon Crop	200	60	60

Nutrient management for sugarcane seed crop

Nutrient management for sugarcane seed crop is very important and the agronomic requirements for tropical and subtropical belts are different. In tropical zone, seed cane is fertilized with 75 to 100% of recommended dose of nitrogen in 2-4 equal splits depending upon soil texture, irrigation practice followed and variety grown. In sub-tropical zone, with wide variability in edaphic, environmental and management conditions, the seed cane needs 25% additional N over recommended doses of N, P and K. Application of total N may be phased out in 4 equal splits for realizing beneficial effects in terms of yield and quality.

Drought & Flood management

Since the effect of flood and drought on the production and productivity of sugarcane and sugar recovery are being made to minimize and sustain sugarcane cultivation with adverse conditions. Under AICRP on sugarcane, the following sugarcane varieties and technologies have been developed for different sugarcane growing states.

1. Under drought conditions, additional application of 60 Kg K_2O/ha at 150-180 DAP over and above soaking setts in saturated lime water + foliar spray of urea and KCl @ 2.5% at 90, 105 & 120 DAP + trash mulching after 60 DAP + application of FYM @ 10t/ha in furrows before planting be adopted to improve cane yield. Under drought conditions in light and medium textured soils, sugarcane planting following pit method may be adopted in combating drought situation.
2. The sugarcane varieties have been developed for adverse climatic conditions and recommended for cultivation in different regions of the country.

Table 13: Sugarcane varieties (Zone wise) tolerant to drought condition in India

S. No.	Zone	States	Sugarcane Varieties
1.	North Central Zone	Punjab, Haryana, Rajasthan, Central and Western Uttar Pradesh and Uttarakhand	CoPK 05191, Co 0238, Co 0239, CoPant 90223, Co 98014, CoPant 97222,
2.	North Central Zone	Eastern Uttar Pradesh, Bihar and West Bengal	CoLk 94184, Co 87268, Co 87263, Co 89029, Co 0232, Co 0233,
3.	East Coast Zone	Coastal Tamil Nadu & Andhra Pradesh and Odisha	CoOr 03151
4.	Peninsular Zone	Gujarat, Maharashtra, Karnataka, Kerala, Interior of Tamil Nadu & Andhra Pradesh, Madhya Pradesh & Chattisgarh	Co 86032, Co 87025, Co 8371, Co 91010, Co 94008, Co 99004, Co 2001-13, Co 2001-15, Co 0218, Co 0403 and CoM 88121

Table 14: Sugarcane varieties (zone wise) tolerant to flood

S. No.	Zone	States	Varieties
1.	North West Zone	Punjab, Haryana, Rajasthan, Central and Western Uttar Pradesh and Uttarakhand	CoPant 90223, Co 98014, CoPant 97222, Co 0118, Co 0124, Co 0239, Co 0237 and CoPK 05191
2.	North Central Zone	Earstern Uttar Pradesh, Bihar and West Bengal	Co 87263, Co 87268, Co 89029, BO 128, CoSe 96436, CoLk 94184, Co 0232 and Co 0233
3.	East Coast Zone	Coastal Tamil Nadu & Andhra Pradesh and Odisha	Co 86249 and CoOr 03151
4.	Peninsular Zone	Gujarat, Maharashtra, Karnataka, Kerala, Interior of Tamil Nadu & Andhra Pradesh, Madhya Pradesh & Chattisgarh	Co 87025,Co 8371 and CoSnk 05104

Management of chlorosis in sugarcane

Iron chlorosis is a widely occurring nutritional deficiency, especially in calcareous soils. It aggravates more in succeeding ratoon crops. Chlorosis has been observed in almost all the sugarcane growing states of India, particularly in Madhya Pradesh, Maharashtra, Tamil Nadu and Bihar. Efforts have been made to ameliorate lime induced iron chlorosis in sugarcane by: (i) Foliar spray of 2 per cent solution of $FeSO_4$ along with 0.5% $MnSO_4$ and 2% urea, two to three times. (ii) Soil application of $FeSO_4$ @ 25 kg/ha. (iii) Soil application of press mud (5 t/ha) + iron pyrite (2 t/ha). (iv) Soil application of farm yard manure (25 t/ha) + foliar application of 1.5% $FeSO_4$ with 1% urea at weekly intervals and 1% $ZnSO_4$ at monthly intervals. (v) Application of elemental sulphur @ 30 to 40 kg/ha, 3 weeks before planting. (vi) Foliar spray of Fe–EDTA (50 ppm solution), is recommended.

Management of flowering in sugarcane

Wherever, there is problem of flowering in sugarcane, one foliar spray of ethrel @ 250-300 ppm (2.5 – 3.0 ml/10 litre of water) at 4 month stage of the crop is recommended.

Crop diversification

Since sugarcane is a crop which gives income after about a year of planting, there is a dire need to diversify the cropping system by introducing other crops, either in a sequence or as intercropping. This not only generates mid-season income for the marginal farmers to meet the expenses for sugarcane cultivation, but also fulfils the household requirement of food, fibre and oilseeds mitigating the ill-effects of sugarcane monoculture. 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.

Sequential cropping system/relay cropping

Sugarcane is grown in the country in about 5.0 million hectares. In order to meet increasing demand of sugar, the sugarcane acreage needs expansion. Since there is little scope of diverting cultivable area in to sugarcane cultivation, sugarcane based-cropping system has become a necessity. In AICRP on Sugarcane, number of crops have been identified in different states of the country. Some sugarcane based cropping systems have become popular in different regions of the country. Few such systems are being given below.

Table 15: Popular sugarcane-based cropping systems in India

Cropping systems	Regions
North West Zone	Rotation in spring Rice (short duration)–Rabi fodder/Potato-Sugarcane ratoon I-ratoon II-Wheat, Rice/ *kharif* fodder-*Toria/Raya*-Sugarcane-ratoon I-Wheat, Maize/Cotton-*Senji*-Sugarcane-ratoon I-ratoon II-Wheat, *Arhar*-Oat/*Senji*-fodder-Sugarcane-ratoon I-ratoon-II-

	Wheat. Rotation in Autumn-Sugarcane *Kharif* fodder/Green manure/Maize/Rice (short duration) *Moong*-Sugarcane with intercrop (*Raya*/ Potato/Wheat/Winter Maize/*Gobhi Sarson*/cabbage) ratoon I-ratoon II-Wheat. Rice – Sugarcane – Ratoon – Wheat – Urd / Moong Sugarcane + Potato/Toria/Lentil/Urd/Moong – Ratoon – Wheat
North Central Zone	Rice- Wheat- Green gram Rice- Sugarcane (plant)- Ratoon- Green gram Sugarcane (plant)- Ratoon- Wheat- Green gram
North Eastern Zone	Rice-pea-sugarcane-ratoon Rice/maize-sugarcane-ratoon
Peninsular Zone	Paddy-Sugarcane-Ratoon-Finger millet Paddy-Sugarcane-Ratoon-Sesamum Paddy-Sugarcane-Ratoon-Blackgram Paddy-Groundnut-Sorghum-Finger millet-Sunhemp-Sugarcane Sugarcane-Fodder sorghum-Groundnut-Tobacco-Cotton-Green manure Sugarcane-Ratoon-*Kharif* Paddy-Winter Paddy-Sunhemp
East Cost Zone	Paddy – Paddy – Fallow Sugarcane – Paddy Paddy – Sugarcane – pulses

Intercropping in Sugarcane

Intercropping in sugarcane offers great opportunity for increasing farm income per unit area and time. The success of intercropping depends on the selection of crop, variety, sowing time, planting geometry, fertilizer management and other crop management practices. In southern India, sugarcane is usually rotated with rice. In north India, sugarcane is generally grown after harvest of cotton, maize, sorghum, paddy, *toria*, potato, pea, wheat etc.

Sugarcane + Potato

Sugarcane + Mustard

Sugarcane + Marrigold

Sugarcane + Cauliflower

Table 16: Crops suitable for intercropping in sugarcane in tropical region in India

Planting season	Intercrops
Seasonal (*Suru*)	Summer groundnut, Soybean, Water melon, cucumber
Preseasonal	Potato, Gram, cabbage, cauliflower, onion
Adsali	Groundnut, soybean, cowpea, radish, Coriander, fenugreek.

Table 17: Package of practices of intercropping in sugarcane for sub-tropical region in India

Intercrop	No. of rows in between two rows of sugarcane crop	Seed rate of intercrop (kg/ha)	Time of sowing /planting
Intercropping in autumn planted sugarcane			
Wheat	3	75	Last week of October
Chickpea	2	50	2 nd fortnight of October
Mustard	2	3	Last week of September to October 20
Lentil	2	20	2nd fortnight of October
Garlic	4	250	Last week of September to end of October
Onion	4	8	2nd fortnight of October for Sugarcane Mid December to mid January for onion
Potato	2	3000	1st fortnight of October
Pea	2	150	Month of October
Cauliflower	2	3	Mid September to October
Cabbage	2	1-1.5	Mid September to October
Knolkhol	2	2	2nd fortnight of October
Fenugreek	3	40	Full Month of October
Coriander	3	30	Full Month of October
Radish	2	20	Full Month of October
Turnip	2	15	Full Month of October
Baby corn	2	40-50	Last week of October
Intercropping in spring planted sugarcane			
Green gram	2	15-20	February 20 to end of March
Black gram	2	15-20	February 20 to end of March
Lady finger	2	50-60	February 20 to first week of March
Cowpea	2	30-35	February 20 to first week of March
Clusterbean	2	15-20	February 20 to first week of March

Weed management

Presence of weeds interferes with the growth and development of the crop and ultimately reduces the cane yield. Among various reasons for the loss in cane yield, intense competition by weeds to the crop for nutrients, moisture and space is the most important one.

1. Weed management in sugarcane plant crop

To manage the weeds in sugarcane, Metribuzin 1.0 kg ai/ha or ametryn @ 2.0 kg ai/ha as pre-emergence is as effective as earlier recommended pre-emergence herbicide atrazine@ 2.0 kg ai/ha. Either of these herbicides should be coupled with application of 2,4-D @ 1.0 kg ai/ha at 60 days after planting (DAP) and one hoeing at 90 DAP to sustain cane yield equivalent to three manual hoeings at 30, 60 & 90 DAP.

2. Weed management in ratoon crop

Three hoeings, at 1, 4, and 7 weeks after ratoon initiation should be adopted for effective control of weeds in sugarcane ratoon crop. However, under limitations of manpower-availability, 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) followed by either of 2,4-D Na salt @ 1.0 kg/ ha ai (in 600-800 litres water/ha) or hoeing at 45 days after ratooning can be successfully practiced. Further, trash mulching in alternate rows and hoeing in unmulched furrow at 1 & 6 weeks after ratoon initiation is also a good option.

3. Management of binding weeds

In sugarcane, application of atrazine @ 2 kg ai/ha or metribuzine @ 1.25 kg ai/ha as pre-emergence followed by DICAMBA @ 350 g ai/ha at 75 DAP is effective for controlling binding weeds in sugarcane.

Hoeing & Earthing-up

Hoeing and earthing-up are two main operations in sugarcane cultivation. Hoeing is done with the help of shovel or cultivators. It starts just after one week of planting (blind hoeing), the second about 3 weeks after planting and subsequent hoeing after every irrigation. Blind hoeings helps in breaking the hard crust at surface, which might create problems to the sprouting of seedlings. Besides covering the exposed setts, it also helps in uprooting the weeds, and replacing the damaged setts by diseases or insects. The hoeings are necessary for better aeration, moisture conservation and control of weeds. Hoeing is done first in a week or so after planting in order to break the surface crust, else light irrigation is followed by the same period in order to help emergence of sprouts. After the sprouts are out, the hoeing by bullock drawn implements is followed to control weeds as well as for loosening surface soil. If the weeds are more, the hoeing is followed by hand weeding. One to two hand weedings and one hoeing are given within 6–8 weeks after planting by which time first top dressing of nitrogen fertilizer is given. Before next nitrogen, fertilizer application (12-16 weeks after planting), one more hand weeding followed by hoeing is usually necessary.

Earthing-up is also required in sugarcane cultivation. It is done to suppress the growth of excess tillers facilitate irrigation and economise water, to drain out the excess water from the field, to control weed infestation and to protect the crop from lodging.

Tying and Wrapping


Tying and Wrapping of sugarcane

These operations are most essential in sugarcane cultivation just to provide mechanical support to the grown up plants to prevent lodging. The leaves are removed from the plants and wrapped together by taking all canes in one bundle. By wrapping the distribution of CO_2 becomes easy and proper throughout the field. After wrapping, the clumps in, adjacent rows are tied together (cross-wise). Tying should be done in the month of August when cane reaches about 2 m height. Green leaves should not be tied up together while tying up the crop.

Maturity and Harvesting


Sugarcane harvesting

Sugarcane crop matures within 10-12 months in north India and 12-16 months in south India depending upon the season of the crop. The crop should be harvested when sucrose contents value reaches to minimum 16.5% with 85% juice purity. Thus impurities of sucrose in total dissolved solids are most important factor which govern the maturity of crop. Usually this stage arrives during December-January when atmospheric temperature is about or below 20°C. Under high temperature conditions, the sucrose gets converted into glucose resulting in poor quality of produce. The yellowing of leaves, emergence of arrows, cane become brittle & brakes easily, cane produce metallic sound and swelling out of buds from nodes are the other indicators of crop maturity.

Cane yield

In north India, a good crop yields about 80-100 tonnes/ha but in south India (*adsali* crop) may yield more than 150 tonnes/ha.

Mechanization in sugarcane cultivation

In the competitive involvement, which is fast encompassing all the operations, the effectiveness of human resources will be the cutting edge for sustaining the productivity. Mechanization in Indian agriculture has proceeded along with the time tested two pronged approach based on improved equipments and enhanced power supply. The analysis of impact of mechanization has shown that the emphasis on timeliness, precision and general improvement in the quality of work, mechanization has undoubtedly contributed to increase the yield, cropping intensity and total production and cutting cost effectively. These machines have been developed for different farm operations such as tillage, seed bed preparation, sowing and planting, weeding and inter culture operations, irrigation, plant protection and harvesting etc. Sugarcane harvester is mainly used for harvesting of sugarcane in tropical states.

Machinery adopted for sugarcane cultivation in India

1. Ridger- type sugarcane cutter-planter

Ridger type sugarcane cutter- planter, PTO driven, has been developed for planting of sugarcane which performs major operations involved in cane planting at a spacing of 75/90 cm. It has effective capacity of planting one ha in 4-5 hours and saves approximately 60% cost of planting operation. The machine has been developed by ICAR-IISR, Lucknow.

2. Three-row multipurpose sugarcane cutter- planter

Three-row multipurpose sugarcane cutter planter, ground wheel driven, was developed for planting of sugarcane which performs all the operations involved in cane planting at a spacing of 75 cm. It has effective capacity of planting of one ha in 3.5 to 4 hours, and saves approximately 70% cost of planting operation.

3. Paired row sugarcane cutter-planter

Paired row sugarcane cutter-planter, PTO driven has been developed for planting of sugarcane under paired row geometry (30:120/ 150 cm spacing). The subsequent spacing between the paired rows could be varied. It has effective capacity of planting of one ha in 4-5 hours, and saves approx. 60% cost of planting operation. The machine has been developed by ICAR-IISR, Lucknow.

4. Zero-till sugarcane cutter-planter

Zero-till sugarcane cutter-planter, PTO driven has been developed for planting sugarcane which performs all the operations involved in cane planting at a spacing of 75/90 cm. It has effective capacity of planting of one ha in 4-5 hours, and saves approx. 60% cost of planting operation. It also saves the cost of seed bed preparation. The machine has been developed by ICAR-IISR, Lucknow.

5. Two row pit digger

Two row pit-digger has been developed for making 25-30 cm deep, circular pits of 75 cm diameter at 30 cm spacing for planting sugarcane under ring pit system. It has effective capacity of digging 150 pits/hr (0.017 ha/hr) and saves 400 man-days/ha. It saves about 70% cost of dgging pits compared to manual digging. The machine has been developed by ICAR-IISR, Lucknow.

6. Raised bed seeder

Raised bed seeder has been developed for making three raised beds (2 full beds + 2 half beds)-for sowing of wheat simultaneously at a spacing of 17 cm, and three furrows at a spacing of 75 cm- for planting of sugarcane as and when required. It has an effective capacity of 0.35-0.40 ha/hr. The machine has been developed by ICAR-IISR, Lucknow.

7. Raised bed seeder-cum-sugarcane cutter planter

Raised bed seeder-cum-sugarcane cutter planter is developed to plant two rows of sugarcane in furrows and make two rows of wheat as intercrop on the main raised beds and one each on the either side of half raised beds. It has effective capacity of 0.20-0.25 ha/hr and saves approximately 60% of the cost of operation. The machine has been developed by ICAR-IISR, Lucknow.

8. Ratoon Management Device

Ratoon management device is developed which executes all the operations involved in management of ratoon crop such as stubble shaving, deep tilling, off-barring, placing manure, fertilizer/bio-agents, chemicals in liquid form and earthing-up operations in a single pass of operation. It has capacity of 0.35-0.40 ha/hr and saves 60% of the cost of operation. The machine has been developed by ICAR-IISR, Lucknow.

9. Plant residue Shedder

This machine has been developed at IISR, Lucknow for in-situ shredding of dry leaves of the sugarcane in the field. Stubble shaving can also be performed simultaneously.

10. Sugarcane Detrasher

A power operated detrasher was developed at IISR, Lucknow for removal of green top as well as dry trash from the harvested sugarcane stalks. The output of the detrasher was 2.4 t/h for feeding of 2-3 cane stalks at a time with trash removal efficiency of 77.5 to 94.5%.

Aerated Steam Therapy

MHAT (front view)

Sugarcane crop often becomes susceptible to sett born diseases. The following methods are used to protect the sett from sett born diseases.

I) Hot Water Treatment

Cane is treated with hot water at 50° C for 2 hours.

ii) Moist Hot Air Treatment (MHAT)

Cane is treated with hot air at 54° C with high humidity for 4 hours. The equipment has been developed by ICAR-IISR, Lucknow.

1. Sprayers

These are - 1. Wide swath spray boom for tall Crop, 2. Self propelled boom sprayer, 3. Bucket type sprayer, 4. Knapsack Sprayer

2. Dusters

These are - 1. Bellow typed dusters, 2. Shoulder carried hand operated rotary duster, 3. Sigma dusters, 4. Rotary type hand and power duster.

Integrated Insect - Pests & Diseases Management

Sugarcane is an annual crop and attacked by number of insect-pests and diseases. They can cause economic and qualitative damage to the crop and crop products. Management of insect-pest and diseases of sugarcane crop is very important and selection of effective management strategy is equally important. These approaches may be-

1. Chemical measures: Application of chemical materials on plants, soils or seeds, fungicides, nematicides, insecticides, herbicides, bio-regulators etc.

2. Biological measures: Beneficial arthropods, pathogens (viruses, bacteria, fungi), use of antagonists, resistant cultivars, induced resistance, organic fertilizers etc.
3. Bio-technical measures: Physical and/or chemical attractants, use of pheromones, insect hormones for fertility and growth, sterile male techniques, etc.
4. Agronomic practices: Location and amelioration, cultivation, crop rotation, elimination of inoculums sources, or alternative and intermediate hosts, proper seeding and planting, etc.
5. Physical procedures: Mechanical, thermal, exclusions (nets, etc), radiation.

Plant quarantine: Import and export control, intermediate quarantine, post-import quarantine, etc.

Table 18: Management of insect-pests of sugarcane

Insect-pests Name	Insect-pests/rodents	Management approaches
Pyrilla		Distribution of *Epiricania melanoleca* @ 4000-5000 cocoons/ha is found effective.
Wooly Aphid		Sugarcane woolly aphid can be effectively managed by the release of bio-agents like *Dipha aphidivora* @ 1000 larvae/ha or *Micromus igorotus* @ 2000 larvae/ha at 15 days Interval from August to October. Need based chemical application of imidacloprid 200SL@100 g a.i./ha or chlorpyriphos 20 EC @ 1 kg a.i./ha or oxydemeton methyl 25 EC @ 1 kg a.i./ha or thiame thoxam 25 WG @ 50 g a.i./ha is found effective.

Sugarcane stalk and internode borer		Release of *Trichogramma chilonis* @ 50,000 adults/ha (two Trichocards) at 10 days interval from July to October and *Cotesia flavipes*, @ 500 gravid females/ ha/week from July to November is found effective.
Top borer		Soil application of Thimet 10 G @ 30 kg/ha (thimet 1 kg a.i./ha) around the clump base during 2nd – 3rd week of June along with trapping of top borer moths using pheromone trap is found effective.
White grub		Light + pheromone trap to catch adult white grub beetles is recommended for effective management.
Early shoot borer & Root borer		Application of Chlorpyriphos 20 EC @ 5 litres/ha in 1600-1800 litres water (3 ml/litre) on cane setts in furrows at planting for checking the infestation of shoot borer. Collection and destruction of infested shoots at periodic intervals from March to May on campaign basis is also recommended.

Termite		Application of Chlorpyriphos 20 EC @ 5 litres/ha in 1600-1800 litres water (3 ml/litre) over cane setts in furrows at planting is recommended.
White fly		Removal of lower leaves followed by foliar application of Imidacloprid 0.005% + 2% urea is recommended. Urea solution should be prepared first and then Imidacloprid is to be added to avoid coagulation of the mixture.
Mealy bug		Sett treatment with imidacloprid 70 WG/SP @ 25 g a.i./ha or thiamethoxam 70 WG/SP @ 25 g a.i./ha (36 g product in 150 litres of water) followed by spraying of imidacloprid 17.8 SL @ 0.05% at cane formation is found effective.
Rodents		Application of zinc phosphide (2%) baiting followed by bromadiolone baiting are effective .

Table 19: Management of Sugarcane Diseases

Sugarcane Disease	Symptoms	Management approaches
Red Rot		Red rot - The disease is caused by a fungus *Colletotrichum falcatum*. The planting of resistant sugarcane varieties is the most effective method of prevention and control. Healthy cultural practices with crop rotation should be adopted.

Smut		Smut - The disease is caused by a fungus *Sporisoreum scitamineam*. The planting of resistant sugarcane varieties, seed selection and rouging of infected clumps, hot water treatment for 52°C for 2 hours is effective, and or sett dipping with 0.2% Bavistin for half an hour before planting should be adopted.
Wilt		Wilt - The disease is caused by a fungus *Fusarium Sacchari*. Seed material should be dipped in Bavistin 0.2% before planting. Crop rotation with coriander or mustard as a companion crop. Use of Borax @ 15 kg/ha for soil treatment. *Trichoderma* culture (10 kg/ha-CFU 10^7 per g) is beneficial. Rouging of infected clumps should be adopted.
Grassy Shoot Disease		Grassy Shoot Disease - The disease is caused by a Phytoplasma. Selection of setts should be avoided from diseased area. Rouging of infected clumps is recommended. Hot water treatment for 52° C for 2 hours is effective. Vector (Aphid) should be controlled by spraying insecticide to prevent secondary infection.
Ratoon Stunting Disease		Ratoon Stunting Disease - The disease is caused by a bacterium *Leifsonia xyli* subsp. *xyli*. The planting of healthy, disease-free seed cane is an important control measure. The planting material can be obtained by tissue culture

		(meristem tip tissue culture), or after hot-water treatment of sugarcane, to eliminate bacteria prior to the establishment of seed cane nurseries. The hot-water treatment consists of an immersion of sugarcane cuttings in running water at ambient temperature for 24–48 hours followed by an immersion in water at 50°C for 2–3 hours.
Yellow Leaf Disease		Yellow Leaf Disease - The disease is caused by a virus. The meristem culture technique is most widely used method for virus elimination in meristematic tissues of apical shoots. There is no any effective control measure for *SCYLD*.
Pokkah Boeng		Pokkah Boeng - The disease is caused by a fungus *Fusarium moniliformae*. Spraying of 0.2% Bavistin or 0.2% Blitox-50 or 0.2% Copper oxychloride are the most effective fungicides for its management.
Sugarcane rust		Sugarcane rust - The disease is caused by a fungus *Puccinia melanocephala.* Propineb @ 0.25% and Mancozeb @ 0.20% are found to be effective against rust, should be sprayed on the foliage just after the appearance of rust pustules, thrice at 15 days interval.

Ratoon management

Ratoon crop yield can be achieved at par plant crop with good management practices. The major constraints observed on farmers fields in both tropical and subtropical regions are late harvesting of cane crop, harvesting above the ground

level, no gap filling, imbalance & lower fertilizers dose application than recommended and non availability of labourers because the initial ratoon management time which coincides with the peak sowing of wheat (specially in sub tropical region), significantly affect the growth and yield of ratoon crop. So, adoption of stubble shaving practices, trash mulching, gap filling with pre-germinated cane settlings and 25% higher dose of fertilizers than plant crop in the sugarcane cultivating zone can help to improve the ratoon yield significantly. The ratoon management practices are described below -

1. Trash Management

Most of the farmers burn the trash in field itself but it can be conserved. Trash add nutrients to the soil. Remove the trashes and keep it near bunds till stubble shaving and off-barring operations are over and then spread it in the field. Trash mulching conserves soil moisture. Mulched trash can be incorporated into the soil at the time of earthing- up.

2. Stubble shaving or stubble pruning

This is an indispensable operation to raise good ratoon crop. The stubble protruding above ground level are cut close to the ground using a spade. It will induce underground buds to sprout and establish deeper root system. Apply Chlorpyriphos 20 EC (5 litres/ha in 800-1000 litres water) after stubble shaving.

Trash mulching in sugarcane ratoon

3. Off-baring or root pruning or shoulder breaking

Cutting sides of the ridges and loosening soils between ridges are the other important operations in ratoon crop. It reduces soil compaction. It can be done manually or using plough or tractor mounted ratoon management device (RMD). The RMD can do harrowing, weeding, dispensing FYM, pesticide, fungicide, fertilizers and earthing- up in a single pass. About 1 ha ratoon field can be worked in 4 to 5 hrs.

3. Gap filling

If ratoon crop has the gap of more than 60 cm, gap filling is done. For gap filling either use pre-germinated settlings from nursery raised from single bud or stubble of previous crop or normal 3 bud setts. Studies showed that there is variation in the ratoonability of crop among different varieties. However, gap filling significantly increased the cane yield.

4. Retention of water shoot/late tillers

Retention of water shoots/late tillers have been found advantageous for obtaining higher ratoon cane yield from late harvested plant cane i.e. in April

and May particularly sub tropical India.

5. Water management

Watering is done in the field immediately after harvest of plant crop. Ratoons are susceptible to water stress and deficiency for a longer period affects growth and development of the crop. Give timely irrigation, avoid excess irrigation and provide proper drainage to good crop health to attain good yield.

6. Harvesting of plant crop

It has been observed that good ratoon comes from good plant crop. Therefore, raise the plant crop by applying recommended package of practices of particular agro-climatic zone and harvest plant crop when weather condition is ideal for stubble sprouting. It is recommended that autumn planted cane when harvested early in the crushing season gives better sprouting and ratoon yield. Besides this, harvesting should be done close to the ground level for better sprouting and survival of tillers.

7. Increasing sprouting in winter harvested crop

Spray stubbles with fungicide carbendazim (1gm/litre) + Etherel (plant growth hormone) @ 50 ml/ha (avoid skin contact as Etherel may cause allergy) is found effective for sprouting and gives good crop growth.

8. Fertilizers management

Application of recommended fertilizers enhance ratoon crop yield. The 25% higher dose of fertilizers is recommended than plant crop of sugarcane. Full dose of phosphorus and potash and one third dose of nitrogen is applied at the time of ratoon initiation and should be well incorporated in soil. Apply the remaining nitrogen in two split doses at 45 and 90 days after ratooning. Besides this, ratoon crop yield can be enhanced with two sprays of 1% ferrous sulphate + 2.5 % urea during tillering phase, if there is deficiency of iron in the crop.

Management of multiple ratooning

Under multiple ratooning, integration of agro-technologies viz. stubble shaving, gap filling, trash mulching and cultivation in alternate rows with the use of phorate (15 kg/ha) may be adopted to sustain higher cane ratoon yields. Keeping ratoon beyond fourth does not appear to be economical. As component technology, trash mulching and gap filling have been identified as critical technologies to sustain multiple ratoon productivity. Following recommendations should adopted while raising good ratoon crop in North India.

1. Do not harvest the crop to be ratooned before the end of January. If the crop is harvested earlier, there will be poor sprouting of the stubbles due to low temperature during December and January.

2. Soon after the early varieties are harvested in November or December, remove

the trash and irrigate the field. When the soil attains the optimum moisture conditions, loosen it by hoeing, ploughing or inter-culture with a tractor-drawn tiller. Do not cover the stubble with cane trash.

3. Harvest the canes as close to the ground as possible to promote better sprouting. If still some big stubble is left, shave or lop them off close to the ground. Also remove late tillers or water-shoots, as they inhibit the full sprouting of the stubbles.

4. Plough the harvested field twice with a desi plough or with a tractor-drawn tiller to check weeds. Alternatively, adopt chemical weed-control measures.

5. The stand of the ratoon crop can be improved by planting the gaps with three budded sets in the beginning of March.

6. The nitrogen requirement of the ratoon crop is 25% higher than that of the plant crop. Hence, apply N to the ratoon crop in three split doses– one third in February-March, one-third in April and the remaining one-third in the beginning of June. Applying phosphorus along the cane rows in the month of March on the basis of soil test.

7. Irrigation, insect-pest and disease management in ratoon crop are same as cane crop.

Cost of production

It is obvious to estimate cost of production/management of sugarcane plant and ratoon crop. So that, sugarcane farming communities can analyse benefits from the sugarcane cultivation. It has been observed that management of sugarcane crop and transportation charges are variable in nature from one state to others. General assessment of cost of production is given in following table.

Table-20: Gross and Net Returns of Sugarcane (Average from 2010-11 to 2012-13)

(Rs/ha,)

State	Cost A_2+FL*	Cost C_2#	GVO	Gross Returns	Gross Returns (Percent)	Net Returns	Net Returns (Percent)
Andhra Pradesh	72154	114551	146668	74515	103	32118	28
Haryana	51224	102140	152361	101137	197	50221	49
Karnataka	54094	92372	167199	113105	209	74827	81
Maharashtra	101115	147229	216373	115257	114	69144	47
Tamil Nadu	106167	135073	212273	106106	100	77201	57
Uttar Pradesh	44168	78000	130367	86199	195	52367	67
Uttrakhand	42918	73587	129391	86473	201	55804	76
All India	63986	101224	160437	96451	151	59213	58

*Source: http://cacp.dacnet.nic.in/View Report.aspx?Input=2&PageId=41&KeyId-53

*A_2+FL cost includes all expenses in cash and kind on account of hired human labour, bullock labour, machine labour, seed, insecticides and pesticides, manure, fertilizers, irrigation charges and miscellaneous expenses including family labour. #C_2 cost includes A_2+FL cost, rental value of owned land and interest on own fixed capital

Table 21: Projected Cost of Production (C_2 & A_2+FL)-Unadjusted for 9.5% Recovery of Sugarcane for 2015-16 Sugar Season and Production Shares

States	Cost of Production (Rs./qtl.)		Shares in
	A_2+FL	C_2	Production(%)
Karnataka	92	175	12
Uttarakhand	139	197	2
Tamil Nadu	146	187	11
Maharashtra	142	196	25
Andhra Pradesh	134	230	5
Uttar Pradesh	150	241	42
Haryana	134	257	2
All India Wtd. Avg.	140	215	

*Source: http://cacp.dacnet.nic.in/View Report.aspx?Input=2&PageId=41&KeyId-53
Note:- Projected cost is exclusive of cost of transportation and crop insurance premium

Table 22: Sugarcane - Break-up of Cost of Cultivation

(Rs/ha)

Cost Items	Andhra Pradesh		Haryana		Karnataka		Maharashtra	
	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12
Operational Cost	45402	78169	55075	58202	53738	58732	112827	101011
Human Labour								
Casual	17814	38615	21215	21778	21537	24217	30059	26928
Attached	5723	2027	1648	790	0	52	3215	3154
Family	3820	8206	5010	5524	10886	6465	13005	13121
Total	27358	48849	27873	28092	32423	30734	46279	43202
Bullock Labour								
Hired	2206	2850	293	92	1272	449	5032	3005
Owned	0	0	134	160	636	1585	2286	1468
Total	2206	2850	427	251	1907	2034	7318	4473
Machine Labour								
Hired	693	2735	886	2411	1868	4931	17610	15167
Owned	0	195	2815	3272	1109	1016	271	1013
Total	693	2930	3701	5683	2977	5946	17882	16180
Seed	946	9472	10141	12995	1377	5332	6141	5062
Fertilisers and Manure								
Fertilisers	6963	5398	4516	3644	8422	7432	17373	12075
Manure	194	874	161	337	1591	2020	1948	1777
Total	7157	6272	4677	3980	10013	9453	19321	13853
Insecticides	2525	1543	2174	1421	118	65	508	485
Irrigation charges	2071	2137	2986	2680	2401	2094	9506	12587
Interest on working capital	2446	4115	2945	3099	2521	3075	5872	5170
Miscellaneous	0	2	151	0	0		0	0
Fixed Cost	46442	46320	53061	53362	42517	35853	53136	45716
Rental value of owned land	27739	42155	47970	46899	37892	30392	43509	33531
Rent paid for leased-in land	15748	0		0	0		0	0
Land revenue, cesses & taxes	3	1		0	13	11	213	199
Depreciation on implements & Farm buildings	169	273	449	269	277	326	902	1080
Interest on fixed capital	2783	3891	4642	6194	4335	5124	8512	10906
Total Cost	**91844**	**124489**	**108136**	**111564**	**96254**	**94586**	**165962**	**146727**

Cost Items	Tamil Nadu		Uttar Pradesh		Uttarakhand	
	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12
Operational Cost	**123142**	**104455**	**49844**	**42249**	**41599**	**40137**
Human Labour						
Casual	68752	58063	12549	10108	13092	13602
Attached	644	537	506	502	8	16
Family	18002	14746	13160	11168	10524	8245
Total	87397	73346	26215	21778	23624	21862
Bullock Labour						
Hired	751	376	300	261	0	58
Owned	21	65	1283	1645	53	361
Total	772	441	1583	1906	53	419
Machine Labour						
Hired	1695	2232	1058	907	439	667
Owned	109	343	401	337	2179	560
Total	1804	2575	1459	1244	2618	1227
Seed	9068	9544	7611	5472	7464	9039
Fertilisers and Manure						
Fertilisers	10458	7095	3811	3070	2718	3098
Manure	3075	2371	507	648	0	0
Total	13533	9467	4318	3717	2718	3098
Insecticides	400	426	538	406	345	410
Irrigation charges	3982	3379	5963	5887	2925	2180
Interest on working capital	6185	5277	2158	1828	1828	1876
Miscellaneous	0	0	0	10	25	25
Fixed Cost	34458	29386	38807	36301	26003	27055
Rental value of owned land	26632	22315	32157	30221	20912	19908
Rent paid for leased-in land	9	12	161	50	0	0
Land revenue,cesses & taxes	13	10	23	21	15	17
Depreciation on implements & Farm buildings	678	599	1020	810	710	1006
Interest on fixed capital	7125	6450	5445	5199	4367	6124
Total Cost	**157600**	**133841**	**88650**	**78549**	**67602**	**67192**

*Source: http://cacp.dacnet.nic.in/View Report.aspx?Input=2&PageId=41&KeyId-53

Table 23: All India Average Annual Growth Rates of Sugarcane, 1992-97 to 2013-14

Particulars	Eighth Plan (1992-1997)	Ninth Plan (1997-2002)	Tenth Plan (2002-2007)	Eleventh Plan (2007- 2012)	Twelfth Plan (2012-2014)*
Area					
Growth	1.9	1.2	4.0	0.0	-0.2
CV	8.8	4.7	13.4	8.4	0.3
Production					
Growth	2.2	1.4	4.9	1.0	-1.7
CV	10.5	2.8	17.7	10.6	1.5
Productivity					
Growth	0.2	0.3	0.7	0.9	-1.5
CV	4.0	2.5	5.6	3.9	1.2

*Source: http://cacp.dacnet.nic.in/View Report.aspx?Input=2&PageId=41&KeyId-53
Notes: CV: Coefficient of Variation,
*Data is available for 2012-13 and 2013-14 period only Source: DES

Resource Conservation Technology (RCT) in Sugarcane

Food security and safety has become prime concern now a days. Attaining food security for increasing human population day by day while sustaining agricultural systems under depleting natural resources is a challenging task. The un-sustainability of agricultural systems is caused due to soil erosion caused by water and wind, decling soil organic matter, salinization caused by applications of heavy dose of inorganic fertilizers/chemical fertilizers, soil structural degradation, reduced water infiltration rates, surface sealing and crusting, soil compaction, insufficient return of organic material and adaptation of mono-cropping. So, it is urgent need to shift a paradigm of farming practices for better crop productivity while sustaining the natural resources. In sugarcane cultivation, management and proper utilization of natural resources are described below.

1. Application of nitrogen fixing (*Azospirillum* and *Gluconacetobacter*) and phosphate solubilizing (Phosphobacteria) bio-fertilizers are found to reduce the requirement of chemical fertilizers to the extent of 25%.
2. Trash mulching of dry leaves and drip irrigation are methods by which we can save water requirement up to 30%.
3. Application of ratoon management device (RMD), sugarcane cutter planter, trench opener, power weeder etc. are required for effective management and cultivation of sugarcane in India

Sustainable Sugarcane Initiative (SSI)

The ICRISAT-WWF project has designed the Sustainable Sugarcane Initiative, (SSI) which is a combination of cane planting innovations and water saving practices that have great potential for not only meeting the growing demands of sugar sector players looking for increased revenues and profitability, but also for the bigger picture of improved natural resource management, reduced environmental footprints and improved livelihoods by means of technologies that are appropriate and effective at household farm level. Sustainable Sugarcane Initiative is a method of sugarcane production that involves the use of less seeds, less water and optimum utilization of fertilizers and land to achieve more yields.

The major principles that govern SSI are:

- Raising nursery using single budded chips.
- Transplanting young seedlings (25-35 days old).
- Maintaining wide spacing (5x2 feet) in the main field.
- Providing sufficient moisture and avoiding inundation of water.
- Encouraging organic method of nutrient and plant protection measures.
- Practicing intercropping for effective utilization of land.

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