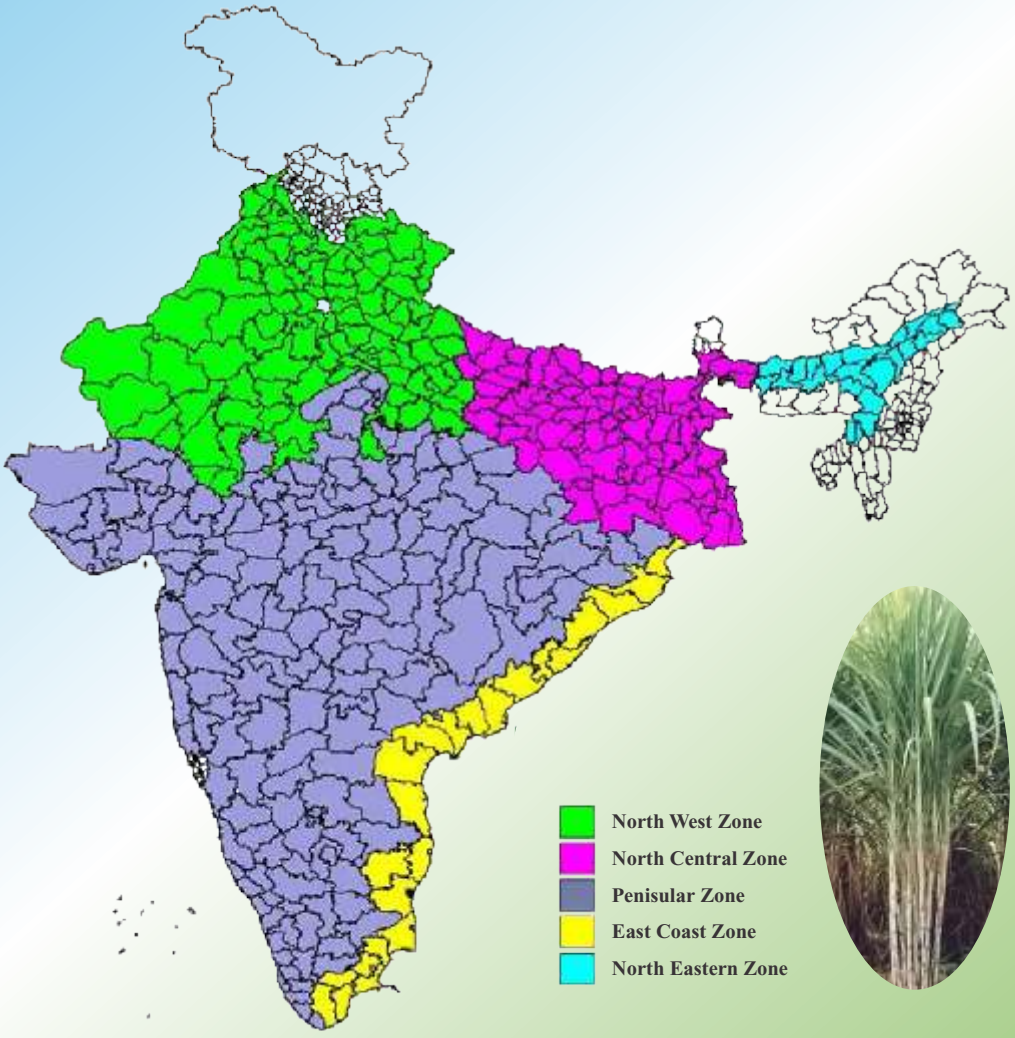
Forty Five Years of AICRP on Sugarcane



2016

All India Coordinated Research Project on Sugarcane

ICAR-Indian Institute of Sugarcane Research

Lucknow 226 002 (U.P.)

45

Forty Five Years of AICRP on Sugarcane

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Preface

In our country, sugarcane research network involves a large number of organizations at Central and State level. Under Indian Council of Agricultural Research, New Delhi there are two research Institutes, the Sugarcane Breeding Institute, Coimbatore and Indian Institute of Sugarcane Research, Lucknow. A number of State Agricultural Universities as well as State government departments and & non-government organizations are conducting research on sugarcane improvement.

All India Coordinated Research Project (AICRP) on Sugarcane was set up in 1970 with the objective to evaluate varieties under location specific conditions in addition to multilocation testing of production and protection technologies developed at various research stations. During the span of 45 years (1970-2015) enormous research work has been carried out under AICRP on Sugarcane which has significantly contributed in increasing sugarcane productivity through development of superior varieties as well as production and protection technologies. Many such varieties of sugarcane have sustained sugarcane production and sugar industry in the country. Sugarcane farmers were benefitted by the technologies made available to them through research stations.

A need was felt to compile the significant research achievements accrued during last 45 years. It is a matter of great pleasure that a publication **'Forty five years of AICRP on Sugarcane'** has been brought out which may be useful for the sugarcane research workers, in general, and scientists working under AICRP on Sugarcane, in particular.

We express our 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. We profusely thank Dr. J.S. Sandhu, Deputy Director General (Crop Science), ICAR for giving guidance and support to us. We thank Dr. R.K. Singh, Asstt. Director General (CC), ICAR for encouragement and guidance.

We are grateful to all the scientists and technical personnel who were associated with the technology development. We are highly grateful to the Directors of Sugarcane Breeding Institute, Coimbatore and Indian Institute of Sugarcane Research, Lucknow as well as Incharges of Sugarcane Research Stations who have significantly contributed in implementation of AICRP trials. For giving all support and providing leadership to the research programme, we are highly thankful to all the Principal Investigators.

We especially thank Dr. N. Vijayan Nair, Ex-Director, SBI, Coimbatore, Dr. Bakshi Ram, Director, SBI, Coimbatore, Dr. A.D. Pathak, Director, IISR, Lucknow and Dr. P. Govindraj, Principal Scientist, SBI, Coimbatore for helping in this endeavour. I thank my colleagues in Coordination Unit viz., Dr. Rajesh Kumar, Principal Scientist, Dr. S.K. Chaudhary, Retired Senior Scientist, Dr. C. Gupta, Principal Scientist, Dr. G.K. Singh, ACTO, Shri Adil Zubair, ACTO, Shri Devendera Singh, Technical Officer, Shri Mahendra Singh, Retired CTO for helping in various ways. I am thankful to Shri Ambrish Kumar Sahu for assisting in computer work.

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Establishment of AICRP on Sugarcane

Preamble

Sugarcane is commercially cultivated in tropical and sub-tropical States of India having diverse agro-climatic conditions. The establishment of Sugarcane Breeding Station (now ICAR-Sugarcane Breeding Institute) at Coimbatore (Tamil Nadu) and Sugarcane Research Station (now U.P. Council of Sugarcane Research) at Shahjahanpur (Uttar Pradesh) in 1912 laid the foundation of organized research in sugarcane in the country. In 1929, the Imperial (now Indian) Council of Agricultural Research (ICAR) was constituted for coordinating research in various crops in different States. In 1944, commodity-based committee, Indian Central Sugarcane Committee (ICSC) was constituted by the Central Government for intensifying research in sugarcane. The major sugarcane growing States, viz., Uttar Pradesh, Bihar and Punjab in sub-tropics and Maharashtra, Tamil Nadu and Andhra Pradesh in tropics had set up sugarcane research stations with one or several sub-stations. ICSC financed certain aspects of research from 1944 to 1966. After abolition of commodity-based Committees in 1965, ICAR took over the coordination of centrally financed research activities. Research support to sugarcane was provided by the State Agricultural Universities (SAU) as well as research institutes at Central and State level. In order to coordinate research efforts of SAUs, State research stations and ICAR Institutes as well as to provide a forum for testing the technologies developed by different research stations on multilocation basis, the All India Coordinated Research Project on Sugarcane was visualized.

ICAR sanctioned the All India Coordinated Research Project on Sugarcane (AICRP on Sugarcane) in 1970 as a Fourth Five Year Plan Project which took over the function of administering centrally sponsored research funds to SAUs and other research stations in the country. The headquarters of AICRP on Sugarcane is housed at the Indian Institute of Sugarcane Research, Lucknow. The project aims at pooling the research resources of the country involving SAUs, Central and State Sugarcane Researh Stations as well as Non-Government Organizations in a national grid for addressing the problems of regional and national importance. It also provides annual forum for the discussion and dissemination of information on new varieties, recommendation of technologies developed on crop production and crop protection.

Centres of AICRP on Sugarcane

AICRP on Sugarcane started its operation with seven main centres located at Jalandhar, Pantnagar, Pusa, Anakapalle, Padegaon, Lucknow and Coimbatore and eleven sub-centres at Uchani (Haryana), Bethuadahari (West Bengal), Sehore (Madhya Pradesh), Cuddalore (Tamil Nadu), Mandya (Karnataka), Kolhapur (Maharashtra), Navsari (Gujarat), Thiruvalla (Kerala), Lucknow University (Uttar Pradesh), Jorhat (Assam) and Bhubaneswar (Odisha). At the same time, Foundation Seed Programme (FSP) was launched in 1971 as a part of the AICRP on Sugarcane and was implemented in 1975 at eight centres viz., Lucknow, Jalandhar, Pusa, Hisar, Bethuadahari, Pravaranagar, Jaora and Shahjahanpur for producing disease-free seed cane through heat therapy. FSP continued till the end of 7th Five Year Plan, i.e., 1992 inasmuch as healthy seed cane production work was taken up under Sugarcane Adaptive Research Project. The FSP centre, Shahjahanpur became regular centre of AICRP on Sugarcane. Later on Sehore, Jorhat, Bhubaneswar and Jalandhar centres were shifted to Powarkheda, Buralikson, Chiplima and Ludhiana, respectively. During 8th Five

Year Plan, three new regular centres at Sankeshwar, Faridkot and Kota were sanctioned, whereas sub-centre at Lucknow University was closed. In 1997, Sriganganagar centre was included as a regular centre in 1997. Again Chiplima centre was shifted to Nayagarh while Ludhiana centre to Kapurthala. Since 9th Five Year Plan, 22 main (regular) centres (Table 1) with no sub-centre are continuing. Regular centres are depicted in the map showing State boundaries (Fig. 1).

With the implementation of AICRP on Sugarcane, a number of voluntary centres gradually came forward from 1982 onwards to participate in the Zonal Varietal Trial of the Crop Improvement programme as well as experiments in other disciplines. These are as follows: Muzaffarnagar, Golagokarannath, Gorakhpur, Seorahi, Modipuram from Uttar Pradesh, Vuyyuru, Perumalapalle, Kovvuru from Andhra Pradesh, Dapoli, Akola, Basmathnagar, Pune, Pravaranagar from Maharashtra, Junagarh, Kodinar from Gujarat, Sameervadi from Karnataka, Madiapakkam, Sirugamani, Nellikuppam, Pugalur from Tamil Nadu, Rudrur from Telangana, Raipur from Chhattisgarh and Jeetpur from Nepal. At present, only 14 voluntary centres are participating in AICRP on Sugarcane (Fig. 2).

Budget during Plan periods

The budget sanctioned for AICRP on Sugarcane in different Plan Periods is detailed below:

S.No.	Five Year Plan Period	
1.	V Plan (1975-80)	98.74
2.	VI Plan (1980-85)	143.48
3.	VII Plan (1985-90)	241.24
4.	VIII Plan (1992-97)	451.40
5.	IX Plan (1997-2002)	730.50
6.	X Plan (2002-2007)	1224.74
7.	XI Plan (2007-2012)	2359.25
8.	XII Plan (2012-2017)	5160.09

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 cane sugar 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 multi-location 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.

Table 1: Regular centres of AICRP on Sugarcane

S.No.	State	Name of centre & affiliation	Date of Start
1.	Andhra Pradesh	Regional Agricultural Research Station, Anakapalle (ANGRAU,Hyderabad)	1971
2.	Assam	Sugarcane Research Station, Buralikson (AAU, Jorhat)	1975
3.	Bihar	Sugarcane Research Institute, Pusa (RAU, Pusa)	1970
4.	Gujarat	Main Sugarcane Research Station, Navsari (NAU, Navsari)	1973
5.	Haryana	Regional Research Station, Uchani (C.C.S. HAU, Hisar)	1975
6.	Karnataka	Zonal Agricultural Research Station Mandya (UAS, Bangalore)	1975
		Agricultural Research Station , Sankeshwar (UAS, Dharwad)	1995
7.	Kerala	Sugarcane Research Station, Thiruvalla (KAU, Trichur)	1975
8.	Madhya Pradesh	Zonal Agricultural Research Station, Powarkheda (JNKVV, Jabalpur)	1970
9.	Maharashtra	Central Sugarcane Research Station, Padegaon (MPKV, Rahuri)	1970
		Regional Sugarcane & Jaggery Research Station, Kolhapur (MPKV, Rahuri)	1970
10.	Odisha	Sugarcane Research Station, Nayagarh (OUAT, Bhubaneswar)	1983
11.	Punjab	PAU Regional Research Station, Kapurthala (PAU, Ludhiana)	1970
		Regional Research Station , Faridkot (PAU, Ludhiana)	
12.	Rajasthan	Agricultural Research Station, Kota (Agriculture University, Kota)1995	1995
		Agricultural Research Station, Sriganganagar (SKRAU, Bikaner)	1997
13.	Tamil Nadu	Sugarcane Research Station , Cuddalore (TNAU, Coimbatore)	1973
		Sugarcane Breeding Institute, Coimbatore (ICAR, New Delhi)	1970
14.	Uttarakhand	G.B. Pant University of Agriculture & Technology, Pantnagar	1970
15.	Uttar Pradesh	UP Council of Sugarcane Research, Shajahanpur (Govt. of U.P.)	1975
		Indian Institute of Sugarcane Research, Lucknow (ICAR, New Delhi)	1970
16.	West Bengal	Sugarcane Research Station, Bethuadahari (Deptt. of Agriculture, Govt. of West Bengal)	1971

Fig.1. Regular centres of All India Coordinated Research Project on Sugarcane

Fig.2. Voluntary centres of All India Coordinated Research Project on Sugarcane as on 2015

Research Achievements

The research activity in AICRP on Sugarcane is performed under four major disciplines viz., Crop Improvement, Crop Production, Plant Pathology and Entomology. On the inception of the Project in 1970, research activity was undertaken in two more disciplines, Plant Physiology and Agricultural Engineering which were discontinued in 1992. Furthermore, Agronomy and Soil Science were two separate disciplines which were later merged into Crop Production discipline. There is one Principal Investigator in each discipline to lead the research activity and monitor the technical programme.

I. Crop Improvement

Under this discipline, initially the following four major programmes were taken up:

(i) Fluff supply programme

(ii) Zonal varietal trial

(iii) Germplasm evaluation

(iv) Development of short duration varieties

(i) Fluff Supply Programme

In early 1940s, hybrid fluff was supplied by the Sugarcane Breeding Institute (SBI), Coimbatore to Lyallpur (now in Pakistan) and Shahjahanpur (U.P.). After partition of the country in 1947, the fluff was supplied to Jalandhar (Punjab) in place of Lyallpur for evolving varieties under local conditions. The varietal denomination was prefixed as CoL (Co for Coimbatore; L for Lyallpur), CoS (S for Shahjahanpur) and CoJ (J for Jalandhar). When AICRP on Sugarcane was set up in 1970, it was decided to supply fluff to the AICRP centres under **'Fluff Supply Programme'**. Since this hybridization programme involved use of large number of parent s, a National Hybridization Garden (NHG) facility was established in 1972 at the SBI, Coimbatore which comprises parents for different traits. Later, SBI, Coimbatore developed National Distant Hybridization Facility (NDHF) also at Agali, Distt. Palakkad, Kerala where different species of the *Saccharum* complex are maintained for hybridization work. These two national facilities are availed of by the Breeders of AICRP centres for carrying out hybridization programme of their need-based choice by effecting crossing at NHG and/or NDHF every year. The Fluff Supply Programme is an important component of Crop Improvement discipline as wider spectrum of genetic material is made available to the Breeders. Every year, fluff of different crosses effected by the Breeders is supplied by SBI, Coimbatore

Sugarcane fluff

Table 2 : Number of crosses made and quantity of fluff supplied to the Centres from 1970 to 2015

Year	Number of crosses			Selfs	Quantity of fluff (kg)
	Bi-parental	Polycrosses	General collection (Total No.)		
1970-72	-	-	-	-	5.28
1973-75	-	-	-	-	18.04
1976-78	-	-	-	-	47.31
1979-81	-	-	-	-	107.11
1982-84	-	-	-	-	109.16
1985-86	-	-	-	-	53.58
1986-87	299	-	58	-	21.40
1987-88	334+60*	-	68	24	22.19
1988-89	-	-	-	-	38.22
1989-90	-	-	-	-	31.87
1990-91	431	-	131	41	32.43
1991-92	583	-	194	06	33.85
1992-93	-	-	-	-	-
1993-94	453	-	227	6	31.66
1994-95	439	-	357	13	36.51
1995-96	998	-	357	20	35.69
1996-97	530	-	161	13	49.83
1997-98	562	140	363	25	59.32
1999-2000	374	-	287	-	25.80
2000-01	407	156	351	9	28.42
2001-02	521	143	67	5	41.35
2002-03	458	264	472	33	28.62
2003-04	575	122	575	32	24.24
2004-05	596	-	869	33	28.57
2005-06	602	7	633	42	27.66
2006-07	535+52*	-	195	-	32.84
2007-08	561+55*	26	74	-	40.84
2008-09	692+51*	17	527	12	32.42
2009-10	685+55*	20	713	-	34.72
2010-11	590+50*	19	456	28	26.55
2011-12	636+49*	21	614	30	33.05
2012-13	632+47*	18	744	10	32.70
2013-14	597+50*	20	204	14	43.88
2014-15	511+56*	21	319	15	38.21

*Zonal crosses

Table 3: Centre-wise slot numbers allotted to sugarcane entries proposed for evaluation in AICRP on Sugarcane

S.No	Centre	Slot number	Centre Code
Peninsular Zone			
1	Coimbatore (including Karnal)	001 - 060	Co
2	Mandya	061 – 070	CoVC
3	Navsari	071 - 080	CoN
4	Padegaon	081 - 090	CoM
5	Powarkheda	091- 100	CoJN
6	Sankeshwar	101 - 110	CoSnk
7	Thiruvalla	111 - 120	CoTl
8	VSI, Pune	121 - 130	CoVSI
9	EID Parry, Pugalur	131 - 140	PI
10	Sirugamani	141 - 145	CoSi
North West Zone			
11	Faridkot	181 - 190	CoPb
12	Kota	191 - 200	CoPK
13	Lucknow	201 - 210	CoLk
14	Kapurthala	211 - 220	CoPb
15	Pantnagar	221 - 230	CoPant
16	Shahjahanpur	231 - 250	CoS
17	Sriganganagar	251 - 260	CoSg
18	Uchani	261 - 270	CoH
East Coast Zone			
19	Anakapalle	321 - 335	CoA
20	Cuddalore	336 –345	CoC
21	Nayagarh	346 - 355	CoOr
22	Vuyyuru	356 –365	CoV
23	Perumallapalle	366- 375	CoT
24	EID Parry, Nellikuppam	376 –385	PI
North Central Zone			
25	Bethuadahari	426 - 435	CoB
26	Pusa	436 - 450	CoP
27	Seorahi	451 - 465	CoSe
28	Motipur (IISR)	466 - 475	CoLk
North East Zone			
29	Buralikson	501 - 510	CoBln

to the centres for seedling raising and selection of elite clones. The quantity of fluff supplied and crosses made under this programme from 1970 to 2015 are summarized in Table 2.

From the fluff supplied to various research stations, seedlings are raised and selection of elite clones is performed at the research stations mainly for higher cane yield, higher sucrose content and resistance to red rot. The selected elite clones are proposed in the Workshop or Group Meeting of AICRP on Sugarcane for inclusion in zonal varietal trial (ZVT). The clones accepted for ZVT are assigned denomination by the Principal Investigator (Crop Improvement). The varietal denomination comprises abbreviated location where crossing is effected e.g., 'Co' for Coimbatore followed by abbreviated location where elite seedling is selected, e.g., 'Lk' for Lucknow, year of inclusion in ZVT e.g., '09' for 2009 and the slot number allotted to the AICRP centre where clonal selection is carried out. The abbreviations of locations and slot numbers are given in Table 3.

Identification of promising crosses

On the basis of performance of progeny, the promising crosses (parents) of different zones are given in Table 4.

Table 4 : Promising parents of *Saccharum* spp., identified in different zones of the country

S.No.	Zone	Crosses (parents)
1	North West	CoJ 64 x Co1148; Co 740 x Co 1148; Co 740 x Co 6806; Co 7717 x Co 1148; Co 775 x Co 6806; Co 1148 x Co 1336
2	North Central	BO 91 x Co 775
3	East Coast	CoC 8201 x Co 775; Co 6806 x CoA 7602; Co 7508 x Co 6304, Cot 8201 x CoA 7602; CoA 7602 x CoC 672
4	Peninsular	Co 740 x Co 775; Co 740 x Co 6304; Co 7318 x CoC 671; Co 740 x Co 6806; Co 740 x Co 7318

(ii) Zonal Varietal Trial

For the conduct of zonal varietal trials, a decision was taken in the first Workshop of AICRP on Sugarcane in 1970 to identify the following five zones (Fig. 3) in the country. The States included in each zone are as follows:

North West Zone : Punjab, Haryana, Rajasthan, Uttar Pradesh (western & central) and Uttarakhand.

North Central Zone : Uttar Pradesh (eastern), Bihar and West Bengal.

North East Zone : Assam

East Coast Zone : Odisha, coastal Andhra Pradesh and coastal Tamil Nadu

Peninsular Zone : Gujarat, Madhya Pradesh, Chattisgarh, Maharashtra, Karnataka, interior plains of Andhra Pradesh, interior plains of Tamil Nadu and Kerala.

In pursuance of the decisions of first Workshop of AICRP on Sugarcane held at the Indian Institute of Sugarcane Research, Lucknow, the project on Zonal Varietal Trial (ZVT) was started by pooling the released varieties of each State in a particular zone with a view to evaluating them under varying conditions of the entire zone, so that proven varieties could be released by the other States also for commercial cultivation.

The methodology of implementation of the zonal varietal trial was thoroughly discussed in Breeders and Pathologists Meet held at the Sugarcane Breeding Institute, Coimbatore in 1982. Now the zonal varietal trial is conducted as per details given below :

The zonal varietal trial consists of Initial Varietal Trial (IVT) and Advanced Varietal Trial (AVT) of two maturity groups of sugarcane varieties viz., early maturity group and midlate maturity group. The pooled entries along with standards are evaluated in a zone for one year in IVT and two years (two plant crops and one ratoon crop) in AVT for cane yield, quality and resistance to major diseases and insect-pests. The details of experimental layout and list of characters to be recorded are communicated to the Breeders in the technical programme which is finalized in the Workshop/Group Meeting. As a follow up action of the recommendation Group Meeting of AICRP on Sugarcane held at Shahjahanpur in 2005, a Breeders Meet is organized after the Workshop/Group Meeting for finalization of technical programme for all the zones except peninsular zone. Breeders Meet is convened to shortlist IVT entries for promotion to AVT in the following crop season based on varietal crop growth performance, sucrose content and red rot reaction and thus multiplication of IVT entries at all the testing centres for one year is avoided. Besides, zonal crosses for each zone are finalized in the Breeders Meet.

The performance of elite varieties in zonal varietal trial is discussed in the Workshop/Group Meeting. The top ranking clones are proposed by the concerned Breeder for variety identification. In a meeting of Variety Identification Committee constituted by the ICAR, varieties are identified for release & notification. The identified varieties are subsequently proposed by the concerned Breeder for release & notification by the Central Sub-Committee on Crop Standards Notification & Release of Varieties for Agricultural Crops (GOI). The varieties identified from 1982 to 2016 in different Workshops/Group Meetings are listed in Table 5.

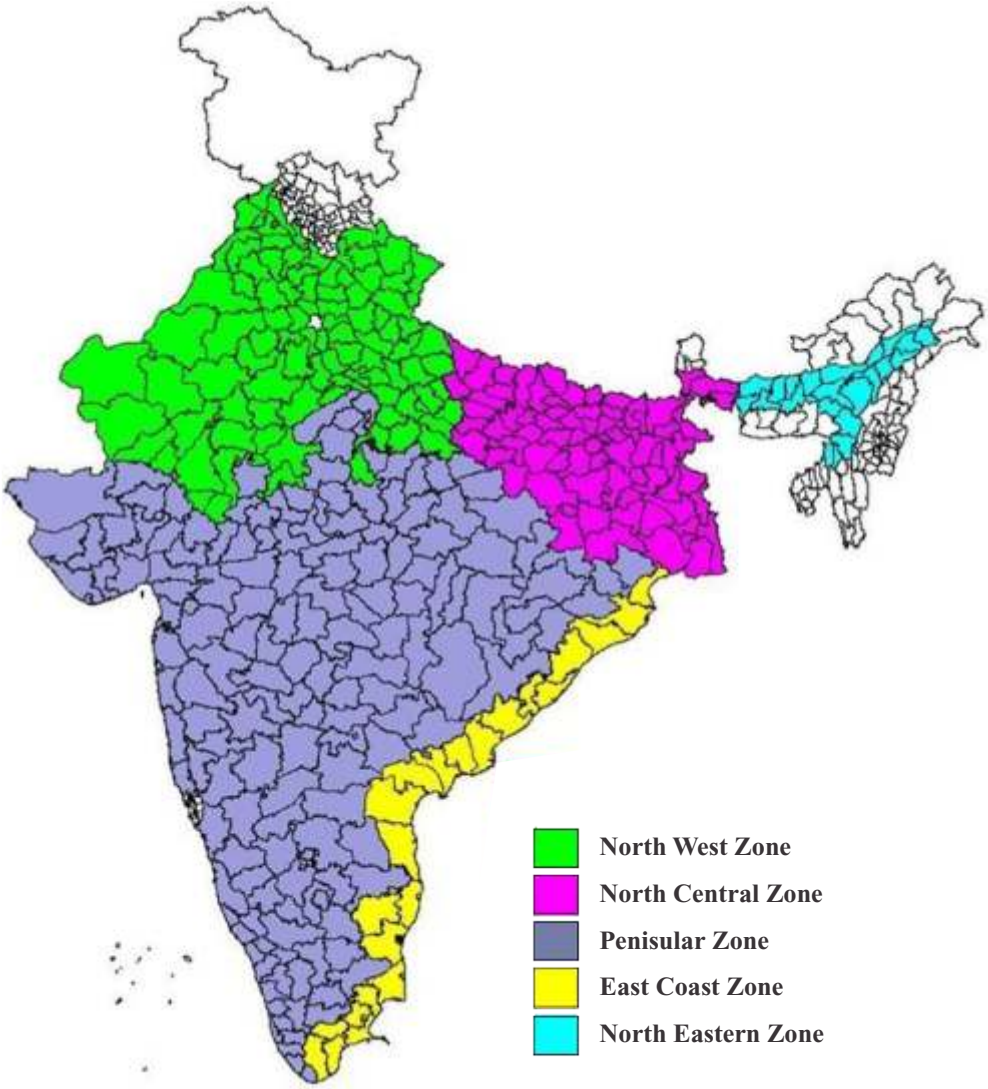


Fig.3. Zones for varietal evaluation under All India Coordinated Research Project on Sugarcane

Table 5 : Sugarcane varieties identified from 1982 to 2016

S.No.	Year	Variety
Peninsular Zone		
1	1982	Co 1295, MS 7110, MS 7455 Early : Co 6907 and CoC 671 Midlate : Co 7219, Co 7318, Co 62175 and CoM 7125
2	1984	Early : CoJN 86141 Midlate : Co 7527 and Co 8021
3	1994	Midlate : Co 87044, Co 86032 and Co 87025
4	1997	Early : CoJN 86141 Midlate : CoM 88121 and Co 8371
5	1999	Midlate : Co 91010
6	2002	Early : Co 94008
7	2006	Midlate : Co 99004 and Co 99006
8	2008	Midlate : Co 2001-13 and Co 2001-15
9	2009	Early : Co 0314 Midlate : Co 0218 and CoM 0265
10	2010	Early : Co 0403
11	2011	Early : CoSnk 05103 Midlate : CoSnk 05104
12	2012	Early : Co 06022 and CoN 05071 Midlate : Co 06027
13	2014	Early : PI 07131
East Coast Zone		
14	1982	Early : Co 6907, Co 7508, CoC 671 and CoC 771 Midlate : Co 7219 and Co 62175
15	1997	Midlate : Co 86249
16	2005	Early : CoC 01061
17	2009	Early : CoOr 03151 and CoA 03081
18	2010	Midlate : CoA 05322
19	2011	Midlate : CoA 05323
20	2012	Midlate : Co 06030
21	2013	Early : CoA 08323 and CoC 08336
North West Zone		
22	1982	Early : Co 7717, CoJ 64 and CoJ 75 Midlate : Co 6304, CoLk 7701, CoS 767, CoS 771 and CoS 802
23	1987	Early : CoLk 7901 Midlate : CoLk 8001
24	1990	Midlate : CoLk 8102 and CoPant 84211
25	1997	Midlate : CoPant 90223
26	1999	Early : CoH 92201 Midlate : CoS 91230
27	2002	Early : CoS 95255 Midlate : CoPant 93227

Continued

S.No.	Year	Variety
28	2003	Midlate : CoS 94270
29	2005	Midlate : CoPant 97222
30	2006	Early : CoS 96268 and Co 98014 Midlate : CoH 119, CoJ 20193 and CoS 96275
31	2008	Early : Co 0118, Co 0238 and Co 0232
32	2009	Early : Co 0239 Midlate : Co 0124
33	2010	Early : Co 0237 Midlate : CoH 128
34	2011	Early : CoPK 05191 Midlate : Co 05011
35	2012	Early : Co 05009 Midlate : CoPant 05224
36	2013	Early : CoLk 07201 Midlate : Co 06034
37	2016	Early : CoPb 08212
North Central Zone		
38	1982	Early :BO 90 Midlate :BO 100
39	1983	Midlate :CoS 767 and BO 91
40	1985	Midlate :BO 109 and CoS 7918
41	1994	Early : Co 87263 and Co 87268
42	1997	Early :BO 120
43	1999	Midlate :CoP 9103 and BO 128
44	2001	Early :Co 89029 and CoSe 95422 Midlate : CoSe 92423
45	2002	Early : CoSe 96234 Midlate : CoSe 96436
46	2007	Early : CoLk 94184
47	2008	Early : Co 0232 Midlate : Co 0233
48	2009	Early : CoSe 01421 Midlate : BO 146
49	2012	Early : CoSe 05451
50	2013	Midlate : CoP 06436
51	2016	Midlate : CoP 09437
North Eastern Zone		
52	1982	Early : Co 7201 and S 101/72
53	1997	Early-mid : CoBln 9605
54	2008	Early : Co 0232 Midlate : Co 0233
55	2012	Midlate : CoBln 04174
56	2016	Midlate : CoP 09437

Since 2013 onwards, the Coordination Unit of AICRP on Sugarcane has taken up analysis of the zonal varietal trial data for determining the stability and simultaneous selection of high yielding elite clones. The details are given below :

Simultaneous selection of high yielding and stable sugarcane genotypes using AMMI stability criterion

Genotype x Environment (GE) interaction continues to be a challenging issue among plant breeders, geneticists and agronomists in conducting varietal trials across diverse environments. Methods of partitioning GE interaction into components measure the contribution of each genotype in GE interaction. Whenever an interaction is significant, use of main effects e.g., overall genotype means across environments is often questionable. Stability performance of genotype is considered as an important aspect in varietal trials. Researchers need a statistics that provides a reliable measure of stability or consistency of performance of a genotype across a range of environments, particularly one that reflects the contribution of each genotype to the total GE interaction and helps in identifying the best genotype. For a successful breeding or genotype testing programme, both stability and yield (or any other trait) must be simultaneously considered. Also integration of stability of performance with yield through suitable measures will help in selecting genotypes in a more precise manner. In crop improvement, it was advocated by the scientists to use simultaneous selection indices using Additive Main Effects and Multiplicative Interaction (AMMI) model. This model is appropriate when main effects (genotypic, environmental) and genotype x environment interaction (GE) effects are both important in yield trials.

AMMI model offers a more appropriate statistical analysis to deal with such situations, compared to traditional methods like ANOVA, Principal Component Analysis (PCA) and linear regression. Currently, selection of sugarcane genotypes is based on the performance of cane yield at different locations across the zone and ranking of genotypes is done on the basis of mean data. Ranking of genotypes based on simultaneous selection of high yielding and stable genotypes gives better and reliable picture in identifying a variety.

For the first time simultaneous selection of genotypes for high cane yield and stability using AMMI criterion in Advance Varietal Trials of Crop Improvemnet discipline was applied by analyzing the data of AVT (early and midlate maturity groups) conducted during 2011-12 and 2012-13 cop seasons. Simultaneous selection criterion was used in this study which selects genotypes for both high cane yield and stability in multi-environmental trials using AMMI model by assigning 80% weight to yield and 20% to stability values of the genotype.

This method was used for selection of superior genotypes under Advanced Varietal Trial of early and midlate maturity group in Plant I & II and ratoon crops conducted during four consecutive years, 2011-12, 2012-13, 2013-14 and 2014-15 in Peninsular Zone, North West Zone and North Central & North Eastern Zones. In each zone, ranking of varieties is based on the above mentioned criterion for commercial cane sugar (CCS t/ha), cane yield (t/ha) and sucrose (%). Results based on analysis for simultaneous selection for high yielding and stable genotypes, the following varieties were found high yielding and stable than the widely adapted varieties of the zone :

North West Zone

Early : Co 07023, Co 07025, CoPb 08212, CoPb 09181 and CoS 08233.

Midlate : CoPb 07213, CoPb 08217, CoPb 09214, CoH 08262, CoH 09264 and CoLk 09204.

Peninsular Zone

Early : PI 07131 and VSI 08121.

Midlate : Co 07010, Co 07008, Co 08008 and Co 08009.

East Coast Zone

Early : CoA 09321.

Midlate : CoC 10337.

North Central & North East Zones

Early : BO 153 and CoP 08436.

Midlate : CoSe 08451 and CoP 09437.

Release and notification of sugarcane varieties developed in AICRP on Sugarcane

After inclusion of sugarcane in Seed Act, 55 varieties have been released and notified during 2000 to 2015 by the Central Sub-Committee on Crop Standards Notification & Release of Varieties for Agricultural Crops (Table 6).

Table 6 : Varieties of sugarcane released and notified from 2000 to 2015 and their salient characteristics

Name of variety	Year of release & otify cation	Gazette notifica-tion no.	Originating centre	Parentage	State (s) for which recommended	Key characteristics (like duration, yield level, quality characteristics etc.)			
						Maturity	Cane Yield (t/ha)	Sucrose (%)	Salient features
Co 85004	2000	S.O. 821(E)	SBI, Coimbatore	Co 6304 x Co 740	Gujarat, Maharashtra, Karnataka, Kerala, Interior of Tamil Nadu & Andhra Pradesh, Madhya Pradesh & Chattisgarh	Early	90.5	19.5	MR to smut, good ratooner
Co 86032	2000	S.O. 821(E)	-do-	Co 62198 x CoC 671	-do-	Midlate	102.0	20.1	R to smut, field tolerant to red rot, tolerant to drought
Co 87025	2000	S.O. 821(E)	-do-	Co 7704 x Co 62198	-do-	Midlate	98.2	18.3	R to smut, field tolerant to red rot and tolerant to drought & water logging
Co 87044	2000	S.O. 821(E)	-do-	Co 62198 x CoC 671	-do-	Midlate	101.0	18.3	MR to smut
Co 8371	2000	S.O. 821(E)	-do-	Co 740 x Co 6806	-do-	Midlate	117.7	18.6	R to smut, tolerant to drought & water logging
CoM 7714 (Krishna)/ CoM 88121	2000	S.O. 821(E)	CSRS, Padegaon	Co 740 x Co 6806	-do-	Midlate	88.7	18.6	R to smut, tolerant to drought, excellent jaggery quality
Co 91010	2000	S.O. 821(E)	SBI, Coimbatore	Co 312 x Co 775	-do-	Midlate	116.0	19.1	R to smut, tolerant to drought
Co 94008	2004	S.O. 161(E)	-do-	Co 7201 x Co 775	-do-	Early	119.8	18.3	MR to red rot, R to smut, tolerant to drought & salinity, good jaggery quality
Co 99004	2007	S.O. 122(E)	-do-	Co 62175 x Co 86250	-do-	Midlate	116.7	18.8	MR to red rot & wilt, tolerant to drought & salinity, tolerant to internode borer, good jaggery quality
Co 2001-13	2009	S.O. 454(E)	-do-	Co 7806 PC	-do-	Midlate	108.6	19.03	MR to red rot & wilt, lerant to drought & salinity, good ratooner, good jaggery quality
Co 2001-15	2009	S.O. 454(E)	-do-	Co 85002 x Co 775	-do-	Midlate	113.0	19.37	MR to red rot & smut, tolerant to drought & salinity, good ratooner, good jaggery quality

Continued

Name of variety	Year of release & otify-cation	Gazette notifica-tion no.	Originating centre	Parentage	State (s) for which recommended	Key characteristics (like duration, yield level, quality characteristics etc.)			
						Maturity	Cane Yield (t/ha)	Sucrose (%)	Salient features
Co 0218	2010	S.O. 2137(E)	-do-	Co 8353 x Co 86011	-do-	Midlate	103.77	20.79	MR to red rot, R to smut, tolerant to drought salinity, good ratooner, good jaggery quality
Co 0403	2012	S.O. 2125(E)	-do-	Co 8371 x Co 86011	-do-	Early	101.6	18.16	MR to red rot, R to smut, tolerant to drought, good ratooner, good jaggery quality
Co 06027	2013	S.O. 2817(E)	-do-			Midlate	110.56	19.18	MR
CoSnk 05103	2014	S.O. 1919(E)	ARS, Sankeshwar	Co 740 x CoA 7602	-do-	Early	105.97	17.21	MR to red rot, smut & wilt, Resistant to sugarcane woolly aphid and tolerant to moisture stress
Co Snk 05104	2014	S.O. 1919(E)	-do-	CoC 771 PC	-do-	Midlate	106.86	17.52	MR to red rot & smut. Tolerant to sugarcane woolly aphid, tolerant to salinity, waterlogging & moisture stress
Co 86249	2000	S.O. 821(E)	SBI, Coimbatore	CoJ 64 x CoA 7601	Coastal Tamil Nadu & Andhra Pradesh and Orissa	Midlate	104.2	18.7	MR to red rot & smut, tolerant to water logging, good ratooner
CoC 01061	2006	S.O. 1572(E)	SRS, Cuddalore	69A591 GC	-do-	Early	110.8	17.4	MR to red rot
CoOr 03151	2011	S.O. 2326(E)	SRS, Nayagarh	CoC 671 x Co 1148	-do-	Early	105.28	15.53	MR to red rot & wilt, tolerant to internode, top & early shoot borers and scale insect, tolerant to drought & water logging
Co 06030	2013	S.O. 2817(E)			-do-	Midlate	103.33	16.60	MR to red rot
CoS 91230	2000	S.O. 821(E)	UPCSR, Shahjahanpur	Co 775 x Co 1148	Punjab, Haryana, Rajasthan, Central and Western Uttar Pradesh and Uttarakhand	Midlate	68.2	18.8	MR to red rot, tolerant to top, shoot & stalk borers
CoPant 90223	2000	S.O. 821(E)	GBPUA & T, Pantnagar	BO 91 GC	-do-	Midlate	73.3	18.5	MR to red rot, R to smut, tolerant to drought, cold & water logging, excellent ratooner

Continued

Name of variety	Year of release & otify-cation	Gazette notifica-tion no.	Originating centre	Parentage	State (s) for which recommended	Key characteristics (like duration, yield level, quality characteristics etc.)			
						Maturity	Cane Yield (t/ha)	Sucrose (%)	Salient features
CoH 92201	2001	S.O. 92(E)	RRS (Uchani), Karnal	Co 7704 GC	-do-	Early	70.0	18.2	MR to red rot
CoS 95255	2004	S.O. 642(E)	UPCSR, Shahjahanpur	Co 1158 x Co 62198	-do-	Early	70.5	17.5	MR to red rot, excellent ratooner
CoS 94270	2005	S.O. 122(E)	-do-	Co 7704 x MS 6847	-do-	Midlate	81.5	17.1	MR to red rot, excellent ratooner
CoH 119	2005	S.O. 1566(E)	RRS (Uchani), Karnal	Co 7704 GC	-do-	Midlate	82.8	17.5	MR to red rot and tolerant to moisture stress
Co 98014	2007	S.O. 122(E)	SBI RC, Karnal (SBI, Coimbatore)	Co 8316 x Co 8213	-do-	Early	76.3	17.6	MR to red rot, tolerant to drought & water logging, suitable for co-generation
CoS 96268	2007	S.O. 1178(E)	UPCSR, Shahjahanpur	Co 1158 x Co 62198	-do-	Early	69.8	17.9	MR to red rot, good ratooner
CoPant 97222	2007	S.O. 122(E)	GBPUA & T, Pantnagar	CoPant 84212 GC	-do-	Midlate	88.2	18.2	MR to red rot, tolerant to drought, water logging & salinity
CoJ 89	2007	S.O. 1178(E)	PAU RRS, Kapurthala	LG 72115 x CoJ 82315	-do-	Midlate	75.9	17.9	MR to red rot, suitable for late crushing and co-generation, good jaggery quality
CoS 96275	2007	S.O. 1178(E)	UPCSR, Shahjahanpur	CoS 8119 x Co 62198	-do-	Midlate	80.8	17.3	MR to red rot, good ratooner
Co 0118	2009	S.O. 449(E)	SBI RC, Karnal (SBI, Coimbatore)	Co 8347 x Co 86011	-do-	Early	78.2	18.45	MR to red rot, tolerant to water stress & water logging
Co 0238	2009	S.O. 454(E)	-do-	CoLk 8102 x Co 775	-do-	Early	81.08	17.99	MR to red rot, good ratoonability in winters, tolerant to water stress & water logging
Co 0124	2010	S.O. 2137(E)	-do-	Co 89003 GC	-do-	Midlate	75.71	18.22	MR to red rot, tolerant to water stress & water logging
Co 0239	2010	S.O. 2137(E)	-do-	Co 93016 GC	-do-	Early	79.23	18.58	MR to red rot, tolerant to water stress & water logging

Continued

Name of variety	Year of release & otify-cation	Gazette notifica-tion no.	Originating centre	Parentage	State (s) for which recommended	Key characteristics (like duration, yield level, quality characteristics etc.)			
						Maturity	Cane Yield (t/ha)	Sucrose (%)	Salient features
CoH 128	2012	S.O. 456(E)	RRS (Uchani), Karnal	CoH 70 x CoS 510	-do-	Midlate	76.23	17.70	MR to red rot, tolerant to top & early shoot borers
Co 0237	2012	S.O. 2125(E)	SBI RC, Karnal (SBI, Coimbatore)	Co 93016 GC	-do-	Early	71.33	18.78	MR to red rot, tolerant to water logging, good ratooner
Co 05011	2012	S.O. 1708(E)	-do-	CoS 8436 x Co 89003	-do-	Midlate	81.87	18.00	MR to red rot & wilt, suitable for harvesting in winter
CoPK 05191	2013	S.O. 312(E)	ARS, Kota	Co 1158 GC	-do-	Early	81.12	17.06	MR to red rot, tolerant to drought & water logging, good ratooner
Co 05009	2013	S.O. 2817(E)			-do-	Early	75.89	17.44	MR
Co 87263	2000	S.O. 821(E)	SBI, Coimbatore	Co 312 x Co 6806	Eastern Uttar Pradesh, Bihar, West Bengal and Jharkhand	Early	66.3	17.4	MR to red rot, smut, tolerant to shoot borer, drought & water logging
Co 87268	2000	S.O. 821(E)	-do-	BO 91 x Co 62399	-do-	Early	78.9	17.5	MR to red rot, smut, tolerant to drought & water logging
Co 89029	2001	S.O. 1134(E)	-do-	BO 91 GC	-do-	Early	70.6	16.3	MR to red rot, tolerant to top borer and shoot borer, tolerant to drought & water logging
BO 128	2001	S.O. 92(E)	SRI (RAU), Pusa	BO 85 x BO 43	-do-	Midlate	69.2	17.6	MR to smut, tolerant to water logging & salinity
CoSe 95422	2001	S.O. 1134(E)	GSSBRI (UPCSR), Seorahi	BO 91 x Co 453	-do-	Early	67.8	17.7	MR to red rot
CoSe 92423	2001	S.O. 1134(E)	-do-	BO 91 x Co 453	-do-	Midlate	70.1	17.5	MR to red rot, excellent ratooner
CoSe 96234	2004	S.O. 642(E)	SRS (UPCSR), Gorakhpur	CP 44-101 x Co 1148	-do-	Early	64.1	17.9	MR to red rot
CoSe 96436	2004	S.O. 642(E)	-do-	BO 91 x Co 62198	-do-	Midlate	67.1	17.7	MR to red rot, tolerant to water logging
CoLk 94184	2008	S.O. 2458(E)	IISR, Lucknow	CoLk 8001 self	-do-	Early	76.0	18.0	MR to red rot, tolerant to drought & water logging

Continued

Name of variety	Year of release & otify-cation	Gazette notifica-tion no.	Originating centre	Parentage	State (s) for which recommended	Key characteristics (like duration, yield level, quality characteristics etc.)			
						Maturity	Cane Yield (t/ha)	Sucrose (%)	Salient features
Co 0232	2009	S.O. 454(E)	SBI, Coimbatore	CoLk 8102 x Co 87267	-do-	Early	67.82	16.51	MR to red rot, tolerant to top borer, water logging & early drought
Co 0233	2009	S.O. 454(E)	-do-	CoLk 8102 x Co 775	-do-	Midlate	67.77	17.54	MR to red rot, tolerant to top borer, water logging & early drought
CoSe 01421	2013	S.O. 2817(E)	GSSBRI (UPCSR), Seorahi	CoS 8119 x Co 62198	-do-	Early	65.87	17.36	MR to red rot, smut & wilt, good ratooner
CoP 06436 (CoP 2061)	2015	S.O. 268(E)	RAU, Pusa	CoLk 8102 x HR 83/65	-do-	Midlate	74.25	17.35	MR to red rot, smut & wilt
Co 0232	2009	S.O. 454(E)	SBI, Coimbatore	CoLk 8102 x Co 87267	Assam	Early	67.82	16.51	MR to red rot, tolerant to top borer, water logging & early drought
Co 0233	2009	S.O. 454(E)	-do-	CoLk 8102 x Co 775	-do-	Midlate	67.77	17.54	MR to red rot, tolerant to top borer, water logging & early drought
CoP 06436 (CoP 2061)	2015	S.O. 268(E)	RAU, Pusa	CoLk 8102 x HR 83/65	-do-	Midlate	74.25	17.35	MR to red rot, smut & wilt

(iii) Germplasm evaluation

During the year 1980-81, the programme of evaluation of germplasm was implemented at ten centres with an objective to identify suitable genetic stocks adapted to various insect-pests and diseases in addition to gathering information on cane yield and quality characteristics for their further utilization as parents in the breeding programme. The germplasm collection comprises two distinct categories – the commercial foreign clones performing well in other countries and the species of *Saccharum* comprising *S. officinarum,*

Table 7: *Saccharum* species suitable for cane yield, cane quality, resistance to red rot and smut, and tolerance to salinity

Character	Genera/species	Genotype
Cane yield	*S. officinarum*	57 NG-57, Oramboo, Kajla, Balghat thin, 51 NG-156, 57 NG-203
	S. barberi	Kewali-14-G, Pathri, Dheli, Mangwa
	S. sinense	Merthizel
	Foreign hybrid	B 45116, B 38192, B 38246, B 46364
Cane Quality	*S. barberi*	Mungo 254, Khat uia-124, Pa raria, Pararia N. Ganj, Kewali-14-G, Matna Shaj, Lalri, Mangwa
	Foreign hybrid	B 46364, B 4772, CP 36-11, Q 61, Q 66, Q 67, H 50-7209
Red rot resistance	*S. officinarum*	Baragua, H.M. Black, Saipan-G, Seleri, 28 NG 4, 28 NG 266, 57 NG 77
	S. barberi	Lalri
Smut resistance	*S. officinarum*	Ardjoena, Swela Green Sport, Balghat Thin, Betec Lupog, Big Tanna, Striped Aubin, Bandjer Masim Hitam, Bois Rogue, Branchue, Bravo de Perico, Caira, Cavengerie, Fiji 15, Fotiogo, Haak Kwat Che, Hitam Broewang, Hawaii Original – 26, Horne Java , Hebbal, Javari Kabbu, Kaludai Boothan, K eong, Khajuria, Kham, Laukona -15, La Purple, Local red, Loethers, Mauritius -131, Ohia-1, Oidang, Badangsche, Pilimai -60, Poona, Port Mackey Black, Preanger Striped, Ratgros Ventre, Red Ribbon, Rood Djapara, SS 60-1, Stripped Tip, Tahiti-3, Tamarin, Tanna, Timor Riet, Tolo Fua Lau-1, Tomohon Zwart, Tonga Tabu -6, UB-1, Vellai, NC -17, NC-24 Dark Purple, NC-25 Purple, NC-32 Sport, NC-33, 37 NG 7, 51 NG 9, 57 NG 45, IJ 76-314, IK 76-2, IM 76-245, IS 76-117, 77 NG-28.
	S. barberi	Baroukha, Dhaur kinara, Hemja, Kansar khatuia, Mankia, Sararoo
	S. sinense	Reha, Kalkya, Kavangire, Maneira (IMP 1648), Mecikrum, Archi, Cayana, Merthizel, Oshima, Rounda, Tekcha-Chiki-Island, Tekcha-Chung-Island, Kukuya No.1, Uba-Del-Natal, Uba -Naquin, Uba-Reunion
Salinity tolerance	*S. robustum*	IJ-76-293, IM-76-232, 51 NG 6, 51 NG 27
	S. barberi	Katha-Coimbatore, Kewali-14-G, Khatuia-124, Kuswar Ottur, Lalri, Nargori, Pathri
	S. sinense	Khakai, Pansahi, Reha, Uba-Seedling
	S. officinarum	IJ-76-442
	S. robustum	IJ-76-470, 28 NG 251, 57 NG 201, 57 NG 231, 77 NG 34, 77 NG 136, 77 NG 160, 77 NG 167, 77 NG 170, 77 NG 221, 77 NG 237

S. barberi, S. sinense and *S. robustum*. The purpose for evaluation of foreign commercial varieties was to identify genotypes suitable for commercial cultivation or for use as genetic stocks in crossing programme. The following genotypes were identified for different characters (Table 7).

During Group Meeting of AICRP on Sugarcane held in 2013 at the Andhra University Campus, Visakhapatnam, the following experiment was proposed in view of climate change that may adversely affect the performance of varieties developed under normal irrigated environmental conditions :

Evaluation and identification of climate resilient ISH genetic stocks

A new project entitled "Evaluation and identification of climate resilient ISH genetic stocks" was initiated to identify elite ISH clones tolerant to drought and water logging in eight selected locations. A total of 139 clones of inter specific and inter generic origin were pooled and planted in multiplication cum observation plot at Sugarcane Breeding Institute, Coimbatore. Twenty seven clones will be selected and sent to the eight centres for initial multiplication and further evaluation in the targeted abiotic condition. In tropics, evaluation for drought will be carried out at Padegaon and Anakapalle centres, while in sub-tropics at Faridkot and Karnal (SBIRC) centres. Evaluation against water logging will be carried out at Kolhapur and Vuyyuru in tropics and Pusa and Motipur (IISR) in sub-tropics.

After initial multiplication of following 27 genetic stocks, the experiment under alpha design has been taken up in 2016-17 at all the identified centres:

BM 1003143, BM 1005149, BM 1009163, BM 1010168, BM 1022173, PG 9869137, SA 98-13, SA 04-454, SA 04-4792, SA 04-458, SA 04-390, SA 04-496, SA 04-409, AS 04-1689, AS 04-245, AS 04-2097, AS 04-635, AS 04-1687, MA 5/51, MA 5/5, MA 5/37, MA 5/99, MA 5/22, GU 07-3849, GU 07-3774, GU 07-2276 and CYM 07-986

(iv) Development of short duration varieties

The experiment was started in 1981 at 4 centres viz., Anakapalle, Mandya, Cuddalore and Padegaon. The objective was to study the adaptability of selected varieties for short duration cropping. At Anakapalle, Co 7508 was found to be high in quality with early maturity. At Mandya, CoA 7601 and H 57-5174 were found promising, whereas at Cuddalore CoC 671 gave the best performance. Co 7314 was good in quality. The project was discontinued in 1983 as no breeding component was involved.

I. Crop Production

A. Plant Physiology

Screening of varieties against abiotic stresses

i) Thick stalked varieties with greater leaf numbers and tillers at early stages suffered less under moisture stress.

ii) Late maturing varieties suffered more in terms of juice quality due to moisture stress.

iii) Moisture stress at formative phase reduced the juice quality more than at elongation phase.

iv) Soil moisture stress reduced green leaf number, leaf area and tiller number resulting in marked reduction in leaf area per plant.

v) Commercial cane sugar per unit area was significantly reduced with increase in soil moisture stress, the reduction being more severe from 40 to 20 per cent ASM.

vi) Varieties Co 975, Co 1148, Co 853, Co 740 and CoS 510 tolerated soil moisture stress better than Co 419, Co 527, Co 658 and Co 1158. Varieties Co 453, Co 740, Co 85007, BO 91 and UP 5 were more suited for saline soils, whereas CoS 8118 was suitable for waterlogged conditions. Co 1148 was found to be more tolerant to frost than Co 1158.

Studies on growth, maturity and ripening

i) Adaptability of sugarcane varieties under various agro-climatic zones : The findings indicate that Net Assimilation Rate (NAR), Relative Growth Rate (RGR), Crop Growth Rate (CGR) and Specific Leaf Weight (SLW) are associated with cane yield throughout the season.

ii) Forecasting of sugarcane yield : Sheath moisture and nitrogen content in leaf at formative and grand growth stages are highly correlated with cane yield.

iii) Control of flowering : Leaf spindle removal once during the second and third week of August or two sprays of paraquat/diquat check the flowering in late varieties, while repeated spindle removal between July 20 and August 12 was needed for early varieties. The effective period of spindle removal in both the categories of varieties coincided with initiation of spikelet primordia. There was improvement in cane yield and juice quality consequent to inhibition of flowering spindle under late harvesting conditions.

iv) Harvesting time for drought affected crop : For extracting maximum sugar, any crop subjected to moisture stress during active growth phase should be harvested 2-3 months later than normal harvesting time.

v) Use of chemical ripeners: Three chemical ripeners viz., polaris, sodium-metasilicate and cycocel were tried for hastening the maturity and sustenance of juice quality over a long period. The beneficial effect of all the three chemicals was evident with polaris being the best. Spray of polaris @ 4 kg ai/ha, 6-8 weeks before harvest was recommended for improvement of quality and maintaining it for three months. Early maturing varieties responded better to all the three ripeners as compared to late varieties.

B. Agronomy and Soil Science

Sequential and intercropping with sugarcane

As the sugarcane is planted in wide spaced rows and its initial growth is slow, the inter-row spaces remain unutilized, where suitable intercrops can be taken successfully. Crops found suitable for intercropping in sugarcane at different locations are listed in Table 8. Suitable variety of wheat was tested as an intercrop in sugarcane. This practice though resulted in reduced cane yield by about 16%, but more than compensated this loss by additional yield of wheat. Growing of potato and sugarbeet did not decrease the yield of sugarcane as compared to its pure crop. Rather potato was identified as one of the best companion crops for inter-cropping with sugarcane. At Jalandhar, however, higher net return was obtained by growing sugarcane + maize as compared to cane + potato. Intercropping of spring planted cane with grain legumes, such as green gram, urd bean, cowpea, etc., increased soil organic matter, total N and available P, but its effect was not conspicuous on cane yield in many cases. In sub-tropical India, autumn cane intercropped with mustard/potato/pea is more profitable than growing of spring cane following mustard/potato/pea (Fig. 4 & 5). Autumn sugarcane with suitable intercrop may be cultivated instead of planting sugarcane alone in late spring/summer season following *rabi* crop.

In Deccan plateau region, usefulness of vegetables like onion, knol khol and cabbage in pre-seasonal planting was found to be giving more returns than from sugarcane alone. In tropical region, intercropping of french bean and soybean has also given encouraging results.

Fig. 4. Intercropping of mustard in sugarcane

Fig. 5. Intercropping of potato in sugarcane

Table 8 : Crops found suitable for companion cropping with sugarcane at different locations in the country

Location	Crops
Autumn planted sugarcane	
Shahjahanpur	Wheat, *lahi*, pea, potato
Lucknow	Wheat, *toria*, sugarbeet, berseem, onion, lentil, garlic, *kalaunzee*, coriander, pea
Pantnagar	Wheat, sugarbeet, lentil, *lahi*
Muzaffarnagar	Pea, gram, sugarbeet
Gorakhpur	Berseem, potato, wheat
Jalandhar	Sugarbeet, wheat, *raya toria*, potato, maize
Sriganganagar	Sugarbeet
Pusa (Bihar)	Lentil, coriander
Spring planted sugarcane	
Lucknow	Cowpea, M.P. c*hari*, Moong
Pantnagar	Onion, *moong*, *urd*, soybean, cowpea
Muzaffarnagar	Onion
Pusa (Bihar)	*Moong*
Hisar	*Moong*
Coimbatore	*Moong*
Anakapalle	*Urd, moong*, soybean, cowpea
Parbhani	Guar, cowpea
Sameerwadi	*Moong*, onion, ground nut
Padegaon	Onion, Lucerne, berseem
Akola	Ground nut

Trash mulching for water economy and improvement in cane productivity

The use of trash mulch in economizing water use and enhancing yield potential not only improves the cane crop under water stress conditions, but also increases the water use efficiency under irrigated conditions. Trash mulching is recommended in U.P., Bihar and Punjab to conserve soil moisture and to economise irrigation water.

Pre-planting conservation tillage in sugarcane based cropping system

Pre-planting tillage operations be economized to the extent of 50% by using rotavator twice over conventional tillage in late planted sugarcane crop following wheat crop in light soils.

Sub-soiling on soil physico-chemical characteristics and sugarcane productivity

Sub-soiling especially cross sub-soiling at 1.0 m is recommended for enhancing cane yield and sustaining soil health.

Technique for increasing cane production under late planting conditions

Delay in sugarcane planting from February to March reduces 16 per cent yield of cane under sub-tropical conditions. The reduction in cane yield increases to 20% with further delay in planting to April. The increase in yield of late planted sugarcane after wheat harvest could be achieved by adopting the following agro-techniques:

i) Use of top portion of cane, preferably pre-germinated ones.

ii) Soaking of cane in water atleast for 6 hours for accelerating sprouting.

iii) Planting of cane in closer rows at 60 cm.

iv) Transplanting of 45 days old polythene bag-raised settlings.

Plant geometry in relation to mechanization in sugarcane

Wider row spacing of 120 cm/30:150 cm is recommended for tropical zone to facilitate the mechanical harvesting as well as maintain cane yield level. However, in sub-tropical zone, sugarcane planting at 30:120 cm is an option to facilitate mechanization.

Priming of cane node for accelerating germination

For Peninsular Zone, where soil moisture does not deplete rapidly, planting of primed cane node may be used as planting material and for North West Zone, conventional planting of 3-bud setts may be continued.

Nutrient management

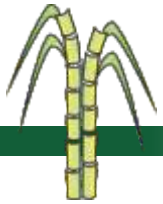
i) Sugarcane did not respond to potassium application under *terai* soils, where soils are rich in available potassium, containing more than 300 kg K_2O/ha. At Padegaon, the maximum yield of cane and CCS were obtained under soil moisture stress condition during summer for spring planted sugarcane with conventional planting application of 150 kg K_2O/ha at planting and trash mulching @ 5 t/ha immediately after germination. At Sehore, the crop significantly responded to potassium application up to 60 kg K_2O/ha.

ii) Soil application of *Azotobacter* or *Azospirillum* @ 4 kg/ha in two equal splits at 30 and 60 days after planting gave 25% saving in nitrogen fertilizers.

iii) Trash mulching in ratoon crop increased sugarcane yield significantly over no mulching at a number of locations in the country; however, at Mandya (Karnataka) and Thiruvalla (Kerala) centers, effect due to mulching was not observed in terms of cane and CCS yields.

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

v) Incorporation of sulphitated press mud cake (SPMC) at the rate of four 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.

vi) 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.

vii) In sugarcane based cropping system, recommended dose of NPK and micronutrients to all the crops in sequence + 20 t/ha FYM or SPMC 10 t/ha + trash @ 10 t/ha to sugarcane crop may be applied to sustain higher cane yield and soil productivity or green manuring once in the crop cycle + recommended dose of NPK to each crop be followed.

Nutrient management of seed crop of sugarcane

Nutrient management for sugarcane seed crop is very important and the agronomic requirements are different for tropical and subtropical belts. In tropical zone, seed cane may be 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.

Fertilzer requirement for promising sugarcane genotypes

Genotypic variations in terms of cane and sugar yield were noted across the country. At almost all the centres in NWZ, ECZ and NCZ crop responded up to recommended dose of NPK. However, in peninsular zone, at 4 locations (Pune, Kolhapur, Thiruvalla, Padegaon) out of 8 locations crop responded up to 125% of the recommended dose of NPK indicating that crop needs 25% more NPK over recommended dose.

Sustaining sugarcane production and soil health through integration of nutrient sources in sugarcane based cropping system

In order to sustain higher cane and sugar yield, sugarcane plant crop should be fertilized with 100% of the recommended NPK fertilizers + 25% N through FYM + biofertilizer (*Azotobacter* + PSB) in plant crop and 100% of the recommended NPK through inorganics + trash incorporation with cellulolytic culture + biofertilizers in ratoon crop. This also improves soil health, by enriching the organic carbon content.

Compatibility of zinc application with sources and levels of phosphorus in sugarcane

SSP and DAP are equally effective as sources of phosphorus. In North West Zone, North East Zone and East Coast Zone sugarcane crop may be fertilized with 60 kg P_2O_5/ha. However, in Peninsular Zone, DAP is superior to SSP and sugarcane crop be fertilized with 60-80 kg P_2O_5/ha. As regards, zinc nutrition, 20-30 kg $ZnSO_4$/ha is sufficient.

Developing organic intensive farming module for sugarcane crop

Application of 75% recommended NPK (inorganic) + 25% N through organic manures + biofertilizer + bio-pesticide in plant crop and 75% recommended NPK (inorganic) + 25% N organic + biofertilizer + trash mulch and green manure crop in alternate rows + biopesticide in ratoon crop significantly improve cane productivity in plant and ratoon crops over recommended NPK + micronutrient through inorganic + pest /disease control through chemical mode.

Response of sugarcane crop to different plant nutrients in varied agro-ecological situations

Application of Zn @ 5 kg/ha and S @ 40 kg/ha along with NPK every year to sugarcane plant crop was recommended for subtropics, while for tropics, the application rate of Zn and S was 10 and 60 kg/ha along with NPK, respectively.

Enhancing sugarcane productivity and profitability under wheat- sugarcane cropping system

Where moisture is not a limiting factor, intercropping of sugarcane and wheat (1:2 or 1:3) with sugarcane in furrow and wheat on raised bed can be taken. Where terminal heat is a problem sequential sowing of wheat in November/December in FIRB followed by sugarcane planting in furrows in February/March was the best.

Drought management in sugarcane

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.

Ratoon management

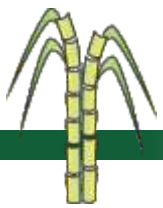
Ratooning offers many advantages in the economy of sugarcane cultivation. The productivity of ratoon can be upgraded to the level of plant crop or even better provided the required inputs, timely harvesting of plants crop and gap filling are ensured. All India Coordinated Research Project on Sugarcane has developed technology for improving the productivity of ratoon separately for different conditions and situations.

Ratooning under optimum conditions of input availability

At the time of harvest of plant crop, stubble shaving flush with the ground is essential to promote bud sprouting. The ridges should be dismantled after harvesting of plant crop. In order to improve the soil physical condition and also to prune the stubble roots, the inter-row spacing must receive deep cultivation (off-barring) followed by irrigation. Fertilizer nitrogen may be applied in one lot after first irrigation. The dose required is 20% higher than for plant crop. The ratoon crop, in general, requires potash at the rate of 80 kg K_2O/ha. The requirement of K_2O and phosphate may be ascertained by soil testing. Gap filling, using pre-germinated setts, is essential. Endosulfan @ 1 kg a. i., per hectare is required to protect the crop where black bug incidence is high.

Ratooning under low availability of inputs

In case of ratooning under low availability of inputs stubble shaving is achieved by trash burning rather than manual/mechanical shaving (Burning trash is now not recommended). Dismantling of ridges and deep inter-culture of inter-row spaces is to be avoided to permit the stubble roots to absorb moisture and economise irrigation. Fertilizer nitrogen requirement up to 75% of the recommended dose may be met by resorting to foliar spray with 3% urea.



Plant crop harvested during very low temperature (below 19°C) usually yields low in ratoon due to poor germination. This should be avoided as far as possible. Fields intended for ratooning should not be harvested before February.

If it is essential, a thick trash blanket (20 cm) may be spread over the stubble to prevent them from sprouting until the season becomes warm (in the month of February when the trash may be removed and spread in the inter-row space).

Ratoon management through retention of water shoots and late tillers

In a study conducted on effect of harvesting of water shoots and late tillers in plant cane on the growth and yield of subsequent ratoon indicated that in subtropical belt and more so in north west zone, where ratoon initiation is delayed due to late harvesting of plant cane in the months of April and May, the water shoots and/or late tillers may be retained to buffer the yield drop. However, appropriate plant protection measures need to be taken to break the continuity of insect-pests and diseases transmitted through such shoots/tillers.

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 third 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.

Improving productivity of winter initiated ratoon of sugarcane in sub-tropical India

Fresh sulphitation press mud cake (SPMC) @ 20 t / ha at ratooning is recommended for improving bud sprouting and cane yield in winter initiated sugarcane ratoon. Alternatively, 10 t fresh SPMC + 25 kg $ZnSO_4$/ha is also recommended.

Control 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 $FeSO_4$ alongwith 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).

Control of flowering in commercial cultivation of sugarcane

In peninsular zone, spraying of ethrel @ 250 ppm was effective in controlling flowering in sugarcane and obtaining higher cane yield as well as better juice quality. However, in east coast zone, crop responded up to 500 ppm of ethrel spray.

Weed management

Unchecked 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.

i) Plant crop : For weed management in plant 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.

ii) Ratoon crop : At all the centres across the zones three hoeings each at 1st, 4th, and 7th week after ratoon iniation resulted in the highest cane yield. However, atrazine 2.0 kg a.i. (pre-emergence) + one hoeing at 45 days after ratoon iniation (DARI) or metribuzine 1.0 kg a.i./ha (pre-emergence) coupled with 2, 4-D 1.0 kg/ha 45 DARI or hoeing at 45 DARI and or trash mulching in alternate rows + hoeing at 1 and 6 weeks after ratoon initiation resulted in cane yield equivalent to three hoeings.

iii) Binding weeds in sugarcane crop : 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.

III. Plant Pathology

Identification of pathotypes of red rot pathogen

Wide range of cultural, morphological and pathogenic variability has been observed in the red rot pathogen. To determine the pathogenic variability, a set of 13 differentials, viz., Baragua (*Saccharum officinarum*), Khakai *(S. sinense*), SES 594 (*S. spontaneum*), Co 419, Co 975, Co 997, Co 1148, Co 62399, Co 7717, CoC 671, CoJ 64, CoS 767, BO 91 and Co 8436 are employed. Later on, one more variety CoS 8436 was included as 14th differential. It was observed that there was a need to add more differentials because most of the differentials being used have shown susceptibile reaction to the emerging new pathotypes. Of late, 5 more differentials, viz., Co 7805, Co 86002, Co 86032, CoV 92102 and CoSe 95422 have been included totalling 19 differentials for pathotype identification.

On the basis of the red rot reaction on 14 differentials, twelve pathotypes (CF 01 to CF 12) have been identified from different parts of the country. The pathotypes CF 01, CF 02, CF03, CF 07, CF 08, CF 09 and CF 11 were identified from North West Zone; CF 04, CF 05, CF06 and CF 10 from East Coast Zone and CF 12 from Peninsular Zone. Pathotypes CF 07 and CF 08 are also prevalent in North Central Zone, whereas CF 06 in Peninsular Zone. The prevalent pathotypes are being used for screening of varieties against red rot as detailed below:

North West Zone	:	CF 08 & CF 09 (To be inoculated separately)
North Central & North Eastern Zones	:	CF 07 & CF 08 (To be inoculated separately)
East Coast Zone	:	CF 04 & CF 06 (To be inoculated separately)
Peninsular Zone	:	CF 06 & CF 12 (To be inoculated separately)

Molecular characterization of isolates/pathotypes of *Colletotrichum falcatum*

It was established that two major clusters/groups exist in different geographical regions of the country. There was no matching with pathotypes identified by differential host reaction and molecular cluster/group. Hence, the pathotype identification is continued with existing method of disease reaction on host differentials.

Methodology for screening of varieties against major diseases

Red rot : The varieties/ genotypes of sugarcane included in zonal varietal trials are evaluated against red rot (Fig. 6) by plug as well as nodal methods of inoculation. In plug method, the spore suspension of the pathogen is placed inside the cane tissues by puncturing a hole in the middle of the internode (3rd from the bottom of the cane). The hole is then sealed with plasticine/ modeling clay.

Fig. 6. Red rot symptoms on internal portion of stalk

After 60 days of inoculation, the inoculated canes are split open longitudinally and the following observations are recorded:

1. Condition of the top : green = 0 score; yellow/dry = 1 score.
2. Lesion width above inoculated internodes is assigned the 1, 2 or 3 score.
3. White spots are assigned the score of 1 when restricted or 2 when spreading.
4. Number of nodes crossed above the inoculated internode and given the score of 1 (when one node crossed), 2 (when two nodes are crossed) or 3 (when three or more nodes are crossed).

Average of the total score is taken for grading the varieties on 0-9 scale, i.e. 0.0 to 2 as resistant (R), 2.1 to 4 as moderately resistant (MR), 4.1 to 6 as moderately susceptible (MS), 6.1 to 8 as susceptible (S) and above 8 as highly susceptible (HS).

Since plug method does not simulate the infection that takes place through nodal region in nature, efforts were made to develop a nodal method of inoculation. In this, the spore suspension is poured between leaf sheath and stalk with the onset of monsoon. Artificial humidity is created when atmospheric humidity is low for better infection. After 60 days of inoculation, the following observations are recorded: presence of mid-rib lesions with or without conidia, presence of acervuli at the nodes especially on leaf scar, root primordia and growth ring. The inoculated nodes are scrapped when the lesions are found developing in the stalk. Fifteen stalks are evaluated as in plug method.

Since nodal method was not giving consistent results due to failure of infection, the method was modified and is given below:

Nodal cotton swab method : Two canes in each of 20 clumps will be inoculated by removing leaf sheath (lower most green leaf sheath) and immediately placing cotton swab (dipped in freshly prepared inoculum suspension) around the cane covering nodal region. The cotton swab should be held in place by wrapping parafilm around the cane stalk. After 60 days, remove cotton swab and scrap the node with a knife. Record presence/absence of lesions. In case lesions are progressing into stalk, the reaction is to be recorded as S (susceptible) and if no lesion development, then R (resistant). This method is being followed in AICRP on Sugarcane for evaluation of varieties against red rot since 2012-13 onwards.

Smut : The zonal varietal entries are evaluated by planting 3-bud setts, inoculated with freshly collected teliospores of smut fungus. Freshly collected smut whips (Fig. 7) are dried by keeping under shade and smut spores are collected and filled in butter paper bags. These spores are either used immediately for inoculating the setts or stored in desiccator under anhydrous calcium chloride, for future use. Spore viability is examined before inoculation.

Fig. 7. Formation of smut whip on apical portion of sugarcane

The setts of the test varieties are inoculated by steeping them for 30 minutes in aqueous suspension of spores of over 90% viability and with a spore load of one million

spores per milli liter. Evaluation of the varieties is based on percentage of clumps infected. It is necessary to maintain atleast 15 to 20 clumps of each genotype before arriving at the percentage of infection. The following grading is followed:

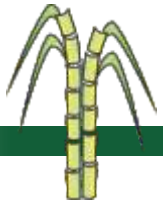
Per cent infection	Reaction
0	Resistant
0.1 to 10	Moderately resistant
10.1 to 20	Moderately susceptible
20.1 to 30	Susceptible
More than 30	Highly susceptible

Wilt : Sick-plot technique has been developed for screening of varieties against wilt disease. The test varieties/genotypes are planted in the wilt-sick plots. At the end of 10 months of planting, 10 clumps are up-rooted along with roots. All canes from the clump are split open longitudinally and wilt severity index is scored as follows on a 0-4 scale:

Grade	Symptoms
0	Healthy canes and roots with no external or internal symptoms of wilt.
1	No wilting or drying of leaves, no stunting or shrinking of the stalk or rind, slight pith formation with yellow discoloration of the internal tissues in one or two lower internodes only. No cavity formation or fungal growth seen. Apparently normal and healthy roots.
2	Mild yellowing of top leaves and drying of lower leaves, mild stunting and shrinking of the stalk and rind. Yellowish discoloration of the internal tissues extending to three or four bottom internodes. Slight cavity formation of the pith, no fungal growth seen, slightly discolored roots.
3	Mild yellowing of top leaves and drying of lower leaves, mild stunting and shrinking of the stalk and rind. Light brown discoloration of the internal tissues throughout the entire length of the cane except the top. Severe pith and cavity formation. Sparse fungal growth observed in the pith cavities.
4	Complete yellowing and death of the leaves, marked stunting, shrinking and drying of the stalk and rind, dark brown discoloration of the internal tissues extending throughout the entire length of the cane. Large pith cavities with profuse over growth of the associated fungi. Most of the roots necrotic with dark discoloration which dislodge easily from the stalks. Roots mildly discolored and slightly necrotic.

The mean wilt severity index is worked out based on the number of canes sampled.

$$\text{Mean wilt severity index : } \frac{\text{Sum of wilt indices of individual stalks}}{\text{Number of stalks sampled}}$$



Yellow Leaf Disease (YLD)

YLD symptoms of mid rib yellowing are expressed during 6-8 months crop stage. If disease severity increases, the yellowing spreads to laminar region and later there will be drying of affected mid rib and adjoining laminar tissue from leaf tip downwards along the mid rib. Another important symptom would be bunching of leaves in the crown. Highly susceptible variety will exhibit severe foliage drying during maturity stage. In place of yellow disclouration, purple or pinkish purple discolouration may also be seen on the mid rib and lamina. Canes of the affected plant do not dry.

To assess YLD severity, the following disease severity grades are to be given during maturity stages of the crop (3 observations by 8th, 10th and 12thmonths). Each time, minimum of 25 canes (free from other biotic stresses) are to be scored.

YLD severity grades:

YLD symptoms displaying severity grades are shown in Fig. 8.

Disease grade	Description
0	No symptom of the disease
1	Mild yellowing of midrib in one or two leaves, no sign of typical bunching of leaves caused by YLD
2	Prominent yellowing of midrib on all the leaves in the crown.No bunching of leaves
3	Progress of midrib yellowing to laminar region in the whorl, yellowing on the upper leaf surface, and bunching of leaves
4	Drying of laminar region from leaf tip downwards along the midrib, typical bunching of leaves as a tuft
5	Stunted growth of the cane combined with drying of symptomatic leaves

Mean of the severity grades to be computed and the following YLD severity scale is to be used to assign disease reaction of the variety.

YLD severity scale :

Score	Disease reaction
0.0 - 1.0	Resistant
>1.0 - 2.0	Moderately resistant
>2.0 - 3.0	Moderately susceptible
>3.0 - 4.0	Susceptible
>4.0 - 5.0	Highly susceptible

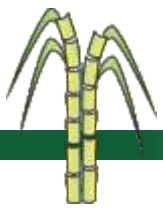


Fig. 8. Yellow Leaf Disease (YLD) symptoms displaying severity grades.

Identification of varieties resistant to red rot, smut, wilt and yellow leaf diseases

The zonal entries evaluated under Crop Improvement discipline in zonal varietal trial are also evaluated for resistance to red rot, smut, wilt and yellow leaf diseases. The disease reaction is utilized for identification of varieties.

Epidemiology of diseases

Red rot : The results have shown that the diseased setts are the primary source of infection of red rot. Poor germination of buds was observed in case of setts taken from naturally as well as artificially infected setts. The red rot pathogen present in the stubble/debris was found to cause disease development in the stools emerging from freshly planted setts up to 60 days of planting. The presence of infected debris in the soil, however, does not interfere with the initial germination of setts. The mid-rib isolates of *Colletotrichum falcatum* appeared to be weak pathogen as they could not infect stalks markedly and their role in the spread of red rot under natural conditions may not be significant.

Smut : The secondary spread of smut disease was found only to the adjacent and adjoining rows from the primary focus of infection. The disease spreads in a centrifugal manner which may be greatly affected by the wind direction.

Disease management

Heat therapy of seed cane

All the heat treatment methods, i.e. moist hot air at 54°C for 2.5 hrs., hot water at 50°C for 2 hours and aerated steam at 52°C for 1 hour, effectively controlled the sett-borne infections of grassy shoot and ratoon stunting diseases. The former two treatment methods were also effective in eliminating smut infection. Besides these diseases, sett borne incipient infection of red rot and leaf scald could also be managed to a greater extent by moist hot air treatment.

Chemotherapy

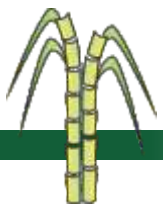
Efforts were made to control the sett-borne infection of red rot, and wilt diseases through both systemic and non-systemic fungicides but without appreciable success. The control of red rot and smut through combination of hot water and fungicides was also attempted. However, the results were not conclusive.

Chemical control of smut

Dipping of setts (10 minutes) in carbendazim (0.2%) or triademephon (0.2%) was found effective in the management of smut and increasing cane yield. However, taking into economic consideration, carbendazim (0.2%) sett treatment was recommended.

Chemical control of brown rust of sugarcane

Two sprays of propineb (0.2%) or mancozeb 75 WP (0.3%) at 15 days intervals from the initiation of the symptoms were found effective against the disease. The cost benefit ratio analysis of different treatments indicated highest C:B ratio (1.02) by Mancozeb 75 WP @ 0.3%.



Integrated disease management

Planting of sugarcane seed from heat treated (moist hot air treatment at 54^0 C for 2.5 hours at 95-99% RH) crop of a variety moderately resistant to red rot, eradication of diseased plants, especially of smut or GSD and spraying of crop before grand growth phase with fungicides like cropper oxychloride (0.25%) against leaf spots effectively reduced incidence of diseases and sustained cane yield and quality.

Nematology

Occurrence of nematodes

Several sugarcane growing tracts of the country have been surveyed for the occurrence of nematodes. *Hoplolaimus indicus, Helicotylenchus dihystera, Tylenchorhynchus elegans, T. mashhoodi* and *Pratylenchus zeae* have been found to be widely prevalent in and around sugarcane roots. Subnormal development of roots, stunting of plants and reduction in yield were associated with nematode infestations.

Host-parasite relationship

The pathogenicity tests of the phytoparasitic nematodes have proved that a number of nematode species could parasitize sugarcane roots and cause extensive damage. *Hoplolaimus indicus*, when released in the root zone of the test plant at a concentration of 1000 individuals/kg of soil, significantly reduced the plant growth. Root system of settlings was not properly developed and the roots were devoid of healthy laterals. Nematodes penetrated the host tissues by mechanically puncturing the epidermis and remain confined to cortical tissues. Subsequent to penetration, the intercellular spaces of the affected cortex were filled with a dark gummy substance.

Nematode-fungus association

Although nematodes alone are detrimental to sugarcane, they often in association with other pathogens form disease complex. Frequently, species of *Fusarium, Rhizoctonia* and *Pythium* were encountered from nematode infested roots of sugarcane. *Pratylenchus* and *Pythiun* have been found associated with root rot complex in sugarcane. Addition of parasitic nematodes in wilt sick soil increased the wilt incidence.

Control of nematodes

Soil treatment with nematicides, viz., D.D., Vapam, Nemagon, Dasanit, Carbofuran, was found effective in reducing the population of nematodes and increasing the cane yield. Despite substantial benefits in terms of tonnage, high cost of chemicals had been a major constraint in large scale adoption of the chemical control of nematodes. To economize the quantity of nematicides, band placement was tried with some success. Soil amendments with oil cakes, saw dust, etc., have also been found to reduce the nematode population.

IV. Entomology

Biology of major insect-pests

Root borer (*Emmalocera depressella*) : A female, on an average, lays 212 eggs singly on leaves along the midrib, stem or clods of soil during night hours. Larvae of this borer are migratory in nature and feed in an irregular semicircular pattern. Egg period lasts for 5-8 days. Larval period varies from 23-43, 25-59 and 191-245 days during summer, rainy and winter seasons, respectively. Pupal period lasts for 7-11 days during summer and rainy season and 8-14 days during the winter season. The borer completes it life cycle in 30-75 days depending on the location and climate.

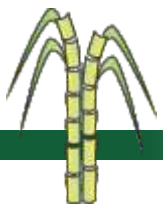
Stalk borer (*Chilo auricilius*) : Moths of this borer are nocturnal in habit. Eggs are laid in masses, arranged in rows, on the underside of the leaves. Longevity of moth was 7.5 to 10 days in single pairs but it ranged from 3 to 7 days only under a crowded condition at room temperature. Males mate with more than one female. Newly hatched larvae feed on leaf sheath and spindle for 10 days before entering into stalk. Seasonal history of the borer has been worked out in Bihar, Haryana and Uttar Pradesh. Depending on the climatic conditions, it completes 4-7 generations in a year.

Scale insect (*Melanaspis glomerata*) and mealy bugs (*Saccharicoccus sacchari*) : In the recent years, the scale insect has assumed the status of a major pest of sugarcane posing severe constraint on sugar industry in the States of Andhra Pradesh, Maharashtra, Gujarat, western part of Madhya Pradesh and Uttar Pradesh. This situation has resulted in heavy losses in cane yield and sugar recovery. The other sucking pest i.e. mealy bug, has also become a serious pest in some pockets specially in ratoons. However, of the two, the scale insect is the predominant stalk sucking pest. Some information on the transmission, life history and population build-up of the scale insect has been gathered.

The dispersal of scale insect is accentuated by the indiscriminate transport of cane material from one area to another without any proper sanitation certificate. This has been the main reason for its spread to new areas in Maharashtra and Andhra Pradesh. Human beings and animals passing through heavily infested fields also help in the spread of the pest in near-by fields. Males complete their development in a shorter period than females. The life cycle of the male insect ranges from 18 to 22 days, while that of female insect, varies from 39 to 46 days. Eggs are elongate, narrow and ovoid in shape. Egg period is very short (4-12 hrs). Nymphs or crawlers hatch within the body of the female. The total duration of nymphal stage is 35-40 days for female nymphs to become adult.

Scale insect has adapted itself to a wide variety of climatic conditions. Its infestation has been noticed from drought condition in M.P., Maharashtra and Gujarat to waterlogged condition of eastern U.P. Maximum population is found during the months of July to October.

The pest survives on the setts, though covered by soil and with the formation of internode, infestation builds up. After harvest, the females produce crawlers even before the formation of nodes but these crawlers again settle on stubbles and multiply. As a result, the infestation is more in ratoons.



Economic injury threshold

Root borer : Damage to sugarcane crop varies with stage of the crop. At early stage during May-June, the dead heart is formed. In grown up crop, the symptoms are visible in September-October. It was observed that in a crop affected by 1st brood of root borer, 52% shoots produced no tillers, 30% only one and 18% had only two tillers. Crop affected by 2nd brood showed 66% reduction in cane length and 73% in cane weight. Canes damaged by 3rd brood were reduced by 14.3% in length and 17% in weight, whereas canes attacked by 4th brood were reduced by 5.2% in length and 6.5% in weight.

Shoot borer : Feeding larva kills the growing point. Central whorl of leaves dries up and forms a dead heart which can easily be pulled out. A single larva may destroy 3-4 shoots before pupation. Because of its migratory habit, sometimes 2 or 3 holes are formed on the affected shoot. Attack of mother shoot at germination stage results in complete elimination of the clump.

Stalk borer : Build up of stalk borer larval population in the post-monsoon period brings about significant reduction in yield of cane. Economic injury threshold at Karnal center ranged from 12.20 to 17.83 larvae and 17.08 to 19.61 bored internodes/6 m row length, while it was 18.36 larvae/6 m row length at Lucknow center.

Top borer : In Uttar Pradesh and Haryana, third brood of the top borer (*Scirpophaga excerptalis*) inflicts maximum loss in yield and quality. At Karnal (Haryana), there was a reduction of 34.24 to 50% in height, 3.6 to 15.89% in girth and 9.4 to 50% in CCS. The relationship between 3rd brood incidence and yield at Lucknow was observed to be $Y = 82.59 - 0.80\,K$ (K is the borer incidence).

Chemical control of insect-pests

For the effective management of key pests of sugarcane, a number of insecticides have been evaluated. Findings of these tests are summarized in Table 9.

Table 9 : Chemicals found effective against key pests of sugarcane

Pest	Control measures
Termite, shoot borer and root borer	Soil application of endosulphan @ 1.0 kg ai/ha
Top borer	Soil application of carbofuran @ 1.0 kg ai/ha or phorate @ 3.0 kg ai/ha against 3rd brood in the 2nd week of June
Stalk borer	Application of monocrotophos 0.75 kg a.i/ha in the first week of September and mid October
Scale insect	Dipping of setts in 0.1% malathion/0.06% or dimethoate for 15 min and drench spraying with the above chemicals at 4-5 internode stage of the crop.
White fly	Spraying of acephate (0.1 %).

Management of root borer

Soil drenching of imidacloprid @ 0.1 kg a.i. /ha during mid-August / 120 days after planting is effective for management of root borer.

Management of white fly

For management of whitefly (*Aleurolobus barodensis*) in sugarcane agro-ecosystem, 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).

Monitoring and management of sugarcane borers through pheromone

Pheromone traps can be used to monitor the activity of moths of sugarcane borers, viz., top borer, stalk borer, early shoot borer and internode borer. It was found that trapping moths of these borers help in reducing incidence of the borer-pest.

Management of mealy bugs in sugarcane

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 stage effectively controlled mealy bug of sugarcane.

Mass multiplication of bioagents of major insect pests

Mass multiplication of *Dipha aphidivora* (Fig.9), the predator of sugarcane woolly aphid, may be carried out on sugarcane woolly aphid susceptible variety (Co 86032, CoC 671) grown under green shadenet. Woolly aphid may be released on the crop by continuous tagging of infested leaves till sizeable population is established. One hundred to two hundred larvae of *Dipha* may be released by tagging leaves. After 45 – 60 days larvae of *Dipha* may be harvested for redistribution.

Fig. 9. *Dipha aphidivora* and woolly aphid of sugarcane

Cotesia flavipes are multiplied on stalk borer larvae reared on artificial diet and on natural food (cane bits). Mature host larvae are offered gravid female of *C. flavipes* individually for parasitization. From a single larvae about 35-36 cocoons are obtained.

Two entomopathogenic fungi viz., *Beauveria bassiana* and *Metarrhizium anisopliae* are multiplied on autoclaved broken rice and PDA media. Growth of *M. anisopliae* was faster than *B. bassiana*. Rice can be used as base for large scale multiplication of both the fungi.

Biological Control

Intensive surveys for the occurrence of natural bioagents of major pests of sugarcane have been carried out by different centers in the country and a number of them have been recorded parasitizing on the insect-pests. Some of these have been evaluated for their effectiveness in reducing the population of the insects in sugarcane. The release of viable cocoons of *Epiricania melanoleuca* produced quick and longer establishment of the parasite for the control of Pyrilla. Eight species of Trichogrammatids have been reported from India. Attempts have been made to mass multiply and release *Trichogramma japonicum* against sugarcane top borer but without much success. Large scale releases of *T. chilonis* against

sugarcane borer complex have been found to reduce the borer population.

A fungal parasite, *Metarhizium anisopliae* has also been found effective in reducing the pyrilla population in cane crop. Among the other fungal parasites, *Beauveria bassiana* and *Fusarium oxyporum* have been found parasitizing on a number of sugarcane pests.

Management of woolly aphid

Woolly aphid of sugarcane appeared as serious pest in tropical India since 2002. For the effective management of sugarcane woolly aphid, the potential bioagents like *Dipha aphidivora*, *Micromus igorotus* (Fig.10) and *Chrysoperla carnea* may be redistributed in sugarcane fields where population of bioagents is deficient or low. However, need-based chemical application of imidacloprid 200 SL @ 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 thiamethoxam 25 WG @ 50 g a.i./ha is recommended.

Fig. 10. *Micromus igorotus* and woolly aphid of sugarcane

Integrated pest management

In view of the rising cost of chemicals as well as risk of environmental pollution, it was considered worthwhile to develop an eco-friendly system of pest management. In view of this, the following integrated pest management schedule has been developed:

A sugarcane variety tolerant to the major insect pest of the area should be selected for planting. Chlorpyriphos 20 EC/endosulfan @ 1 kg ai/ha may be applied in soil at planting where termite and shoot borer occur together in pest form. Dead-hearts should be removed where shoot borer infestation does not occur in pest form. Removal of top borer egg masses in Ist and IInd brood should be done followed by release of the parasite in the field, emerging from the collected egg masses. Carbofuran 3G @ 1 kg ai/ha should be applied against IIIrd brood of top borer in synchronization with pest activity. For controlling population of pyrilla, *Epiricania melanoleuca* cocoons may be distributed in IInd fortnight of July, if the parasite is deficient in the field. Where Gurdaspur borer occurs, the infested plants having borer larvae in gregarious phase should be removed at 15 days interval from July to September. In stalk borer prone areas, lower dry leaves should be removed in the month of November and thereafter late shoots and water shoots should be removed at 30 days interval.

Host plant resistance

This programme was undertaken with a view to identify cane varieties resistant/tolerant to the attack of major insect pests, such as stalk borer, internode borer, top borer, scale insect, etc. This approach in the management of pests is economical, long lasting and free from the undesirable side effects which are associated with the chemical control.

For testing the resistance of different varieties, elaborate varietal screening programme was launched. For this, it was imperative to maintain a culture of a large number of pests for artificial infestation. Since it was not possible to maintain the same under natural conditions, investigations were taken up to develop semi-synthetic diets for two species of borer, namely stalk borer and internode borer. The synthetic diets developed are being successfully used for mass culture of these two borers and their use in biological control and varietal resistant studies.

Methodology for recording observations on major insect-pests of sugarcane

During Group Meeting of AICRP on Sugarcane held at the Andhra University Campus, Visakhapatnam on October 25-26, 2013, a decision was taken to develop methodology for recording obervations on major insect-pests of sugarcane. A 'Research methodology for recording observations of sugarcane pests' was compiled by Dr. G.G. Radadia, Professor & Head and Principal Investigator (Entomology), Deptt. of Entomology, NM College of Agriculture, Navsari Agricultural University, Navsari. The methodology has been developed for the following insect-pests of sugarcane – Early shoot borer, Top borer, Internode borer, Stalk borer, Root borer, Pyrilla, White fly, Scale insect, Mealy bug, Sugarcane woolly aphid, Web mite, Thrips, Black bug, Sprittle bug, Termite and White grub. The methodology is being used by the Entomologists of AICRP on Sugarcane.

V. Agricultural Engineering

Scarcity of labourers as well as increase in their daily wages for agricultural operations is becoming a serious constraint in sugarcane cultivation. This has resulted in increase in cost of production per unit area and time. Keeping these factors in view, simple time and labour saving devices, which reduce the cost of cultivation, are very much needed. A number of machines have been designed and developed at the Indian Institute of Sugarcane Research, Lucknow keeping in view the soil and agroclimatic conditions and prevailing agronomic practices.

Under AICRP on Sugarcane, field evaluation trials of a number of sugarcane equipments developed at IISR, Lucknow were conducted at the Sugarcane Research Stations in different States from 1971 to 1992. The details are given below:

Bullock drawn semi-automatic sugarcane planter

This machine was designed for flat planting of sugarcane in light to medium type of soils. The machine opens a furrow, setts are dropped manually, fertilizer and insecticide are applied and the planted setts are covered with a blanket of soil followed by compacting of soil cover. All the operations involved in cane planting are completed in a single process basis.

This planter was tested at Lucknow, Pusa, Shahjahanpur and Jalandhar. The implement required a good pair of bullocks for its working as the draft was slightly higher. The fertilizer metering required improvement. The hitching and covering arrangements of the furrow making unit were also improved. The performance of the equipment was found satisfactory and the cost of the operations was about one-third of the cost spent under conventional method.

Efforts made under AICRP on Sugarcane helped to remove the short-comings in the design of the machine by making necessary improvements. The planter was recommended for use in light soils for flat sowing of sugarcane.

Tractor drawn sugarcane planter

This machine is also similar to that of bullock drawn sugarcane planter with the only difference that this was used for ridge and furrow type planting of cane. This unit was field evaluated at Lucknow, Shahjahanpur, Pusa, Seorahi, Padegaon, Pantnagar, Anakapalle, Mandya and Cuddalore. The earlier design posed many problems like clogging of trash between the covering lines, fertilizer metering, heavier weight and improper deposition of setts in the furrow. The unit was modified in the light of the experience of field trials and an attachment for insecticide application was also included. The cost of operation ranged between one half to one third to that of conventional method of planting. The crop stand and yields were at par with the conventional method.

Multi location trials under AICRP on Sugarcane helped to modify the design for trouble free working under different conditions. The planter was found suitable under all the conditions and was recommended for extension.

Power operated sett cutting machine

The machine is used for cutting three-bud sugarcane setts for planting. It is operated by a 5 h.p. engine or a tractor pulley. Two circular saw blades are mounted on a mild steel

angle iron frame. Drive to the blades is given through flat belt from the prime mover. Three-bud setts are cut and dropped through a slanting platform into the treatment tank with a solution of fungicide. Bud damage due to cuts on the buds is about 2% . With the help of four persons, 12000 to 13000 setts per hour can be cut. For planting of one hectare of field about 40,000 three-bud setts are required and these can be cut in 3 hours.

Power operated sett cutting machine was tested at Lucknow, Pantnagar, Mandya and Dimapur (Nagaland) for preparation of setts. The machine gave good performance. The output was around 12000 setts per hour and damage of buds was within permissible limits. The machine was very much liked by the farmers. The machine was found quite suitable and efficient. The design was recommended for extension.

Tractor drawn stubble shaver

A tractor mounted P.T.O. shaft operated stubble shaver (Fig. 11) was designed and developed. With a view to increasing its utility, attachments for off-barring and fertilizer dispensing system were also incorporated. The design was further modified. The latest equipment is a double row stubble shaver. Besides stubble shaving, other cultural operations, viz., off-barring, tilling in the interspace of cane rows and fertilizer application in the close proximity of root zone, are accomplished simultaneously. The equipment gives an output of 3.0-3.5 hectares per day.

Fig. 11. Tractor-drawn stubble shaver for shaving stubble of sugarcane

Tractor drawn stubble shaver was tested at Lucknow, Pravaranagar and Cuddalore. The quality of stubble shaving was satisfactory. The machine performance under normal soil and moisture conditions was good, however, under difficult conditions the gearbox gave some trouble. The unit was identified as a potential unit for stubble shaving. The field trials indicated that the vertical drive system should be made sturdier.

Hot air seed cane treatment plant

This seed treatment unit was designed and developed by IISR, Lucknow in 1971. The rectangular outer box (2.7x1.8x1.8 m) is made of plain iron. The inner layer of the chamber is made of iron or aluminium and the space between the two layers is filled up with insulating material. The front portion of the box is provided with double panelled door. The floor is made of wooden planks.

Inside the box, a cylindrical drum is fitted with open ends. Removable racks are provided for keeping full length canes. The base is provided with two semi-circular trays containing water for avoiding desiccation of canes during heat treatment. Eight fin type air heaters (1 KW each) are fitted in the space between outer box and cylindrical drum in front of the unit. A fan (60 cm sweep) for circulating air is provided inside the chamber which is powered by 1 HP motor fitted at the rear end of the unit.

About 4.0 quintal of canes are loaded onto the racks of the inner drum. The doors of the unit are closed and heaters along with fan are switched on. After attaining 54°C temperature, it is maintained for 8 hours and then fan and heaters are switched off. Doors are opened and treated canes are removed from the unit. The canes are cut into 3-bud setts and planted in the field.

This unit was tested at Lucknow, Shahjahanpur, Balrampur, Majhola, Tulsipur, Nawabganj, Jalandhar, Captainganj, Narkatiaganj, Mandya and Pravaranagar for their working. A number of defects as improper maintenance of temperature, non-uniform circulation of air, leakage of air from chamber resulting into driage of buds were noticed and suggested for modification in the design of the unit.

Later, it was found that by increasing the humidity inside the chamber to about 100% and checking leakage of hot air overcame the problem of driage of buds and reduced the time of initial heating as well. This led to development of moist hot air seed cane treatment plant.

Moist Hot Air Treatment (MHAT) plant

Based on the experience of working of hot air seed cane treatment plant the design was modified and moist hot air treatment plant (Fig. 12) was developed by IISR, Lucknow in 1977. In this unit, two hygrometers were provided at two ends for indicating humidity level inside the chamber. During treatment high humidity (95%) is maintained. A steam injection unit is fitted at the rear of the unit. It is run by a 2 KW immersion heater. Steam generated is injected in the chamber through a pipe. This reduces the treatment time from 8 to 4 hours, while temperature was maintained at 54°C during the treatment. The unit was more sturdy and gave trouble free working. It was tried at Lucknow, Jalandhar, Dimapur, Shahjahanpur and Pusa and its working was found satisfactory and effective for controlling ratoon stunting and grassy shoot diseases and seed-borne insect pests.

Fig.12. Moist hot air treatment unit (front view with doors open)

Based on the good performance of MHAT plants on germination and disease control, about 100 units were installed at different places in the country.

Wide swath spray-boom

Wide swath spray-boom in combination with two 'Maruti' foot sprayers was tried at Lucknow, Mandya, Shahjahanpur, Dimapur and Seorahi for foliar spraying and its working was found satisfactory. In large scale trials, it gave an output of 4 ha per day.

The unit was found very suitable for foliar spraying in tall cane crops. It was recommended for extenstion.

Motorized sprayer in combination with wide swath spray-boom

A back motorized sprayer using positive pump was developed in combination with wide swath spray-boom. The unit was field tested. The output was same as that of non-motorized sprayer and the cost of spraying was high. The performance was, however, not very satisfactory.

VI. Foundation seed programme

The programme was initiated in 1971 and implemented in 1975 at eight centres viz., IISR, Lucknow, Shahjahanpur, Pusa, Jalandhar, Jaora, Hisar, Bethuadahari and Pravaranagar. The project was taken up as an operational research for multi-location testing of heat treated material for the control of seed piece transmissible diseases and also to supply disease-free seed material to different agencies. A three tier-seed programme, i.e. Breeder Seed, Foundation Seed and Certified Seed, was implemented throughout the country for production and distribution of quality seed cane.

Foundation seed of sugarcane varieties was raised with planting of heat treated seed material. The crop raised was free from major diseases. However, from the information gathered in later years, it was found that there was accumulation of ratoon stunting and grassy shoot diseases in the subsequent multiplication of the treated crop. The seed, however, remained reasonably usable up to five years after which it seemed to need replacement. The foundation seed crop was multiplied on a large scale and distributed among the growers. Encouraged by the quality of seed, moist hot air treatment units were installed at several sugar factories farm. The Foundation seed programme continued up to 1992 till the end of VII Five Year Plan.

VII. Sustainable development of sugarcane based cropping stystem (SUBACS)

The Department of Agriculture and Cooperation (DAC), Ministry of Agriculture, Government of India, launched Centrally Sponsored Scheme on 'Sustainable development of sugarcane-based cropping stystem' (SUBACS) during 1995-96 for increasing productivity of sugarcane, especially in low productivity areas, as improved technologies play the most vital role in enhancing sugarcane production. Two major components of this scheme i.e., Front Line Demonstration and Breeder Seed Production have been implemented by ICAR through the All India Coordinated Research Project on Sugarcane with active involvement of scientists of its coordinating centres. The scheme continued till 2009-10 crop season.

Later in 2014-15, DAC initiated implementation of centrally sponsored scheme on National Food Security Mission- Commercial Crops (NFSM-CC) with two components, viz., Breeder Seed Production and Demonstration of Intercropping. These two components have been implemented at the centres of AICRP on Sugarcane w.e.f., 2015-16 crop season.

Special attainments

National Hybridization Garden

With the start of the All India Coordinated Research Project on Sugarcane in 1970, the main plank on which the coordination of sugarcane research was aimed at was in breeding. A decision was taken to supply fluff to the centres located in different States. As a follow up action, a National Hybridization Garden was established in 1972 at the Sugarcane Breeding Institute wherein all the parents so far identified for their characters for hybridization are planted in a separate plot and the breeders of the centres are invited in the programme. This has resulted in the State/University centres to freely participate and making use of National Hybridization Garden for crossing and fluff production. SBI, Coimbatore has also extended facility for crossing work at the National Distant Hybridization Facility established at Agali (District Palakkad, Kerala).

Fluff increases the genetic diversity and enlarges the scope of variation to enable rapid evolving of commercial varieties. After crossing work, SBI, Coimbatore facilitates collection and drying of fluff and subsequently dispatch to the AICRP centres for raising seedlings and selection of elite clones under location specific soil-agro-climatic conditions. This programme has been working very well over the years.

Flowering in sugarcane at the National Hybridization Garden

Co 86032 (Nayana) : A wonder variety of sugarcane in tropical India

Fig. 13. Sugarcane variety Co 86032 (Nayana

The wonder variety, Co 86032 (Fig. 13) of the decade was developed at the Sugarcane Breeeding Institute, Coimbatore from the progenies of Co 62198 x CoC 671 and identified in 1994 for the peninsular zone (Gujarat, Madhya Pradesh, Chattisgarh, Maharashtra, Karnataka, interior plains of Andhra Pradesh, interior plains of Tamil Nadu and Kerala). It was released and notified in the year 2000. In Tamil Nadu it occupies nearly 80% of the area and in Andhra Pradesh, Karnataka, Gujarat and Maharashtra around 40% in each State. This is a high yielding, high sucrose midlate variety with good ratooning ability. This is cultivated in wide range of soils except water logging. It yields 120 t/ha and 15.09 t/ha of cane and sugar, respectively. The average sucrose content is 19.19%. This is resistant to smut, moderately resistant to wilt and field tolerant to red rot. This is amenable for multiple ratooning and suitable for mechanization as it performs well under wide row spacing. This can be cultivated in drought and saline affected areas. Co 86032 substituted CoC 671, a predominant variety in the early 1990s when it gradually succumbed to red rot and subsequently withdrawn from cultivation.

As a high sugar variety, this variety improved the sugar recovery up to 1 unit in many factories. In a case study conducted by SBI, Coimbatore at Bannari Amman Sugars Ltd., Tamil Nadu, the sugar recovery had increased by 1.21 units between 10 years average of pre (9.25 %) and post (10.46%) introduction of Co 86032. Due to introduction of this variety many factories in tropical India had expanded crushing capacity, extended the crushing duration and started new mills. Critical analysis revealed that sugar recovery in factories improved by about 0.24 to 1.22 units and jaggery farmers were also benefitted significantly from the variety due to high jaggery recovery. Economic analysis indicated that in Tamil Nadu alone cumulative benefit of Rs. 525 crores was realized up to 2012. In Maharashtra the area under Co 86032 had increased from 0.84 % in 1996-97 to 41.29 % in 2002-03 and the sugar recovery during the corresponding period showed an improvement of 0.5 units This wonder variety of the decade is still a preferred as a major variety in all the states of peninsular zone.

Co 0238 (Karan 4) : Spreading fast in north west zone

This variety Co 0238 (Fig. 14) was developed at the ICAR-Sugarcane Breeding Institute Research Centre, Karnal. Co 0238 (early maturing) is a selection from the progeny of the cross CoLk 8102 x Co 775. It was identified in 2008 and released & notified in 2009 for cultivation in North West Zone (Punjab, Haryana, Rajasthan, Uttar Pradesh (western &

central) and Uttarakhand). In the zonal varietal trials conducted across 8 centres of North West Zone, it recorded 81.08 t/ha of cane yield, 9.95 % of CCS t/ha and 17.99 % of sucrose. There was 19.96, 15.83 and 0.50 per cent improvement over the best check CoJ 64. The fibre (%) is around 13.05 %. Experiments conducted in Uttar Pradesh at DSCL Sugar, Ajbapur and Simbhaoli Sugar Mills Ltd., Simbhaoli indicated an improvement in cane yield under water stress and water logging conditions by more than 20 t/ha over respective standards. Co 0238 is good ratooner as the reduction in cane yield when harvested during winter was 4.66% compared to CoJ 64 which recorded 41.29 % reduction. This variety also performed well in UP, Bihar and Haryana. Sugar recovery was found to be improved by an average of 1.14 units over mill recovery of 10.83% across crushing during the months of March and April, 2008 at Shahabad Co-op Sugar Mills Ltd., where it is a major variety occupying 45% (18,505 ha) of the total area. Due to its wider adaptability, the variety is fast spreading in Haryana (19,517 ha), Punjab (26,683 ha), Uttarakhand (2,950 ha), UP (72,628 ha) and Bihar (91,795) which was 14.83, 27.78, 2.68, 3.08 and 0.66 % of the total sugarcane areas of the respective states.

Fig. 14. Sugarcane variety Co 0238

CoLk 94184 (Birendra) : Spreading fast in north central zone

This variety was developed at the ICAR-Indian Institute of Sugarcane Research, Lucknow. CoLk 94184 (Fig. 15) is a selection from the progeny of selfed CoLk 8001. It was identified in 2007 and released & notified in 2008 for North Central Zone (eastern U.P., Bihar and West Bengal). This 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 with existing varieties. In a varietal trial at Balrampur Chini Mills, Balrampur (U.P.), the sugar recovery ranged from 10.23 to 11.13% showing increase up to 1.23 units. The variety is moderately resistant to red rot and tolerant to top borer. It is fast spreading in U.P. and Bihar.


Fig. 15. Sugarcane variety CoLk 94184

CoOr 03151 (Sabita) : Spreading fast in east coast zone

This early maturing variety, CoOr 03151 (Fig. 16) is a selection from the progeny of CoC 671 x Co 1148. It was identified in 2009 and released & notified in 2011 for cultivation in East Coast Zone (Odisha, coastal Andhra Pradesh a nd coastal Tamil Nadu). This variety, on an average, yields 105.28 t/ha of cane 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. In front line demonstrations, the variety has given more than 60% higher cane yield over the existing varieties. There is growing demand of this variety and is fast spreading in Odisha.

Fig. 16. Sugarcane variety CoOr 03151 (Sabita)

CoM 0265 (Phule 265) : Spreading fast in Maharashtra

This is a midlate maturing variety. It is a selection from the progeny of Co 87044 GC. It was identified in 2009 for release in the peninsular zone (Gujarat, Madhya Pradesh, Chattisgarh, Maharashtra, Karnataka, interior plains of Andhra Pradesh, interior plains of Tamil Nadu and Kerala). This variety is high yielding (111.45 t/ha) with good ratooning ability. It is suitable for cultivation in spring, autumn and as *adsali* (18-month duration) crop. It is moderately resistant to red rot and tolerant to drought and salinity. The *adsali* crop of this variety yielded about 200 t/ha with increase of 16.9% over existing varieties like Co 86032. In pre-season and *suru* planting also, the cane yield was higher than existing varieties. It has recorded 21.8 t/ha sugar which was 18.75% higher than existing variety Co 86032. It is most suitable for cultivation in salinity affected soils and is fast spreading in Maharashtra and other states in peninsular zone. It is now most preferred by the farmers.

Varieties resistant to woolly aphid of sugarcane

During 2002-03 there was an unprecedented epidemic of woolly aphid on sugarcane crop affecting large areas in Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu. There was heavy reduction in cane yield as well as sucrose recovery from the affected crop. A few clones resistant to woolly aphid were found at the Agricultural Research Station, Sankeshwar (Karnataka). The clones were evaluated for other desired traits also. Two varieties viz., CoSnk 05103 and CoSnk 05104 were identified in 2011 and released & notified in 2014 for cultivation in peninsular zone (Gujarat, Madhya Pradesh, Chattisgarh, Maharashtra, Karnataka, interior plains of Andhra Pradesh, interior plains of Tamil Nadu and Kerala). CoSnk 05103 is an early maturing variety with cane yield of 105.5 t/ha. CoSnk 05104 is a midlate maturing with cane yield of 106.86 t/ha. Both the varieties are moderately resistant to red rot and tolerant to moisture stress. These two varieties are suitable for cultivation in regions prone to woolly aphid infestation.

Sugarcane-based cropping system

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 to sugarcane cultivation, sugarcane based-cropping system has become a necessity. Intercropping in sugarcane offers great opportunity for increasing farm income per unit area and time.

In AICRP on Sugarcane, a 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. A few such systems are given below in Table 10. The success of intercropping depends on the selection of crop, variety, sowing time, planting geometry, fertilizer management and other crop management practices.

Table 10 : Popular sugarcane-based cropping systems in the country

Cropping systems	Regions
Rice (early)-pea-sugarcane-ratoon-wheat	Eastern U.P.
Rice (early)-sugarcane (autumn)-ratoon-green gram	-do-
Green manure-sugarcane-ratoon-wheat	-do-
Rice-chickpea/pea-(green manure)-sugarcane-ratoon	-do-
Rice-potato-sugarcane-ratoon-wheat	Western and central U.P.
Rice-wheat/mustard-sugarcane-ratoon-wheat	-do- -do-
Green manure-potato-sugarcane-ratoon-wheat	-do-
Green manure-potato-sugarcane-ratoon-wheat	-do-
Sugarcane-ratoon-wheat	-do-
Rice-pea-sugarcane-ratoon	Bihar
Rice/maize-sugarcane-ratoon	-do-
Maize-wheat-sugarcane-ratoon	Punjab, Haryana, western U.P.
Groundnut-wheat-sugarcane-ratoon	Gujarat
Sorghum (fodder)-berseem-sugarcane-ratoon	Punjab
Rice-sugarcane-ratoon	Tropicalstates
Ragi-sugarcane-ratoon	-do-

Three-tier Seed Programme for production of healthy seed of sugarcane

Under Foundation Seed Programme which was initiated in 1971 under AICRP on Sugarcane as an operational research for multi-location testing of heat treated seed material for the control of seed piece transmissible diseases, the heat treatment of Breeder was performed by the moist hot air treatment (MHAT) unit at seven locations. The seed cane was treated at 54°C for 2.5 to 4.0 hours under humidity of 95-99%. The treated seed was planted to raise Foundation Seed which was multiplied on a large scale. The crop raised from foundation seed was found free from major diseases. Seed from such crop was reasonably usable up to 5 years after which it seemed to need replacement. The success of heat treatment led to installation of about 100 MHAT units at different places in the country. Currently, heat treatment units are employed at number of places for production of healthy seed. Different activities involved in Three-tier seed programme for healthy seed cane production are shown in Table 11.

Table 11 : Three-tier Seed Programme for healthy seed cane production

Year	Breeder	Foundation Seed	Certified Seed
I	• Selection of genetically pure and apparently healthy crop • Heat treatment of planting material • Selection of setts • Treatment of setts with fungicides • Planting • Insecticide application at planting • Field hygiene		
II	-do-	• Selection of seed crop • Selection of setts • Treatment of setts with fungicide • Planting	
III	-do- -do-	• Application of insecticide at planting • Field hygiene	All the operations as in case of foundation seed

Integrated pest management module

In view of the rising cost of chemicals as well as danger of environmental pollution, it was considered worthwhile to develop an eco-friendly system of pest management. In view of this, integrated pest management modules were evaluated and verified at different centres in the country. Although the pest complex differs from location to location, the following IPM module was developed and recommended.

Resistant varieties : A number of sugarcane varieties have been identified as tolerant/resistant to key pests of the area. The infestation level of the pests could be reduced by planting of such varieties provided the variety is recommended for cultivation.

Chemical control : Soil application of chlorpyriphos/sevidol/phorate/ cartap/carbofuran could provide protection against shoot borer, root borer and termites and top borer. For the control of white fly, foliar spray of monocrotophos has been recommended. The stalk borer incidence was reduced by the application of monocrotophos, two times i.e., in the first week of September and mid October.

Biological control : Intensive surveys for the occurrence of natural bioagents of major pests of sugarcane were carried out at different centres in the country and a number of bioagents have been recorded parasitizing on the insect pests. Some of these are being evaluated for their effectiveness in reducing the population of the insects in sugarcane. The release of viable cocoons @ 4,000 to 5,000 per hectare of *Epiricania melanoleuca* (Fig. 17) produced quick and longer establishment of the parasite for the control of pyrilla. A fungal parasite, *Metarhizium anisopliae* @ 1.50 x 10^6 spores/ml has also been found effective in reducing the population of pyrilla in cane crop. *Trichogramma chilonis* @ 1, 25, 000 /ha has been found effective against *Chilo infuscatellus*.

Fig. 17. ***Epiricania melanoleuca*** moth and eggs (top), the parasite of pyrilla (bottom) on sugarcane leaf

Seed Certification Standards

The first Indian Standard for sugarcane seed material was adopted by the Indian Standards Institution (ISI) on 5th December, 1966 and published as - ISI : 3866 – 1966 **'Specifications for Sugarcane Seed Material'**. During VII Workshop of AICRP on Sugarcane held in 1978 MPKV, Pune, a decision was taken for formulating standards for seed cane at various stages of its clonal multiplication as the standards adopted by ISI needed revision.

A task force was constituted by ICAR under the Chairmanship of Dr. Kishan Singh, the then Director, IISR, Lucknow. Views of many working sugarcane scientists were obtained by wide circulation. The task force submitted Draft for 'Quality standards and code of agricultural practices for raising sugarcane seed' to the Project Coordinator (Sugarcane). The content of the 'Draft' was discussed in AICRP Workshop held in 1979 in Bhopal. The Workshop recommended that the draft may be communicated to the ISI for printing and inviting comments from prospective users.

ISI decided to revise the standards in its 18th meeting of Seed Technology Sectional Committee (AFDC 22) held on 23rd January, 1984. The seed standard document prepared by the task force was discussed and accepted in XII AICRP Workshop held in Waltair in 1985. The re-drafted document was sent to ISI for approval. The re-drafted document was compiled by AICRP on Sugarcane and published by IISR in 1990 as Bulletin No. 25 under the title **Standards for sugarcane seed material.**

Consequent upon inclusion of 'Sugarcane' in Seed Act, a Sub-Committee for formulation of Minimum Seed Certification Standards for sugarcane was constituted in 1999 under the Chairmanship Dr. H.N. Shahi, the then Director, IISR, Lucknow by the Central Sub-Committee on Crop Standards Notification & Release of varieties of Agricultural Crops, Deptt. of Agriculture & Cooperation, Ministry of Agriculture, Govt. of India. The Sub-Committee meeting was held on 10th September, 1999 at IISR, Lucknow and proceedings were sent to DAC, Ministry of Agriculture, Govt. of India. The proceedings of the meeting mentions following steps to be taken up at a later stage :

(i) There is a need to develop sample size of sugarcane seed for testing its germination.

(ii) Methodology of each aspect related to seed standard should be developed.

The Technical Committee of Central Seed Certification Board approved the following seed certification standards for sugarcane crop in October, 2001.

Sugarcane (*Saccharum* spp; hybrid)

Age of the seed cane crop at harvest for seed purpose shall be 6 to 8 months and 8 to 10 months for the sowing in tropics and sub-tropics, respectively seed cane material undamaged and reasonably clean. Each node of seed cane shall bear on one sound bud. The number of nodes without sound bud shall not exceed 5% (by number) of the total number of buds per seed cane. The number of buds, which have swollen up or have projected beyond one centimeter from the rind surface shall not exceed 5% (by number) of the total number of buds.

1. Application and Amplification of General Seed Cane Certification Standards

The General Seed Cane Certification Standards are basic and together with the following specific standards constitute the standards for certification of sugarcane seed cane.

The certified classes shall be produced from seed canes and/or meri-clones whose sources and identity may be assured and approved by the Certification Agency.

2. Land Requirements :

i) A seed crop of sugarcane shall not be eligible for certification if planted on land on which sugarcane was grown in the previous season.

ii) Land/seed crop shall be kept free from sugarcane residues and drainage from other sugarcane fields.

3. Heat Treatment : Foundation Stage (1)shall be raised from heat-treatment seed cane

4. Field Inspection

A minimum of three inspections shall be made as under :

l **Stage-I** The first inspection shall be made at 45-60 days after planting in order to verify isolation and detect volunteer plants, designated diseases and pests and other relevant factors.

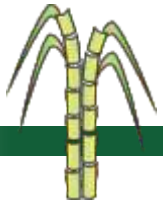
l **Stage-II** The second inspection shall be made at 120-130 days after planting to verify off-types, designated diseases and pests and other relevant factors.

l **Stage-III** The third inspection shall be made 15 days prior to the harvesting of seed canes to verify the age of cane, off-types, designated diseases and pests and other relevant factors.

5. Field Standards :

A. General Requirements

Isolation : The sugarcane seed production fields shall be isolated from other fields with a minimum distance of 5 m to avoid mechanical mixture of other varieties.



B. Specific Requirements

S.No.	Factors	Stage of field inspection	Maximum permissible limits (%)	
			Foundation	Certified
I.	Off-types	1, II, III	None	None
II.	Plants affected with designated diseases			
	Red rot	I, II, III	None	None
	Smut	I	0.02*	0.10*
		II	0.01*	0.10*
		III	None	None
	Grassy shoot	II	0.05*	0.50*
		III	None	None
	Wilt	III	0.01*	0.01*
	Leaf scald	II	0.01*	0.05*
		III	None	None
III.	Plants affected by designated Insect-pests			
	Top borer	II & III	5.0	5.0
	Internode borer	III	10.0* None**	10.0 None**
	Stalk borer	III	20.0+ None**	20.0 None**
	Plassey borer, Gurdaspur borer, Scale insect, mealy bug	III	5.0 None**	5.0 None**

* Subject to immediate roguing of the whole clump

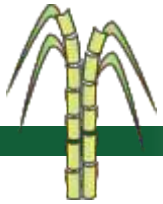
** In areas where the presence of the pest has not been recorded

\# It gives around 10% affected buds

\+ It gives around 0.5% affected buds.

Designated diseases shall be :

1. Red rot (*Glomerella tucumanensis* (Speg.) Arx & Muller)
2. Smut (*Ustilago scitaminea* Sydow)
3. Wilt (*Cephalosporium sacchari* Butler)
4. Grassy shoot disease (Mycoplasma-like-organism)
5. Leaf scald (*Xanthomonas albilineans* (Ashby) Dowson



Designated Insect-Pests shall be :

1. Top borer (*Scirpophaga excerptalis* Wlk.)
2. Internode borer (*Chilo sacchariphagus indicus* Kapur)
3. Stalk borer (*Chilo auricilius* Ddgn.)
4. Plassey borer (*Chilo tumidicostalis* Hmpsn.)
5. Gurdaspur borer (*Acigona steniellus* Hmpsn.)
6. Scale insect (*Melanaspis glomerata* Green)
7. Mealy bug (*Sacchariphagus sacchari* Cockerell)

Note :

1. All off-types and diseased plants shall be rogued out along with roots and destroyed.
2. Maximum permissible limits for the stripping of dry foliage shall be 2.0%
3. The crop should not have more than 10% lodged canes.
4. Seed canes should not have nodal roots. In water logged areas, relaxation may be given up to a maximum of 5%.
5. Moisture in seed cane should not be less than 65% on wet weight basis.
6. Germinability of buds should not be less than 85%
7. Physical purity of seed should be 98%.
8. Genetic purity of seed should be 100%.

Methodology for testing seed cane standards

At nine centers of AICRP on Sugarcane, experiments for standardizing methodology for testing germination of buds and determining moisture percentage in setts were conducted in 2007. The methodology and findings are detailed below:

Methodology for testing germination of sugarcane buds

Immediately after harvesting the cane samples, single-bud setts may be cut in such a manner that the distances of the cut from the node shall not be less than 4 cm. A total of 400 single-bud setts are to be planted @ 25 setts per plastic tray (with perforated bottom) filled with fine sterilized sand as a support medium and kept at 28-30^{0}C for 30 days Germination (%) is recorded after 30 days of planting. Water is to be sprinkled frequently to keep the sand medium moist.

Findings : Variation in germination of buds in different varieties at different centers was very wide. In tropical centers, germination ranged from 56 to 92%, whereas in sub-tropical centers from 48 to 95. Therefore, no single value can be assigned and the germination of buds for the purpose of seed cane standards may be kept specific to the variety being certified.

Methodology for determining moisture content of setts

With the help of hack-saw or sharp knife, cut the middle-most internode of the cane stalk transversely into 4 cm thick pieces (samples). Place the samples in a perforated paper bag and immediately take the gross weight (fresh wt.). Place the paper bag containing samples in a hot air oven maintained at 80^0 C for 120 hours. Record weight (dry wt.) of sample + paper bag after room temperature is attained. During cooling, the bag is to be stored in a desiccator containing anhydrous calcium chloride so that chances of absorption of moisture by the sample tissue is minimised. Place the sample again in the oven till constant weight is attained. In case, difference of weight between two readings is 0.01% or lesser, final dry weight is recorded. Moisture content of the sample may be calculated as mentioned below:

$$\% \text{ moisture content} = \frac{\text{Fresh wt - Dry wt}}{\text{Fresh wt}} \times 100$$

Findings: On an average, 65.0% moisture content in setts was recorded at testing centers in different varieties after 120 hours of drying at 80^0C.

A meeting to formulate methodologies for sugarcane seed certification standards was convened by Project Directorate on Seed Research, IARI, New Delhi at Sugarcane Breeding Institute, Coimbatore on 31st January, 2006. As a follow-up of ICAR- DAC interface meeting, ICAR took initiation in developing standards for tissue culture raised planting material of sugarcane. The Project Director, Project Directorate on Seed Research, Mau convened a meeting of concerned officers/scientists on 16th March, 2006 at Division of Seed Science & Technology, IARI, New Delhi. It was decided that the Project Coordinator (Sugarcane) will pursue further meeting and a Brain Storming session and development of strategy/standards for tissue culture raised planting material of sugarcane. The Brain Storming Session was organized by the Project Coordinator (Sugarcane) at the Vasantdada Sugar Institute, Pune on 9th June, 2006. Two Technical Sessions viz., Developing standards for tissue culture raised planting material and Methodology for determining seed cane standards were held.

On the recommendations of the Brain Storming Session, a meeting of the Committee was organized at IISR, Lucknow on 9th October, 2006 for finalization of seed certification standards of tissue culture raised planting material of sugarcane. The meeting was chaired by Dr. R.L. Yadav, the then Director, IISR, Lucknow. The members were: Dr. N. Vijayan Nair, the then Director, Sugarcane Breeding Institute, Coimbatore, Dr. S.B. Singh, the then Director, U.P. Council of Sugarcane Research, Shahjahanpur, Dr. R.K. Chowdhury, the then Professor & Nodal Officer (Seeds), Indian Agricultural Research Institute, New Delhi and Dr. O.K. Sinha, Member-Secretary & Project Coordinator (Sugarcane), IISR, Lucknow. The Committee recommended the standards as follows :

Sugarcane–Tissue Culture Raised Plants (TCRP)

I. Application and Amplification of General Seed Certification Standards

A. The General Seed Certification Standards are basic and, together with the following specific standards, constitute the standards for certification of TCRP. As the name implies, these standards are applicable to tissue culture raised plants multiplied under laboratory and greenhouse conditions as laid here.

B. The General standards are amplified as follows to apply specifically to the TCRP:

1. Eligibility requirements for certification

The TCRP to be eligible for certification shall be from a source meeting the following standards for laboratory and greenhouse facilities:

i) Laboratory and greenhouse facilities used for production of tissue culture raised plants shall be maintained free of sugarcane pests or vectors of sugarcane pathogens. Failure to keep such pests under control may cause rejection of all lots maintained in the facility. All potting or growth media shall be sterile. Clean water shall be used in laboratory or greenhouse operation.

ii) Hygienic conditions shall be strictly observed during micropropagation, potting, planting, irrigating, movement and use of equipments and other laboratory and greenhouse practices to guard against the spread of diseases or pests in the facilities used for seed multiplication.

iii) All micro-propagation and greenhouse facilities must be approved, as per the standard/guidelines. These facilities must have a changing area between the double doors.

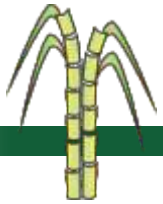
iv) The greenhouse must be insect proof and be equipped with a double-door entrance, provision for footwear disinfection prior to entering the greenhouse and insect proof ventilation screening on intakes and exhaust openings. The persons entering the greenhouse should use Wellington boots (synthetic boots) and change lab-coat in the changing area to reduce the chances of inadvertent introduction of vector insects clinging to clothes.

v) The material being initiated for producing TCRP must be a notified variety or released by State Varietal Release Committee or registered with State Agencies. It must be duly documented with respect to origin.

vi) The genetic purity of the variety selected for producing TCRP should be certified by the originating or sponsored Breeder.

vii) For freedom from most of the pathogens, the plant material (to be used for initiating TCRP) should be obtained from sugarcane plants raised after heat treatment of seed cane (for moist hot air treatment at 54^0C for 2.5 hours at 90 – 99% R.H; for hot water treatment at 50^0C for 2.0 hours; for aerated steam treatment at 50^0C for 1.0 hour). The heat treated seed cane should be planted in a field or microplot where sugarcane had not been a crop in the preceding year.

viii) The initiating plant material (explant) for TCRP should be taken from 4 to 6 months old crop with adequate soil/cane moisture.



2. Classes and Sources of Seed

i) The facility should use recognized aseptic initiation and propagation procedures (i.e., follow procedures and use equipments which will maintain sterile conditions as per standard tissue culture norms).

ii) The initiating facility must maintain following information on each variety for review and audit by the competent authority once in a year: variety identification, date of initiation, origin, details of tissue culture protocol, inspection reports at different stages, certificate from Breeder for genetic purity and freedom from diseases and insect pests, testing results from accreditated laboratory (Accreditated by the ICAR/Dept. of Biotechnology, notified as Certification Agency under the National Certification System for Tissue Culture Raised Plants).

iii) For *in vitro* shoot multiplication, 6-8 cycles of subculture may be done.

iv) Tests must be carried out on a minimum of ten plantlets or 0.1 per cent plantlets, selected at random from a batch, for each variety by an acreditated laboratory.

v) Molecular tests should be carried out for genetic fidelity and freedom from pathogens of red rot, smut, grassy shoot, sugarcane mosaic virus, sugarcane yellow leaf disease (SYLD). No plant should contain these pathogens.

vi) Valid disease indexing results are required prior to the initiation of tissue culture raised plant production cycle or planting of test tube plantlets in the greenhouse.

vii) Tissue culture raised plantlets should be hardened for 45 days in greenhouse and should attain the height of 12-15 cm with 4-5 opened leaves before subsequent planting. Such a planting material is referred to as TCRP.

viii) Molecular test for genetic fidelity, preferably by Inter Simple Sequence Repeat (ISSR) method may be carried out in a crop raised from TCRP.

ix) Seed cane of a crop raised from TCRP is referred to as Breeder Seed and should be tagged with golden yellow label as per provisions of the Seed Act.

x) Tagged Breeder Seed may be used for producing Foundation Seed and further for Certified Seed. Minimum seed cane standards prescribed by GOI should be followed for production of Foundation and Certified Seed.

II. Greenhouse/Controlled Environment Requirements

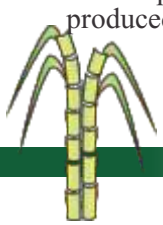
1. All micropropagation and greenhouse facilities must meet the standards given above under eligibility requirements.

2. The soil used for TCRP production may be subjected to formaldehyde fumigation at least a week before planting for minimizing chances of attack by soil-borne pathogens and insect pests.

III. Inspection of Greenhouse/ Breeder Seed Plot

1. The seed grower must notify the competent authority of his seed production plans well in advance of the planting.

2. The crop must be grown from certified basic *in vitro* plants i.e., TCRP which were produced in aseptic environment.



3. A minimum of three inspections shall be made as follows:

(i) The first inspection shall be made 30-45 days after transplanting in greenhouse in order to verify growing conditions, extent of designated diseases & insect pests and off-types.

(ii) The second inspection shall be made in field at 120-150 days after first transplanting to verify off-types, designated diseases, if any, and insect pests.

(iii) The third inspection shall be made in field 15 days prior to harvesting to verify the maturity of crop, off-types, designated diseases and insect pests and other related factors.

4. Effective sanitation practices including insect pests and diseases, monitoring and prevention must be adhered to.

5. The greenhouse must be free from all plant debris before planting.

6. No field-produced seed cane, or any other crop can be grown in the protected environment while used to produce Basic Stock.

7. Varieties must be separated by appropriate partitioning of greenhouse to prevent varietal mixture.

8. If testing performed by an accreditated laboratory reveals presence of designated pathogens, the total batch in the protected environment will be ineligible for certification and the entire material will be destroyed.

IV. Field Standards

A. Field Standards for direct planting of TCRP

a. General requirements

1. Isolation : Not applicable in greenhouse, but 5.0 m isolation should be maintained in field.

2. All micropropagation and greenhouse facilities must be notified/approved by the ICAR/Dept. of Biotechnology, notified as the Certification Agency under the National Certification System for Tissue Culture Raised Plants.

b. Specific requirements

Maximum permissible limits -

Parameter	Maximum permissible limit (%)		
	Stage I	Stage II	Stage III
1. Off- types	-	-	0.0
2. Diseases (on clump basis)			
(i) Red rot	0.0	0.0	0.0
(ii) Smut	0.01*	0.01*	0.0
(iii) Grassy shoot	-	0.02*	0.0
(iv) Leaf scald	-	0.01*	0.0
3. Insect pests (on clump basis)			
(i) Top borer	-	5.0	5.0
(ii) Internode borer*	-	-	10.0
(iii) Stalk borer	-	-	20.0
(iv) Plassey borer, Gurdaspur borer, scale insect, mealy bug	-	-	5.0
(v) Woolly aphid	-	-	0.0

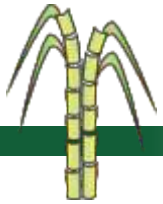
* Subject to immediate roguing of the whole clump.

c. Standards for TCRP

Factor standards for certified seed class

(i)	Height of plantlet	:	12-15 cm
(ii)	Number of leaves in a plantlet	:	4-5 opened leaves
(iii)	Varietal purity	:	100%
(iv)	Virus or smut infection	:	0.0%

B. Field standards for Foundation Crop and Certified Crop raised from Breeder Seed developed from TCRP shall be same as prescribed for conventional method notified by Govt. of India



Registration details of sugarcane varieties

The following 35 varieties of sugarcane have so far been registered with PPV&FRA, New Delhi:

S. No.	Certificate SI. No.	Registration No.	Denomination
1.	000496	162/2012	Dhanush (Co 91010)
2.	000497	163/2012	Kalyani (Co 87025)
3.	000498	164/2012	Nayana (Co 86032)
4.	000499	165/2012	Bhima (Co 8371)
5.	000500	166/2012	Moti (Co 87268)
6.	000501	167/2012	Bhavani (Co 86249)
7.	000502	168/2012	Uttara (Co 87044)
8.	000503	169/2012	Sarayu (Co 87263)
9.	000504	170/2012	Prabha (Co 85004)
10.	000505	171/2012	Gandak (Co 89029)
11.	000506	172/2012	Shyama (Co 94008)
12.	000690	144/2013	Co 94102
13.	000691	145/2013	Damodar (Co 99004)
14.	000701	155/2013	CoSe 95255 (Rachana)
15.	000702	156/2013	Sweta (CoS 94270)
16.	000703	157/2013	CoJ 89
17.	000704	158/2013	Rajbhog (CoSe 92423)
18.	000705	159/2013	Mithas (CoS 96268)
19.	000706	160/2013	Haryana 92 (CoH 92201)
20.	000708	162/2013	Co 2001-15
21.	000709	163/2013	Co 0232
22.	000710	164/2013	Karan-1 (Co 98014)
23.	000711	165/2013	Sulabh (Co 2001-13)
24.	000712	166/2013	CoH 119 (Haryana Ganna -119)
25.	000713	167/2013	Promod (BO 128)
26.	000714	168/2013	Rasbhari (CoSe 95422)
27.	000715	169/2013	CoPant 90233
28.	000716	170/2013	Raseeli (CoS 91230)
29.	000717	171/2013	Co 0218
30.	000718	172/2013	Karan 5 (Co 0124)
31.	000719	173/2013	Sweety (CoS 96275)
32.	000720	174/2013	CoSe 96434 (Jalpari)
33.	000729	183/2013	Birendra (CoLk 94184)
34.	000816	270/2013	CoC (Sc) 23 (CoC 01061)
35.	000841	295/2013	Co 0233

Quinquennial Review Teams

The progress of AICRP on Sugarcane was reviewed by the Quinquennial Review Teams (QRT) constituted by the Indian Council of Agricultural Research. The Constitution of teams during 1971-2015 period is given below :

1. Review period : 1971-1981

(i) Dr. N. Parthasarathy - Chairman
Ex-Director, Central Rice Research Institute, Cuttack

(ii) Prof. S.V. Arya - Member
Ex-Vice Chancellor, JNKVV, Jabalpur

(iii) Dr. Lallan Rai - Member
Ex-Professor of Entomology,
Banaras Hindu University, Varanasi

(iv) Dr. H.K. Saxena - Member
Ex-Professor & Head
C.S. Azad University of Agricultural &
Technology, Kanpur

(v) Dr. J.T. Rao - Member
Ex-Director,
Sugarcane Breeding Institute, Coimbatore

(vi) Dr. S.C. Srivastava - Member Secretary
Project Coordinator (Sugarcane)
IISR, Lucknow

2. Review period : 1982-1988

(i) Dr. D.G. Hapase - Chairman
Director, Deccan Sugar Institute, Pune

(ii) Shri P.S. Mathur - Member
Ex-Director, Sugarcane Development, G.O.I.,
New Delhi

(iii) Dr. S. Jayaraj - Member
Director, Institute of Plant Protection Studies,
TNAU, Coimbatore

(iv) Dr. H.N. Singh - Member
Senior Scientist, Dept. of Genetics & Plant Breeding
C.S. Azad University of Agriculture & Technology,
Kanpur

3. Review period : 1988-1992

(i) Dr. P.S. Mathur - Chairman
Ex-Director, Sugarcane Development, G.O.I.,
New Delhi

(ii) Dr. K.K. Prasada Rao - Member
Retd. Associate Director of Research
Advisor,
A.P. Cooperative Sugar Factories Federation,
Hyderabad

(iii) Dr. R.K. Grover - Member
Retd. Professor of Plant Pathology,
Himachal Pradesh Krishi Vidyalaya.
Palampur

(iv) Shri P.N. Avasthy - Member
Retd. Principal Scientist,
Division of Entomology,
Indian Institute of Sugarcane Research, Lucknow

(v) Dr. G.C. Tewari - Member Secretary
Senior Scientist (Entomology),
ICAR, Krishi Bhavan, New Delhi

4. Review period : 1993-1998

(i) Dr. Y.S. Nerkar - Chairman
Director Research,
Marathwada Agricultural University, Parbhani

(ii) Dr. C.N. Babu - Member
C 4-C/1118, Pocket 14,
Janakpuri, New Delhi
(Could not participate in QRT due to ill health)

(iii) Dr. S.B. Jadhav - Member
Director,
Vasantdada Sugar Institute, Pune

(iv) Dr. K.C. Alexander - Member
No. 23, Bhavaneshwari Nagar,
Velandi – Palayam, Coimbatore

(v) Dr. R.P. Singh - Facilitater
Principal Scientist,
Division of Plant Pathology,
Indian Institute of Sugarcane Research,
Lucknow

5. Review period : 1999-2004

(i) Dr. A.N. Mukhopadhyay - Chairman
Ex-Vice Chancellor,
(Assam Agricultural University),
Lucknow

(ii) Dr. V.S. Bhide - Member
Ex-Professor,
(Rajendra Agricultural University, Pusa),
Ghaziabad

(iii) Dr. M.N. Khare - Member
Ex-Professor & Dean,
Jawaharlal Nehru Krishi Vishwa Vidyalaya,
Jabalpur

(iv) Dr. P.K. Pathak - Member
Ex-Professor of Entomology,
G.B. Pant University of Agriculture & Technology,
Pantnagar

(v) Dr. G.C. Srivastava - Member
Principal Scientist & Head,
Division of Plant Physiology,
Indian Agricultural Research Institute, New Delhi

(vi) Dr. R.P. Kachru, - Member
Ex-Asstt. Director General (Process Engineering),
Indian Council of Agricultural Research,
Krish Bhavan, New Delhi

(vii) Dr. Menhi Lal, - Member Secretary
Principal Scientist,
Division of Crop Production,
Indian Institute of Sugarcane Research,
Lucknow

6. Review period : 2005-2009

(i) Dr. N.N. Singh - Chairman
Vice Chancellor,
Birsa Agricultural University,
Ranchi

(ii) Dr. M.N. Premachandran - Member
Head,
Division of Crop Improvement,
Sugarcane Breeding Institute, Coimbatore

(iii) Dr. O.P. Dubey - Member
Ex-Asstt. Director General (PP),
Indian Council of Agricultural Research,
B-9, Green View Apartments,
Sector-9, Rohini,
Delhi

(iv) Dr. Narayan Rishi - Member
Prof. of Plant Pathology (Retd.), HAU,
Director,
School of Life Science,
Jaipur National University,
Jaipur

(v) Dr. G.C. Srivastava - Member
Principal Scientist & Head,
Division of Plant Physiology,
Indian Agricultural Research Institute, New Delhi

(vi) Dr. P. Kumar, - Member
Professor of Agril. Economics (Retd.)
Indian Agricultural Research Institute,
Pusa, New Delhi

(vii) Dr. A.K. Shrivastava, - Member Secretary
Principal Scientist,
Division of Physiology & Biochemistry,
Indian Institute of Sugarcane Research,
Lucknow

7. Review period : 2010-2015

(i) Dr. J.B. Chowdhury - Chairman
Ex-Vice Chancellor,
G.B. Pant University Agricultural & Technology,
Pantnagar

(ii) Dr. N. Vijayan Nair - Member
Ex-Director,
Sugarcane Breeding Institute,
Coimbatore

(iii) Dr. D.C. Uprety - Member
Ex-National Fellow,
Indian Agricultural & Research Institute,
New Delhi

(iv) Dr. Menhi Lal, - Member
Principal Scientist & Head,
Division of Crop Production,
Indian Institute of Sugarcane Research,
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(v) Dr. Bachchan Singh - Member
Ex-Professor of Agril. Engineering,
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(vi)	Dr. Satyavir, Ex-Dean (Agriculture), CCS Haryana Agricultural University, Hisar	-	Member
(vii)	Dr. R.K. Samantha Ex-Director, MANAGE & NAARM, Hyderabad	-	Member
(viii)	Dr. P.K. Singh Principal Scientist, Division of Crop Improvement, Indian Institute of Sugarcane Research, Lucknow	-	Member Secretary

Workshops / Group Meetings of All India Coordinated Research Project on Sugarcane (1970 to 2015)

S.No.	Title	Venue	Coordinator's Name	Duration	No of participants
1.	1st Workshop on Sugarcane Research	Indian Institute of Sugarcane Research, Lucknow	Dr. Kishan Singh	January 15-19, 1970	75
2.	2nd Workshop on AICRP on Sugarcane	Indian Institute of Sugarcane Research, Lucknow	Dr. Kishan Singh	October 15-17, 1970	60
3.	3rd Workshop on AICRP on Sugarcane	MPKV, Pune	Dr. S.C. Srivastava	May 5-9, 1972	97
4.	4th Work shop on AICRP on Sugarcane	Indian Institute of Sugarcane Research, Lucknow	Dr. S.C. Srivastava	October 27-29,1975	122
5.	5th Workshop on AICRP on Sugarcane	Sugarcane Breeding Institute, Coimbatore	Dr. S.C. Srivastava	November 7-9,1976	170
6.	6th Workshop on AICRP on Sugarcane	Indian Institute of Sugarcane Research, Lucknow	Dr. S.C. Srivastava	November 29 to December 1, 1977	162
7.	7th Workshop on AICRP on Sugarcane	MPKV, Pune	Dr. S.C. Srivastava	October 16-19, 1978	214
8.	8th Workshop on AICRP on Sugarcane	Technical Training Institute, Dept. of Agriculture, M.P. Govt., Bhopal	Dr. S.C. Srivastava	September 25-27, 1979	-
9.	9th Workshop on AICRP on Sugarcane	Agriculture College and Research Institute, Madurai	Dr. S.C. Srivastava	August 12-14, 1981	176
10.	10th Workshop on AICRP on Sugarcane	MPKV, Pune	Dr. S.C. Srivastava	September 27-30,1982	-
11.	11th Workshop on AICRP on Sugarcane	UPCSR, Shahjahanpur	Dr. S.C. Srivastava	September 26-29, 1983	169
12.	12th Workshop on AICRP on Sugarcane	Gujarat Agricult ural University, Navsari	Dr. S.C. Srivastava	November 1-3, 1984	186
13.	13th Workshop on AICRP on Sugarcane	Andhra University, Waltair	Dr. S.C. Srivastava	October 8-11, 1985	154
14.	14th Workshop on AICRP on Sugarcane	Hissar Agricultural University, Hissar	Dr. S.C. Srivastava	November 9-12, 1986	-
15.	15th Workshop on AICRP on Sugarcane	Sugarcane Breeding Institute, Coimbatore	Dr. S.C. Srivastava	September 7-9, 1987	-
16.	16th Workshop on AICRP on Sugarcane	University of Agricultural Sciences, Bangalore	Dr. S.C. Srivastava	October 3-5, 1988	-
17.	17th Workshop on AICRP on Sugarcane	Vasantdada Sugar Institute, Pune	Dr. S.C. Srivastava	September 28-30, 1989	-
18.	18th Workshop on AICRP on Sugarcane	Indian Institute of Sugarcane Research, Lucknow	Dr. U.S. Shukla	October 23-24, 1990	-
19.	Group Meeting of AICRP on Sugarcane	G.S. Sugarcane Breeding & Research Institute, Seorahi	Dr. U.S. Shukla	October 25-26, 1991	-
20.	19th Biennial Workshop of AICRP on Sugarcane	Indian Institute of Sugarcane Research Institute, Lucknow	Dr. U.S. Shukla	October 15-17, 1992	-

Continued

S.No.	Title	Venue	Coordinator s Name	Duration	No of participants
21.	XXI Group Meeting of AICRP on Sugarcane	Indian Institute of Sugarcane Research Institute, Lucknow	Dr. U.S. Shukla	September 24-25, 1993	-
22.	20th Biennial Workshop of AICRP on Sugarcane	Gujarat Agricultural University, Navsari	Dr. U.S. Shukla	November 28-30, 1994	-
23.	Group Meeting of AICRP on Sugarcane	Indian Institute of Sugarcane Research Institute, Lucknow	Dr. S.R. Misra	November 8-9, 1995	-
24.	21st Workshop of AICRP on Sugarcane	Indian Institute of Sugarcane Research Institute, Lucknow	Dr. S.R. Misra	December 23-24, 1996	155
25.	Group Meeting of AICRP on Sugarcane & Sugarbeet Network Programme	Agricultural Research Station (RAU), Sriganganagar	Dr. S.R. Misra	October 17-18, 1997	-
26.	22nd Biennial Workshop of AICRP on Sugarcane & Sugarbeet Network Programme	Vasantdada Sugar Institute, Pune	Dr. S.R. Misra	September 13-15, 1998	141
27.	Group Meeting of AICRP on Sugarcane	CCSHAU Regional Research Station, Uchani (Karnal)	Dr. S.R. Misra	October 11-13, 1999	115
28.	23rd Biennial Workshop of AICRP on Sugarcane	Sugarcane Breeding Institute, Coimbatore	Dr. S.R. Misra	November 2-4, 2000	140
29.	Group Meeting of AICRP on Sugarcane	Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola	Dr. S.R. Misra	December 20-22, 2001	120
30.	24th Biennial Workshop of AICRP on Sugarcane	Indian Institute of Sugarcane Research Institute, Lucknow	Dr. S.R. Misra	October 29-31, 2002	150
31.	Group Meeting of AICRP on Sugarcane	Punjab Agricultural University, Ludhiana	Dr. O.K. Sinha	October 7-9, 2003	130
32.	25th Biennial Workshop of AICRP on Sugarcane	University of Agricultural Sciences, Dharwad	Dr. O.K. Sinha	October 27-29, 2004	150
33.	Group Meeting of AICRP on Sugarcane	U.P. Council of Sugarcane Research, Shahjahanpur	Dr. O.K. Sinha	October 27-29, 2005	130
34.	26th Biennial Workshop of AICRP on Sugarcane	G.B. Pant University of Agriculture & Technology, Pantnagar	Dr. O.K. Sinha	October 16-18, 2006	150
35.	Group Meeting & AICRP on Sugarcane	College of Agriculture (MPKV), Pune	Dr. O.K. Sinha	October, 9-11, 2007	140
36.	27th Biennial Workshop of AICRP on Sugarcane	Andhra University, Visakhapatnam	Dr. O.K. Sinha	October, 17-19, 2008	150

Continued

S.No.	Title	Venue	Coordinator's Name	Duration	No of participants
37.	Group Meeting of AICRP on Sugarcane	Rajendra Agricultural University, Pusa	Dr. O.K. Sinha	November 6-8, 2009	142
38.	28th Biennial Workshop of AICRP on Sugarcane	Navsari Agricultural University, Navsari	Dr. O.K. Sinha	October 27-29, 2010	146
39.	Group Meeting of AICRP on Sugarcane	Orissa University of Agricultural & Technology, Bhubaneswar	Dr. O.K. Sinha	October 17-19, 2011	145
40.	29th Biennial Workshop of AICRP on Sugarcane	Tamil Nadu Agricultural University, Coimbatore	Dr. O.K. Sinha	October 19-20, 2012	149
41.	Group Meeting of AICRP on Sugarcane	Andhra University, Visakhapatnam	Dr. O.K. Sinha	October 25-26, 2013	140
42.	30th Biennial Workshop of AICRP on Sugarcane	Indian Institute of Sugarcane Research, Lucknow	Dr. O.K. Sinha	November 1-2, 2014	143
43	Group Meeting of AICRP on Sugarcane	Rajendra Agricultural University, Pusa	Dr. O.K. Sinha	December 15-16, 2015	137

Publications

Bajpai, P.K. and Rajesh Kumar. (2001). New method of simultaneous selection for yield and stability. ***Indian J. Sugarcane Technol***. 16 (2) : 32-35.

Bajpai, P.K. and Rajesh Kumar. (2005). Comparison of methods for studying genotype x environment interaction in sugarcane, ***Sugar Tech*** 7 (4) : 129-135.

Bajpai, P.K. and Rajesh Kumar. (2006). Selection criteria for high yielding and stable sugarcane genotypes. ***Sugarcane International (UK)***, 24 (5) : 3-7.

Bajpai, P.K., V.T Prabhakaran and Rajesh Kumar (1998). **Simultaneous selection for high yielding and stable crop genotypes in sugarcane ratoon.** In, National Seminar on Sugarcane ratoon management held on August 8-10, IISR, Lucknow.

Bajpai, P.K., V.T. Prabhakaran, Rajesh Kumar and H.S. Sikarwar. (1998). Simultaneous selection for high yielding and stable crop genotypes. ***Indian J. Sugarcane Technol***. 13 (1) : 1-5.

Bajpai, P.K., J. Singh, S.S. Hasan and Rajesh Kumar. (2014). Minimum number of seedlings for evaluation of crosses in sugarcane. ***Indian J. Sugarcane Technol.*** 29(1) : 13-16.

Kumar, Rajesh and S. R. Misra. (1996). Stability performance of sugarcane agro-ecological zones in India. ***Indian J. Sugarcane Technol***. 11 (1) : 72-74.

Kumar, Rajesh and S.R. Misra. (2002). Sugar recovery zones of India - Delineation and critical analysis. ***Sugar Tech.*** 4 (1&2) : 38-44.

Kumar, Rajesh and O.K. Sinha (2015). Simultaneous selection of high yielding and stable mid-late maturing sugarcane genotypes of East Coast Zone in India using AMMI Model. ***Indian J. Sugarcane Technol.*** (Communicated).

Kumar, Rajesh, S.C. Srivastava and R.K. Rai. (1999). Sugar and allied industry in the post independence economic development of the country. *Financing Agri*. 31 (2) : 18-20.

Kumar, Rajesh, O.K. Sinha and A. Zubair. (2012). Regional variations in sugarcane production and productivity in India - A district level analysis. ***Indian J. of Sugarcane Technol***. 27(2) : 95-97.

Kumar, Rajesh, O.K. Sinha and A. Zubair (2012). **Regional variations in sugarcane production and productivity of India-A district level analysis.** Proc. International Symposium on New paradigms in sugarcane research, Sugarcane Breeding Institute, Coimbatore on October 15-18, 2012. pp. 107-108.

Kumar, Rajesh, S.S. Hasan and, P.K. Bajpai (2014). **GIS based mapping approach for sugarcane planning at district level in India.** Proc. International Conclave on Sugar Crops on 'Sweeteners and green energy from sugar crops : Emerging Technologies', Indian Institute of Sugarcane Research, Lucknow on February 15-17, 2014.

Kumar, Rajesh, P.K. Bajpai and A.D. Pathak. (2016). Comparison of modified joint regression analysis, fitcon analysis, em-ammi and proposed improved-imammi under incomplete genotype and environment interaction data of sugarcane. ***Int. J. Agri. Stat. Sci.,*** 12 (1) : 173-179.

Kumar, Rajesh, R.L. Yadav, Rajendra Gupta and D.V. Yadav (2008). Planning of sugarcane crop *vis-à-vis* soils and climate for sustainable sugar productivity in India. ***Sugarcane International (UK),*** 26 (6) : 15-23.

Pathak, A.D., Rajesh Kumar and R.K. Rai. (2001). Evaluation of inter-specific hybrids of sugarcane using cluster analysis. ***Sugar Cane International (U.K.),*** pp. 11-13.

Pathak, A.D., N. Kulshreshtha, Rajesh Kumar and V.K. Saxena. (2009). Genotype x Environment Interaction in sugarcane under late-planting conditions using AMMI. ***Indian J. Sugarcane Res***., 24 (1 & 2) : 1-6.

Misra, S.R. (2000). **Sugarcane research network in India.** In : 50 years of sugarcane research in India (Eds. H.N. Shahi, A.K. Srivastava and O.K. Sinha), IISR, Lucknow, pp. 15-26.

Misra, S.R. and S.K. Chaudhary. (2003). Promising varieties of sugarcane released through AICRP (S) system. ***Indian Sugar,*** April 2003 : 19-26.

Shukla, U.S. and O.K. Sinha (1993). S**ugarcane research and development network in sub tropical India.** In : Sugarcane research and development in sub-tropical India (Eds. G.B. Singh and O.K. Sinha), IISR, Lucknow, pp. 17-36.

Shukla, U.S. and Rajesh Kumar. (1996). Some new stable mid-late varieties for Peninsular Zone including Madhya Pradesh. ***Indian J. Sugarcane Technol***. 11 (2) : 116-119.

Singh, G.B. and Rajesh Kumar (1992). Sugarcane agro-ecological zones of ***India. Indian J. Sugarcane Technol***. 7 (2) : 71-77.

Sinha O.K. (2006). **Status of wilt-root borer complex in sugarcane.** National Seminar on 'Status of wilt-root borer complex in sugarcane ' held at SBI Regional Centre, Karnal on 25th January, 2006.

Sinha O.K. (2006). **Chronological progress on fixing standards for sugarcane seed material.** Brain Storming Session on 'Developing standards for tissue culture raised planting materials of sugarcane' held on June 6, 2006 at Vasantdada Sugar Institute, Pune, pp. 1-2.

Sinha O.K. (2007). **Three-tier seed cane production technology.** National Seminar on 'Sugarcane seed pro-duction and certification' held at the Vasantdada Sugar Institute, Pune from 22-23 February, 2007, pp.18-20.

Sinha, O.K. (2007). **Seed Cane Standards.** In: National Symposium on Seed Cane held on September 27-28, 2007, IISR, Lucknow, pp. 9-12.

Sinha O.K. (2007). **Current sugarcane scenario and research priorities.** Group Meeting of AICRP on Sugarcane held at the College of Agriculture (MPKV), Pune from October 9-11, 2007, pp. 3-4.

Sinha O.K. (2009). **Sugarcane improvement technologies recently developed under AICRP on Sugarcane.** Group Meeting on AICRP on Sugarcane held at the Rajendra Agricultural University, Pusa from November 6-8, 2009.

Sinha, O.K. (2014). **Sugarcane variety development for 2G ethanol production : A perspective.** National Symposium on 'Bioenergy for sustainable development – Potential role of sugar crops held at the Sugarcane Breeding Institute, Coimbatore on June 23-25, 2014.

Sinha, O.K. (2014). **Diagnosis of major diseases of sugarcane and their management** National Seminar on 'Integrated crop management in sugarcane for increasing cane, sugar and jaggery yields held at the Andhra University Campus, Visakhapatnam on December 5, 2014.

Sinha, O.K. (2015). **Sugarbeet : A potential energy crop in India.** Brain Storming Seminar on Harnessing energy feedstocks for sustainability of sugar industry in sub-tropical India held at the Indian Institute of Sugarcane Research, Lucknow on August 22, 2015.

Sinha, O.K. and Rajesh Kumar (2008). **Growth of sugarcane productivity in India and improvement strategies.** In, Souvenir, 27th Biennial Workshop of AICRP on Sugarcane held at Andhra University Campus, Visakhapatnam on October 17-19, 2008.

Sinha, O.K. and Rajesh Kumar (2011). **Sugarcane production constraints in East Coast Zone and technologies for improving cane productivity.** In, Souvenir, Group Meeting of AICRP on Sugarcane held at Orissa University of Agriculture & Technology, Bhubaneshwar on October 17-19, 2011.

Sinha, O.K. and Rajesh Kumar (2012). **Sugarcane production constraints in Andhra Pradesh and technologies for improving cane productivity.** In, Souvenir 25th meeting of Sugarcane research and development workers of Andhra Pradesh, Regional Agricultural Research Station, Anakapalle on July 20-21, 2012, pp. 11-15.

Sinha, O.K. and Rajesh Kumar (2013). **Spread index based analysis of sugarcane production and productivity for the crop improvement in Andhra Pradesh.** In, Souvenir, Group Meeting of AICRP on Sugarcane held at Andhra University Campus, Visakhapatnam and RARS, Anakapalle on October 25-26, 2013, pp. 13-15.

Sinha, O.K. and Rajesh Kumar (2015). **Improving sugarcane productivity and production in Bihar based on spread index analysis**. In, Souvenir, Group Meeting of AICRP on Sugarcane held at Rajendra Agricultural University, Pusa, Distt. Samastipur (Bihar) on December 15-16, 2015.

Sinha, O.K., Rajesh Kumar and Sangeeta Srivastava (2007). **Management of diseases in sugarcane seed crop.** In, National symposium on Seed Cane held on September 27-28, 2007, Indian Institute of Sugarcane Research, Lucknow.

Srivastava, H.M., Sangeeta Srivastava, Rajesh Kumar and G.P. Misra (1998). **Genetic divergence and genetic variability in interspecific hybrids (ISH) of *Saccharum* spp.** In, 4th ISSCT meeting, Breeding and Germplasm Workshop held in Mauritius on May 18-22, 1998.

Srivastava, N., H. M. Srivastava, Sangeeta Srivastava, Rajesh Kumar and G.P. Misra. (1999). Genetic divergence among interspecific hybrids of sugarcane. ***Sugar Tech*** 1(1&2) : 19-22.

Srivastava, S.C. (1971). Improving the efficiency of fertilizer nitrogen in sugarcane production under Indian Conditions. ***Indian Sugar*** 21(5) : 97-98.

Srivastava, S.C. (1971). Nitrogen fertilization in sugarcane. ***J. Farm Extn. Digest.*** March 3.

Srivastava, S.C. (1972). Programming for nitrogen fertilization for sugarcane. ***Cane Growers Bulletin*** 1 (1) : 9.

Srivastava, S.C. (1973). **Recent trends in fertilizers use in increased production in sugarcane.** In, Souvenir, Diamond Jubilee, 1913-73, S.R.S. Anakapalle.

Srivastava, S.C. (1974). The All India Coordinated Research Project on Sugarcane. ***Fertilizer News.***

Srivastava, S.C. (1975). Performance of legume as inter-crop in sugarcane. ***Indian Soc. Genetics Plant Breeding***, New Delhi.

Srivastava, S.C. (1975). A case study in varietal management for maximizing cane and sugar yield under long crushing season. ***Coop. Sugar.*** 6 (10) : 1-3.

Srivastava, S.C. (1985). **Thermo-insensitivity as a trait of wider adaptability in sugarcane –** Souvenir, "Sugarcane and its product', 13th Workshop of AICRP on Sugarcane held at Visakhapatnam on Oct. 8-11, 1985.

Srivastava, S.C. and D.K. Banerji. (1981). R & D Impact on sugarcane productivity. ***Indian Sugar Crops. J.*** 8(1).

Srivastava, S.C. and D.P. Johari. (1980). Measures to impart stability in sugarcane. ***Maharashtra Sugar***, Sept. 1980.

Srivastava, S.C., D.P. Johari and D.K. Banerji (1982). Revised sugarcane agro-climatic zones in India. ***Maharashtra Sugar*** 8(2).

Srivastava, S.C. and S.R. Seth. (1985). Research Achievements of All India Coordinated Project Improvement on Sugarcane. ***Fertilizer News*** 30(4).

Srivastava, S.C., P.K. Bajpai and Rajesh Kumar (1993). P**rofit maximization through increased cane crush versus recovery : A case study on relative strategy.** Proc. National Symposium on Improvement in sugarcane quality for increasing sugar production held on September 21-23, IISR, Lucknow.

Srivastava, S.C., N.S.L. Srivastava and D.K. Banerji. (1986). Warehousing for *Gur.* ***Coop. Sugar,*** 17 (10).

Books and Bulletins

All India Coordinated Research Project on Sugarcane. (1991). ***Sugarcane Production Technology***, IISR, Lucknow, 57 p.

All India Coordinated Research Project on Sugarcane. (2003). ***Three decades of research.*** IISR, Lucknow, 22 p.

Avasthy, P.N. and D.K. Banerjee (1982). ***Entomological studies*** 1971-80 under AICRP on Sugarcane. A Review, IISR, Lucknow.

Misra, S.R. and P.K. Singh (Eds.). 2003. ***Sugarcane nucleus and breeder seed production manual,*** IISR, Lucknow. p.19.

Misra, S.R., B.L. Gaul and Rajesh Kumar. (2001). ***AICRP on Sugarcane - At a Glance***. Coordination Unit, IISR, Lucknow.

Radadia, G.G. and C.U. Shinde. (2013). ***Research methodology for recording observations of sugarcane pests.*** AICRP on Sugarcane, 35 p.

Singh, G.B. and O.K. Sinha. (2009). ***Sugarcane and Sugarbeet***. In: Handbook of Agriculture. Indian Council of Agricultural Research, New Delhi, pp. 1195-1216.

Sinha, O.K. and R.B. Doule (Eds). (2006). ***Developing standards for tissue culture raised planting materials of sugarcane.*** Vasantdada Sugar Institute, Pune, p. 74.

Srivastava, S.C. and D.P. Johari. (1979). ***The Irrigated Sugarcane in India.*** IISR, Lucknow.

Srivastava, S.C., D.P. Johari and P.S. Gill (1988). ***Manual of Sugarcane Production in India.*** IISR, Lucknow.

Srivastava, S.C., S.R. Seth and U.S. Shukla. (1990). ***AICRP on Sugarcane : Research achievements in last two decades (1971-89).*** Bulletin No. 23, IISR, Lucknow, 12 p.

Srivastava, S.C., U.S. Shukla, D.P. Johari and S.B.L. Shukla. (1987). ***Optimal cropping zones for sugarcane in India.*** IISR, Lucknow.

Srivastava, S.C., U.S. Shukla, R.A. Yadav and D.K. Banerji (Eds). (1990). ***Standards for sugarcane seed material.*** Bulletion No. 25, Indian Institute of Sugarcane Research, Lucknow, 14 p.

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