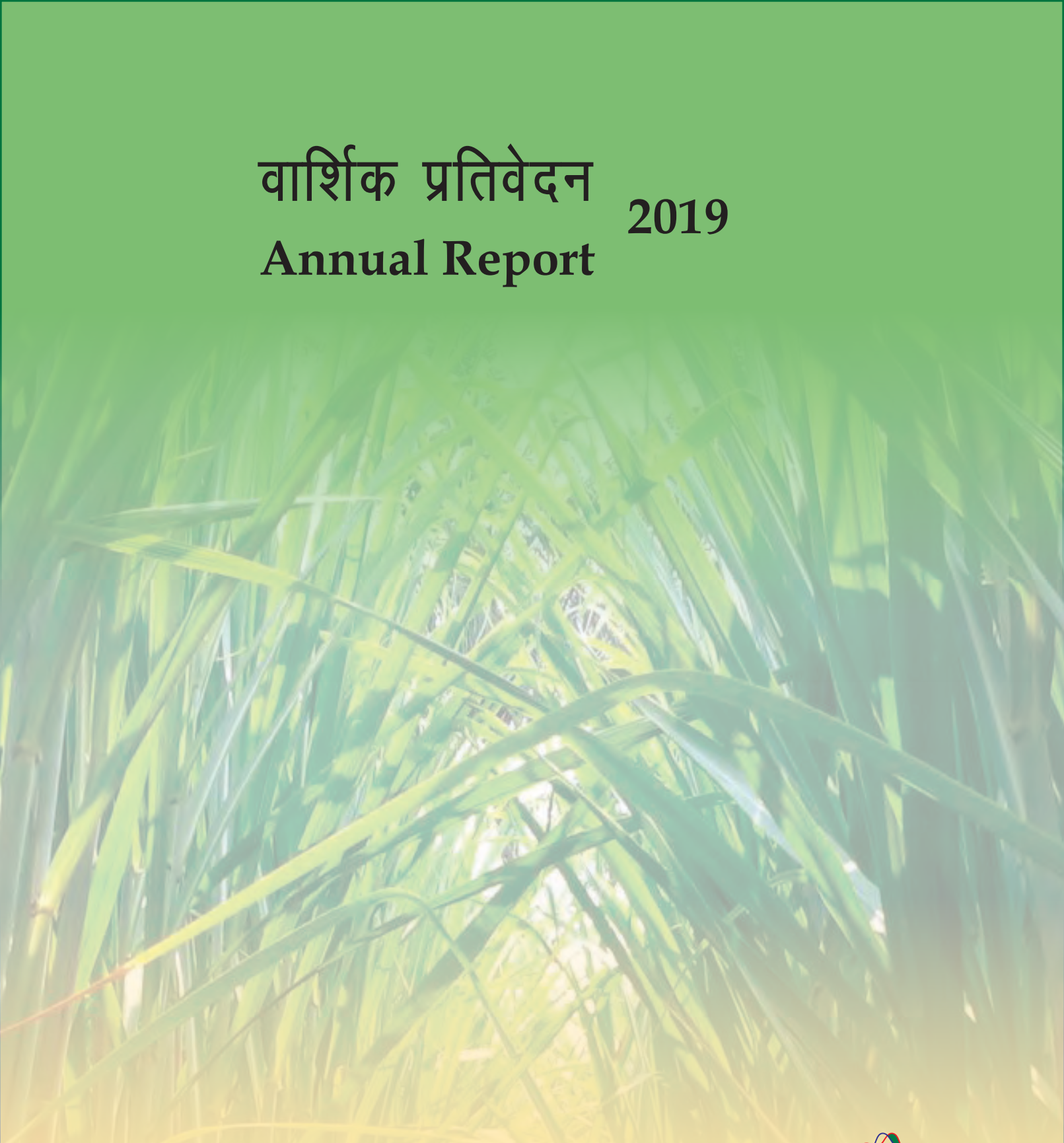
वार्षिक प्रतिवेदन 2019
Annual Report



भा.कृ.अनु.प. - गन्ना प्रजनन संस्थान
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ICAR - Sugarcane Breeding Institute
(ISO 2001:2008 Institution)

Coimbatore - 641 007

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Contents

Preface

Sugarcane varieties play a major role (~70% contribution) in sugarcane production, productivity and sugar recovery. The extra ordinary contribution of Co 0238 continues in subtropical India with increase in area from 2.30 million ha during 2018-19 to 2.59 million hectare (79.2%) during 2019-20. As a result the sugar production in India during 2019-20 season is expected to be more than the consumption inspite of severe drought like situation in Maharashtra and other southern states. During the season, Co-varieties evolved by the Institute alone covered about 3.75 million hectare area (60% in tropical region and 85.4% in sub-tropical region) which is 77% of the total area under sugarcane in the country. There has been more than two-fold increase in sugarcane area under Co varieties since 2014-15, i.e. from 32.96% to 77% during 2019-20 season. Co 0238 and Co 86032 continued to be the predominant varieties with about 79.2% and 47.3% area coverage in sub-tropical and tropical regions, respectively.

The main factor responsible for this trend is adoption of Co 0238, which occupied 2.59 million hectare or 79.2% of the sugarcane area in subtropical states. The variety was recommended in Uttar Pradesh during 2012 and since then it has increased to over 2.20 million hectares (82.2%) area during 2019-20. For the first time in the history of sugarcane cultivation, single variety (Co 0238) has spread to the extent of 53.2% area in the country.

The foremost objective of the Institute is to develop improved sugarcane varieties for different agro-climatic regions of the country. In a further step to meet the varietal requirements of the country, the Institute has released Co 11015, a short duration maturing, in Tamil Nadu and Puduchery for commercial cultivation. Co 13035 (Karan 14), a midlate maturing clone from Institute's Regional Centre at Karnal, in North West Zone and Co 12009, a midlate maturing variety for Peninsular Zone have been identified for release in respective zones.

Based on the superior performance among PZVT entries, 19 'Co' canes, including 14 from Coimbatore and 5 from Karnal Centre, were identified for further evaluation under AICRP(S).

In an effort towards identification of location specific sugarcane varieties, the Institute has signed MoU with SISMA-Tamil Nadu, Commissioner of Sugar, TN and 19 other individual sugar mills in Maharashtra, Karnataka, Uttar Pradesh, Bihar and Haryana. Co 11015 has been released and notified for commercial cultivation in the state of TN and Puducherry within 3 years of initiation of varietal evaluation trials under SISMA's 'Sweet Bloom' project. Second set of trials with 17 elite clones in 8 private sugar mills and 21 clones in 6 Co-operative factories is in field to identify location specific varieties.

In National Hybridization Garden, 617 parental clones with diverse genetic background were maintained and 23 fluff receiving centres were facilitated. Being a good year for flowering (91.9%), the participating centres utilized 146 female and 104 male parents. to make 539 bi-parental, 14 poly crosses and 154

general collections. In an effort to improve the quality of crosses made by participating centres, the Parental Diversity Index and Parental Utilization Index of crosses made by the 23 centers were computed. Pune and Perumalappalle centres with the maximum values were the best for Parental Diversity Index and Parental Utilization Index.

Breeder seed production of varieties Co 86032, Co 0212, Co 09004 and Co 11015 was taken up with tissue culture plantlets and 37.495 tons of nucleus seed were distributed to trained progressive farmers in Coimbatore district for quality/breeder seed production in about 30 acres. About 1200 tons of quality seed has been supplied to both cooperative and private sugar factories of Tamil Nadu. A total of 48,910 tissue culture plantlets of the varieties *viz*., Co 0212, Co 09004, Co 0238, Co 86032, CoV 09356 and Co 11015 were supplied to sugar factories and progressive farmers. At Karnal, a total of 108.45 tons of breeder seed from centre and 109.82 tons from seed famers, attached with centers' Farmers Participatory Seed Production (FPSP) programme, during autumn season were sold to the various stakeholders of the subtropical region. For the promotion of quality seed production activities in the region the setttling transplanting technique and mechanization of sugarcane agriculture were demonstrated to the farmers and sugar mill personals of the region. Trainings on Settling Transplanting Techniques were organized for 4 sugar mills in UP and Haryana at the centre.

For the first time, good progress has been made in anther culture. The right callusing medium and the appropriate age of the arrows were standardized and upto 20% callus induction was realized in sugarcane variety Co 86032. Characterization of 28 green plantlets for ploidy level through cytology, physiological parameters, marker allelic distribution and flow cytometry is in progress. In the process of identifying CENH3 mutants to enable *en bloc* elimination of chromosomes, TILLING was carried out on EMS treated calli of Co 775. Five putative samples (E2, E5, E6, E10, and E11) were subjected for sequencing analyses to identify single nucleotide modification.

Sugarcane germplasm is maintained at Coimbatore (3,922 accessions), Kannur (3,373 accessions) and Agali (1,271 accessions) stations of the Institute and Wellington Centre of ICAR-IARI (111 accessions). An exploration was conducted in the Western Ghats covering the states of Kerala, Tamil Nadu, Karnataka, Goa and Maharashtra and 39 *S. spontaneum*, 11 *E. arundinaceous,* three *E. bengalense* and two *S. officinarum* were added to germplasm collection.

Development and evaluation of pre-breeding material are carried out with different objectives. For development of novel drought tolerant genetic stocks, 42 crosses using the drought tolerant ISH and IGH and 13 basic crosses utilizing *S. officinarum, S. robustum, S. barberi and S. sinense* were made. At Agali, 161 biparental crosses involving commercial canes, *Saccharum* species and related genera were made in the National Wide Hybridization Facility. Forty elite clones with diverse genetic base were evaluated for cane and juice quality traits and the wide hybrid, GU15-1586 was remarkable with sucrose of 21.10%. Development of multi-parent advanced generation inter-cross population have reached up to the stage of screening of four-way cross populations and seven drought tolerant and 15 red rot resistant hybrids were identified.

Genetic control and genomic selection for important traits in sugarcane, and comparison of elite Indian and Australian germplasm under Indo-Australia fund progressed with phenotyping of progeny from the populations of Co canes, Co 86002 x BO 91, CoM 0265 x Co 775) for red rot, cane yield and juice quality traits and the populations from BO 91 x Co 775 for drought tolerance in ratoon trial. SNP based genotyping of randomly selected samples were categorized into AA, AB and BB variance.

The significant differences in light interception was observed among different spacing i.e. the clones planted in narrow spacing recorded more light interception than other two spacing, while the 150cm showed less

light interception. The global solar radiation during the month of May month was significantly more than the required radiation for photosynthesis and *vice versa* was recorded in December.

Soil carbon dioxide flux for 31 sugarcane genotypes was measured in the field. At 300 DAP the flux ranged from 3.02 to 12.94 µM/m^2/s. The CO_2 flux in Co 0314 (12.94 µM/m^2/s) was the highest followed by Co 92005 (12.13 µM/m^2/s) and the lowest was recorded in Co 7219 (3.02 µM/m^2/s). The correlation among soil pH, EC, NMC, soil organic carbon (SOC) and CO_2 flux showed negative correlation of CO_2 flux with SOC and positive correlation with NMC although not significant.

About 2805 clones from Coimbatore, Kannur and Agali were screened for red rot resistance under controlled conditions at the headquarters against CF06 (Cf671) pathotype and ~1504 clones were identified as resistant to red rot.

The chitosan (CS) coated benzothiadiazole (BTH) and salicylic acid (SA) nanoparticles (NPs) indicated that the formulated SAR inducer NPs especially, CS- BTH NPs combined with Psi and CS- SA NPs combined with PVP are efficient in inducing the resistance in the host against red rot pathogen.

Molecular characterization of phytoplasma associated with sugarcane confirmed association of SCGS phytoplasma in most of the test samples yielding an expected specific amplification in 1.2kb in size.

Nanoparticle enabled lateral flow immunoassay (LFA) kit was developed and standardized for on-site detection for viruses *Sugarcane mosaic virus* (SCMV) and *Sugarcane streak mosaic virus* (SCSMV) causing mosaic disease in sugarcane.

As part of the Virus indexing service, about 2427 tissue culture raised plants from different tissue culture production units viz., M/s EID Parry, Pugalur, M/s RSCL, Theni and ICAR-SBI tissue culture lab were indexed for SCYLV, SCMV, SCSMV and grassy shoot phytoplasmas by following SOPs. A revenue of Rs 6,12,800/- was generated under virus indexing charges from the private tissue culture labs.

Out of 20 red-fleshed *Saccharum robustum* clones screened under field conditions for resistance against internode borer (INB), the genotypes GUK14-836 and GUK14-129 were found to be least susceptible; while GUK14-48, GUK 14-675 and GUK 14-829 were moderately susceptible, the remaining 15 genotypes were highly susceptible.

Erianthus arundinaceus genotypes viz. IK 76 78, IJ 76 400, IK 76 84, IK 76 88, IJ 76 370, ERI 2798, Fiji 55 and IJ 76 364 identified as resistant to SB in field screening were subjected to laboratory screening. The lowest larval and pupal survival was recorded in the genotypes IJ 76 370, IK 76 78 and IJ 76 364 and the highest in the genotype IJ 76 400 and the control Co 86032.

It is my pleasure to present the Annual Report of the ICAR-Sugarcane Breeding Institute, summarizing the salient achievements of the institute during the year 2019. I thank all the scientists and other staff of the institute who helped in the successful conduct of research and members of the editorial board for their tremendous efforts in bringing out the Annual Report. Continuous encouragement and guidance received from Dr. T. Mohapatra, Secretary, DARE and DG, ICAR, Dr. A.K. Singh, DDG (CS) and Dr. R.K. Singh, ADG (CC), ICAR are gratefully acknowledged.

Bakshi Ram
Director

2. THE ORGANIZATION

Background

ICAR- Sugarcane Breeding Institute (SBI), Coimbatore has been conducting research on various aspects of sugarcane agriculture and varietal improvement since its inception in 1912. The Institute has developed over 3260 'Co' selections, many of them becoming popular as commercial varieties in different parts of the country. Co canes bred at SBI along with the varieties identified from the crosses made at the institute by the State Sugarcane Research Stations occupy nearly 95% of the cane area in the country. Thus, the sugarcane varieties cultivated in the country today are directly or indirectly derived from this institute. Co canes were successful as commercial varieties in over 30 countries at one time and are being extensively used as parents in breeding programmes even today. The Institute maintains one of the largest collections of sugarcane genetic resources in the world.

Location

The Institute is located 8 km from the Coimbatore railway station and 19 km from the Coimbatore airport. Geographically it is located at 77° E longitude and 11° N latitude at an altitude of 427 m above mean sea level.

Centres

The Institute has one Regional Centre at Karnal (Haryana) and two Research Centres at Kannur and Agali (Kerala).

Mandate

- To breed superior sugarcane varieties / genotypes having high sugar productivity as well as sustainability and to assist State sugarcane breeding programmes.
- To collect, maintain, evaluate, document and conserve sugarcane genetic resources.
- To conduct basic and strategic research on crop improvement, production and protection aspects of sugarcane cultivation.
- To effect technology transfer, consultancy and human resource development in the areas of sugarcane agricultural research.

Staff position

Table 1. Staff position as on 31.12.2019

Category	Sanctioned	Filled	Vacant
Director	1	1	-
Scientific	78	73	5
Technical	73	53	20
Administrative	40	25	15
Supporting	56	51	05
Total	271	203	45

Financial Statement

Table 2. Abstract of expenditure during April – December 2019

Head	Amount in Lakhs (Rs.)
Government Grant	3612.53
Plan Schemes	10.12
Externally funded schemes	193.03
Total	3815.68

Organizational set up

The research activities of the Institute are being carried out in three divisions and two sections at the main Institute and its Regional / Research Centres under the administrative control of the Director.

The Prioritization, Monitoring and Evaluation Unit (PME) supports the research management functions like prioritization, coordination, planning and review of research programs to ensure that the system functions with the requisite accountability in terms of efficiency and optimal utilization of resources. An administrative wing comprising Establishment, Audit and Accounts, Cash and Bills, and Stores effectively provides the required administrative support. The Estate section, besides maintenance of buildings, takes care of the vehicle management and security arrangements (Fig. 1).

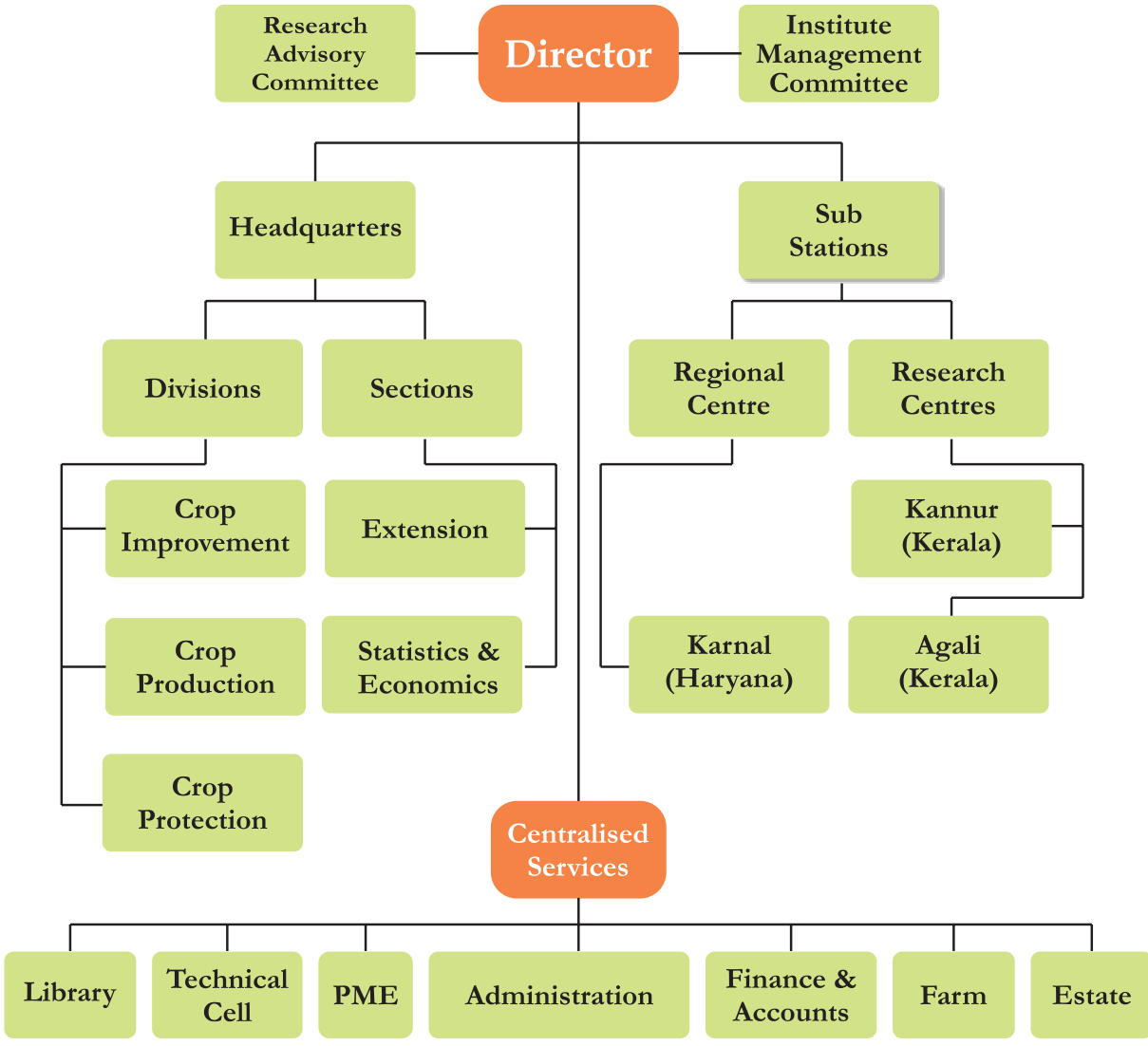


Fig. 1. Organizational structure of SBI

Farm

The main Institute has a total area of 89.09 ha including farm, laboratory and office buildings. The farm area is 54.98 ha and is situated in four campuses *viz.*, Main (7.28 ha), ECC (28.50 ha), Additional land (17.20 ha) and VPT (2.00 ha). ICAR-SBI Regional Centre, Karnal has 22 ha, ICAR-SBI Research Centre, Kannur has 8.33 ha and ICAR-SBI Research Centre, Agali has 12 ha.

Library and documentation services

The library provides information support to the Research and Development activities of the Institute. It has a collection of 12,723 books including bound volumes of journals. Library incurred an expenditure of Rs.6,396/- towards purchase the purchase of a book.

Continued to provide IP based online access to e-journals and e-books through CeRA. Library has facilities viz. Internet terminals, scanning and photocopying for the users. Library has got ISBN and ISSN assigning facility for the publications of the Institute.

Library has digital access to its holdings, and the OPAC using KOHA is progressing.

The priced publications of the Institute (92 nos.) were sold for an amount of Rs.18,195.

Weather data

Table 3. Weather data for April 2019 to December 2019

Month	Temperature °C		RH (%)		Wind velocity (km per hour)	Open pan evaporation (mm/day)	Rainfall (mm)	No. of rainy days
	Maximum	Minimum	Fore noon	After noon				
April 2019	35.89	23.36	83.51	39.33	1.47	6.19	24.10	3.00
May	32.26	24.29	84.35	49.32	1.79	5.37	85.80	6.00
June	29.38	23.53	81.00	53.93	4.39	5.58	23.40	4.00
July	31.89	23.10	82.52	56.23	4.34	5.05	15.80	3.00
August	30.05	22.48	86.84	66.45	3.27	4.10	277.30	9.00
September	30.10	22.60	87.93	65.93	2.83	3.45	63.00	7.00
October	31.48	22.27	88.23	63.39	1.16	3.18	261.80	13.00
November	30.17	21.73	89.57	61.73	1.11	2.89	50.40	1.00
December	28.08	20.94	87.97	64.87	1.13	2.52	30.80	3.00
Mean/ Total	31.03	22.70	85.77	57.91	2.39	4.26	832.40	49.00

4. कार्यकारी सारांश

फसल सुधार

को. 11015, एक अल्प अवधि प्रजाति को तमिलनाडू राज्य द्वारा अधिसूचित किया गया। इस प्रजाति ने 360 दिनों पर औसतन 142.72 टन/हे. गन्ना उत्पादन, 20.22% रस में शर्करा और 20.16 टन/हे. चीनी उत्पादन आंकड़े दर्ज किये जो मानक प्रजाति को. 86032 से क्रमशः 10.23%, 9.66% और 20.13% अधिक थे। इस प्रजाति में जल्द शर्करा संग्रहण और तीव्र वृद्धि वाली विशेषतायें होने के कारण इसे आठवें महीने से ही काटा जा सकता है अतः इसकी खेती से राज्य में गन्ना उत्पादक्ता और चीनी परता में सुधार की सम्भावना है।

प्रायद्वीपीय क्षेत्र में लोकार्पण के लिये एक मध्यम देरी से पकने वाले कृन्तक को. 12009 को अखिल भारतीय समन्वित अनुसंधान परियोजना (गन्ना) द्वारा पहचाना गया है। इस कृन्तक ने 360 दिनों पर क्षेत्र भर में औसतन 17.31 टन/हे. चीनी उत्पादन दर्ज किया, जो सर्वोत्तम मध्यम देरी वाले मानक को. 86032 से 10.76% बेहतर था। इस प्रजाति की पौधा और पेड़ी की फसलों द्वारा बेहतर गन्ना व चीनी उत्पादन के साथ साथ तीव्र वृद्धि, शुरुआती बल और लाल सड़न रोग प्रतिरोधिता के गुण होने के कारण अधिसूचना के साथ ही इसे उच्च स्तर पर अपनाये जाने की सम्भावना है। इस प्रजाति को एस. स्पॉन्टेनियम (एस.इ.एस. 91) की भागीदारी से उत्पादित किये जाने के कारण एक नया अनुवांशिक आधार हमारे पास उपलब्ध हो गया है।

पुष्पण मौसम 2019 पुष्पण के लिये अत्युत्तम साबित हुआ जिसके दौरान एरोइंग प्लॉट में 85% में पुष्पण देखा गया। इस अवसर का प्रयोग करते हुए प्रमुख गुणों के लिये उच्च प्रजनन क्षमता वाले पैतृकों के साथ साथ नये संसाधनों के उपयोग से 402 क्रॉसेस बनाये गये। करीब 30,000 बीज जनित पौधों को 113 क्रॉसेस से भूतल नर्सरी में उगाया गया और 22,869 सन्ततियां, जो पूर्वक्षेत्रीय प्रजाति परीक्षण तक चयन के लिये विभिन्न स्तरों पर थी, को उत्पादित कर उन्हें गन्ना उत्पादन और रस की गुणवत्ता मापकों के लिये जाँच कर, चयन किये गये। को. प्रजातियों की पहचान के लिये 65 परीक्षण प्रविष्टियों का मूल्यांकन किया गया जिनमें से 5 प्रविष्टियों ने 300 दिनों पर बेहतर शर्करा : दर्ज की जबकि 48 को लाल सड़न रोग प्रतिरोधी पाया गया। श्रंखला 2019 से को. गन्नों का वानस्पतिक विज्ञानिक वर्णन और भा.कृ.अनु.प. – गन्ना प्रजनन संस्थान और अखिल भारतीय समन्वित अनुसंधान परियोजना (अ.भा.स.अनु.प.) के 3 केन्द्रों द्वारा लोकार्पण के लिये पहचानी गई प्रजातियों के डी.एन.ए. का प्रोफाइलिंग किया गया।

सूखे पर परीक्षणों के अन्तरगत आशावान को. गन्नों के साथ महाराष्ट्र में चार स्थानों और बेलगवी कर्नाटक में कार्य प्रगति पर है। महाराष्ट्र में 18 प्रविष्टियों का पौधा और पेड़ी फसलों से सूखे के हालात में मूल्यांकन के आधार पर को. 85019, को. 06022 और को. 98017 को कटाई के समय बेहतर गन्ना उत्पादन और रस में शर्करा की दृष्टि से उच्च प्रदर्शन करने वाला पाया गया।

स्थानीय विशिष्ट प्रजातियों की पहचान के लिये कोहलापुर (महाराष्ट्र), वुयुरू (आन्ध्र प्रदेश) और तमिलनाडु में (अनुकूली अनुसंधान परीक्षण के अन्तरगत) परीक्षण भी प्रगति पर हैं। भा.कृ.अनु.प.– भारतीय चरागाह एवं चारा अनुसंधान संस्थान, झांसी के साथ मिलकर एक नई परियोजना की शुरुआत पोषण संबंधी मूल्यांकन, नये चारा संसाधनों में सुधार एवं उनका पशुधन उत्पादन में उपयोग की दृष्टि से की गई है। इसके लिये भा.कृ.अनु.प.– भारतीय चरागाह एवं चारा अनुसंधान संस्थान, झांसी को पोषण संबंधी मूल्यांकन के लिये रोपण समग्री का प्रथम समूह भेजा गया है।

अ.भा.स.अनु.प. (गन्ना) के अन्तरगत एक शुरुआती प्रजाति परीक्षण (शु.प्र.प.) और तीन उन्नत प्रजाति परीक्षणों को संचालित किया जा रहा है। इनमें को. 11015 और को. 16006 को शु.प्र.प. के अन्तरगत, को. 14032 को पौधा फसल के आधार पर उ.प्र.प. (उन्नत प्रजाति परीक्षण) के अन्तरगत, को. 13002, को. 13018, को. 13004, को. 13013 और को.संके. 13103 को द्वितीय पौधा फसल के आधार पर उ.प्र.प. के अन्तरगत और को. 13004, को. 13002 तथा को. 13020 की पेड़ी फसल के आधार पर उ.प्र.प. के अन्तरगत शुरुआती उच्च शर्करा के लिये इन प्रजातियों को सर्वोत्तम पाया गया। प्रजाति परीक्षण के अलावा वातावरण लचीले अन्तरजेन्रिक और अन्तरजातीय संकरों की प्रविष्टियों के बहुगुणन और आपूर्ति का कार्य अच्छी प्रकार से प्रगति पर है। संस्थान–उद्योग भागीदारी पद्धति के अन्तरगत 20 प्रविष्टियों के प्रथम समूह का परीक्षण मिलों के ठिकानों पर पूरा कर लिया गया। कुल मिलाकर को. 13014, को. 11015, को. 13018, को. 14016 और को. 06031 ने राज्य की प्रजाति को. 86032 से कटाई के समय बेहतर गन्ना उत्पादन और चीनी उत्पादन दर्शाया। इनमें से को. 11015 को पूरे तमिलनाडु भर में साफतौर पर बेहतर प्रदर्शन के आधार लोकार्पित कर दिया गया है। दूसरे समूह के 17 कृन्तकों को 8 प्राइवेट मिलों के ठिकानों पर और 6 सहकारी चीनी मिलों के ठिकानों पर 21 कृन्तकों को तमिलनाडु में मूल्यांकित किया जा रहा है।

राष्ट्रीय संकरण उद्यान में 617 पैतृक कृन्तकों में 91.09% स्तर का उच्च पुष्पण देखा गया। भागीदार केन्द्रों में से 23 ने क्रॉसिंग कार्यक्रम – 2019 के दौरान 146 मादा और 104 नर

पैतृकों का क्रॉसेस बनाने में उपयोग किया। पैतृकों में से सबसे अधिक को. 775 और को.पन्त 97222 को नर पैतृकों के रूप में जबकि को. 96032 तथा को. 0238 का दोनों पैतृकों के रूप में उपयोग किया गया। विभिन्न 23 केन्द्रों द्वारा बनाये गये क्रॉसेस के पैतृक विभिन्नता सूचकांकों और पैतृक उपयोगिता सूचकांकों से पता चला की पूना और पेरुमलाप्पल्ले ने क्रमशः इनके सार्वधिक मूल्य दर्शाये।

राष्ट्रीय क्रियाशील जर्मप्लास्म में 240 अधिसूचित व पंजीकृत अनुवांशिक स्टॉक्स को अनुरक्षित कर तीन कृन्तकों, नामशः को. 12009, को. 13034 और को. 13035 को सूचकांक नम्बर दिये गये। अगली में कुल 1,380 जर्मप्लास्म अभिप्राप्तियों, जिनमें को. गन्नों, को. सम्बंधित कृन्तकों, विदेशी कृन्तकों, अन्तर जातीय और अन्तर जैन्रिक संकर कृन्तकों, सैकेरम ऑफिश्नेरम के मूलभूत संग्रहण, एस. बारबेरी, एस. साइनेंस और एस. रोबस्टम के जातियों के कृन्तकों, इरिएन्थस जतियों, स्कलेरोस्टाइका और नारेंगा को खेत में, रोग मुक्त हालातों में अनुरक्षित किया जा रहा है। डस (कोयम्बत्तूर और अगली) कार्यक्रम के अन्तरगत 233 उष्णकटिबंधीय गन्ना संदर्भ प्रजातियों को अनुरक्षित किया गया। किसानों की प्रजातियों अंगऊगबाए देसी 1 और देसी 2 के आकारिकीय लक्षणों का मुकाबला 11 एस. ऑफिश्नेरम कृन्तकों के साथ किया गया। संदर्भ प्रजाति 51एन.जी.105 को देसी 2 के काफी समीप पाया गया। देसी 1 को किसी भी अध्ययन की गई संदर्भ प्रजातियों से मिलते नहीं पाया गया। डस परीक्षण के लिये दो किसान की प्रजातियों, नामशः सुगम कटारी और जीत कटारी, को प्राप्त किया गया है।

समरूपी पैतृक लाइनों को विभिन्न पद्धतियों द्वारा विकसित कर वास्तविक बीज उत्पादन तकनीक के मानकीकरण का कार्य प्रगति पर है। इन्ब्रैड्स का गन्ना उत्पादन, रस की गुणवत्ता, पुष्पण, बीजस्थापन, लाल सड़न रोग प्रतिक्रिया और आणविक समरूपता के लिये लक्षण वर्णन का कार्य जारी है। परिणामों के आधार पर 20 चुने गये इन्ब्रैड्स को अन्तरक्रॉस कर 13 क्रॉसेस को संतति मूल्यांकन के लिये बनाया गया है। सैल्फों का प्रयोग कर बनाये गये क्रॉसेस से उत्पादित संततियों का मूल्यांकन करने पर दो छटी पीढ़ी के इन्ब्रैड्स (1148–237–एस. 6–2–61 x 1148–एस.5–242–3–277) से बनाये गये जिस क्रॉस में निमन्न स्तर की जीवन शक्ति देखी गई। परागण संवर्धन के कार्य में पहली बार भारी प्रगति देखी गई। घट्टे बनाने के लिये 20 विभिन्न माध्यमों से उपयुक्त माध्यम को और ऐरों की उचित आयु को मानकीकृत किया गया और इससे गन्ना प्रजाति को. 86032 में 20% तक घट्टे बनने प्रारम्भ होते पाये गये। अठाइस हरे नन्हें पौधों का कोशिकाविज्ञान द्वारा सूत्रगुणता के स्तर, कार्यकि मापकों, मारकर विकल्पों के विभाजन और फलो सायटोमीटरी द्वारा लक्षण वर्णन का कार्य प्रगति पर है। गुणसूत्रों के पूर्ण–रूपेण विलोपन की प्रक्रिया के लिये सक्षम बनाने के लिये सी.इ.एन.एच.3 उत्परिवर्तीयों की पहचान करने की दृष्टि से को. 775 के इ.एम.एस. द्वारा उपचारित घट्टों पर टी.आइ.एल.एल.आइ.एन.जी. का प्रयोग किया गया। पांच तथाकथित नमूनों (इ.2, इ.5, इ.6, इ.10 और इ.11) का अनुक्रम विश्लेषण किया गया ताकि एकल न्यूकलिओटाइड परिवर्तन को पहचाना जा सके। उपयोग के लिये 3 उत्परिवर्तीयों को खेत में रोपित किया गया। इस अभ्यास को 2 इरिएन्थस कृन्तकों (इ.ए सरकन्दर और एस.इ.एस. 153) पर भी किया जा रहा है। वृहत संकरण के अन्तरगत अक्तूबर से दिसम्बर 2019 के बीच 69 अन्तर–जैन्रिक क्रॉसेस गन्ना और मीठी मक्का, मीठी जवार, बाजरा तथा चारे के लिये प्रयोग होने वाली जवार (सोरघम हेलेपेंस) के बीच अगुणित सूत्री उत्पादित करने के लिये बनाये गये। संदिग्द्ध 73 अन्तरजैन्रिक संकरों (बाजरा, मीठी मक्का, मीठी जवार, नारेंजा और इरिएन्थस x गन्ना के बीच) की गुणसूत्र संख्या की जाँच की गई, मगर अब तक अगुणित सूत्री पौधे नहीं पाये गये हैं। असंगजनन नियंत्रक जीनों को जवार व मक्का से लेकर दिग्दर्शक के रूप में प्रयोग कर, गन्ने के प्रकाशित पच्चीकारी एकलसूत्री जिनोम डाटा से अनुक्रमों का पता लगाया गया जिसके आधार पर मारकरों को डिज़ाइन किया गया। इससे केवल कुछ ही जीनों को पहचान कर कलोन किया गया और इनका जीन सम्पादन के लिये इनका अध्ययन जारी है, जो एक बार गन्ने से पूरी लम्बाई में जीन के अनुक्रमों को प्राप्त करने के बाद सहायक होगा। गन्ने के वास्तविक बीजों पर कवकनाशियों के पादप विशाक्त प्रभाव का अध्ययन करने पर अंकुरण पर कोई बुरा प्रभाव नहीं देखा गया। ताकत 0.1% से उपचारित किये गये रोयें रहित बीजों का भंडारण के 90 दिन बाद उनमें कन्ट्रोल के मुकाबले बेहतर अंकुरण देखा गया। लाल मृदा के पाउडर से फल्फ से रोयें हटाने के कार्य को प्रभावी पाया गया।

गन्ने के जर्मप्लास्म को अनुरक्षित कर मूल्यांकित किया जा रहा है तथा नई अभिप्राप्तियों को सम्मिलित किया जा रहा है। केरल, तमिलनाडू, कर्नाटक, गोवा और महाराष्ट्र के दक्षिणी घाटों का अन्वेषण कर 39 एस. स्पॉन्टेनियम, 11 इ. अरुंडिनेशियस, 3 इ. बेंगालेंसिस और 2 एस. ऑफिश्नेरम इकट्ठे किये गये हैं जिन्हें संगरोधन के बाद जर्मप्लास्म बैंक में सम्मिलित किया जायेगा। कोयब्तूर में अनुरक्षित किये जा रहे जंगली जर्मप्लास्म संग्रहण में इस समय 2,140 अभिप्राप्तियां हैं जिनमें 1,620 एस. स्पॉन्टेनियम, 215 इ. अरुंडिनेशियस, 172 इरिएन्थस जातियों से, 59 सम्बंधित जैन्रा से, रेशों के लिये 48 उन्नत इरिएन्थस और 26 सैकेरम कृन्तक शामिल हैं। अरूणांचल प्रदेश से इकट्ठी की गई 47 अभिप्राप्तियों को भा.कृ.अनु.प. के आइ.ए.आर.आइ., क्षेत्रीय स्टेशन, वैलिंगटन में अनुरक्षित किया जा रहा है।

पंजाब, हरियाणा, अरूणांचल प्रदेश और झारखंड से हाल ही में एकत्रित किये एस. स्पॉन्टेनियम के 86 कृन्तकों के

दैहिक गुणसूत्र नम्बर (2 एन) को जाँचा गया जिससे एक अद्वि तीय कृन्तक, आइ.एन.डी.17–1852, को पहचाना गया जिसका आधार सायटोटाइप 2एन = 40 था। इ. प्रोसेरस के 10 कृन्तकों का कोशिकाविज्ञानिक अध्ययन करने पर उस जाति का गुणसूत्र नम्बर 2एन = 40 पाया गया। दो व्यवसायिक संकरों (2 एन = 108 और 114) और एस. स्पॉन्टेनियम (2 एन = 56, 60 और 64) के विभिन्न सायटोटाइपों के मेल से बने संकरों के अर्धसूत्रण विश्लेषण करने पर द्विसंयाजकों की बहुतायत देखी गई, जिसका एफ.1 संकरों के गुणसूत्र नम्बर के साथ कोई सम्बंध नहीं पाया गया। 5 इ. अरुंडिनेशियस जर्मप्लास्म के 215 कृन्तकों में से 47 कृन्तकों को सूखे के प्रति सहनशील पाया गया। सैकेरम के 91 कृन्तकों को लाल सड़न रोग के सी.एफ.06 रोगजनक के विरुद्ध प्रतिक्रिया के लिये मूल्यांकन करने पर 9 अभिप्राप्तियों, नामशः नारगोरी, मनगेसिक, मनेरिया, आइ.एम.पी. 1552, दौर किनारा, चिन, मुंगो 254, खेली और रेहा को प्रतिरोधी पाया गया।

प्रजनन में प्रयोग पूर्व समग्री का विकास और मूल्यांकन, विभिन्न लक्ष्यों को ध्यान में रखते हुए किया गया। नवीन सूखा सहनशील जेनेटिक स्टॉक्स के विकास के लिये 42 क्रॉसेस सूखा सहनशील आइ.एस.एच. और आइ.जी.एच. का प्रयोग कर और 13 आधारभूत क्रॉसेस एस. ऑफिश्नेरम, एस. रोबस्टम, एस. बारबेरी और एस. साइनेंस का प्रयोग कर बनाये गये। अगली में 161 द्विपैतृक क्रॉसेस व्यवसायिक गन्नों, सैकेरम जाति और सम्बंधित जेनेरा की भागीदारी से राष्ट्रीय वृहत संकरण सुविधा के यहां बनाये गये। विस्तृत आनुवांशिक आधारा वाले 48 विशिष्ट कृन्तकों का मूल्यांकन गन्ना उत्पादन और रस की गुणवत्ता मापकों के लिये करने पर वृहत संकर, जी.यू. 15–1586 को ध्यान रखने योग्य 21.10% शर्करा वाला पाया गया। बहु–पैतृक उन्नत पीढ़ी अन्तर–क्रॉस जनसंख्या के विकास का कार्य चार–मार्गी क्रॉस जनसंख्या की जाँच के स्तर तक पहुँच गया है जिससे 7 सूखा सहनशील और 15 लाल सड़न रोग प्रतिरोधी संकरों की पहचान की गई।

अजैविक तनाव और शर्करा से सम्बंधित तुलनात्मक ट्रान्सक्रिप्टोमों और छोटे आर.एन.ए. के विश्लेषण की पहचान कर ली गई है। आक्सीडेटिव तनाव के दौरान एमआइआर.एन.ए.ओं को जंगली जातियों के मुकाबले को. 86032 में अति प्रकट होते पाया गया। कन्ट्रोल में साकारात्मक रूप से उच्च प्रकटन करने वाले 20 एमआइआर.एन.ए.ओं जबकि केवल तनाव के हालातों में ही प्रकट हाने वाले 9 एमआइआर.एन.ए.ओं की पहचान कर ली गई है। सूखे के लिये अति महत्वपूर्ण ट्रान्सक्रिप्टों, जो 10 दिनों के तनाव के दौरान प्रकट हुए, को संवेदनशील (को. 8021) और प्रतिरोधी (को. 06022) प्रजातियों के ट्रान्सक्रिप्टोम डाटा से निकाल लिया गया है। दो दिनों के तनाव से 15 जीनों को को. 8021 में 19 जीनों को को. 06022 को उच्च नियंन्त्रित पाया गया और तनाव के 10 दिन तक बढ़ने के साथ उच्च नियन्त्रण के स्तर में वृद्धि होते देखी गई और यह फोल्ड बदलाव 2 दिनों के तनाव के मुकाबले उच्च स्तर का था। दोनों प्रजातियों में उच्च नियंन्त्रित जीनों में से अधिकतर विभिन्न कार्यों से सम्बंधि ात होने के कारण तनाव सहनशीलता प्रक्रियाओं में प्रजातियों के स्तर पर विभिन्नता का कारण बनती है। कुल 2,339 और 4,038 विभिन्नता से प्रकट होती लवणता प्रतिक्रियाशील यूनीजीनों को लवणता तनाव पीड़ित और कन्ट्रोल के बीच प्रतिरोधी आइ. एन.डी. 99–907 और संवेदनशील को. 97010 के नमूनों को क्रमशः पहचाना गया। इसी प्रकार 34 विभिन्नता से प्रकट होते लवणता प्रतिक्रियाशील एमआइआर.एन.ए.ओं को आइ.एन.डी. 99–907 में और 317 एमआइआर.एन.ए.ओंको. 97010 में पहचाना गया। शर्करा चयापचय के तीन सूक्ष्म आर.एन.ए. परिवारों (जैडएमए–एमआइआर.169ओ–3पी, वीवीआइ–एमआइआर.396ए, एसएमओ–एमआइआर.396) को कन्ट्रोल के हालातों में सैकेरम स्पॉन्टेनियम और तीन सूक्ष्म आर.एन.ए. परिवारों (एमआइआर. 167आइ–3पी, एमआइआर. 1848, एमआइआर. 159बी) को को. 86032 में पहचाना गया।

गन्ने के महत्वपूर्ण गुणों के लिये अनुवांशिक नियन्त्रण और जिनोमिक चयन और भारत–अस्ट्रेलिया निधि के अन्तरगत विशिष्ट भारतीय और अस्ट्रेलिया के जर्मप्लास्म के तुलनात्मक अध्ययन का कार्य प्रगति पर है। को. गन्नों, को. 86002 x बी.ओ. 91, को.एम. 0265 x को. 775 से प्राप्त जनसंख्याओं की संतान की लक्षणसमष्टि का कार्य लाल सड़न रोग और गन्ना उत्पादन व रस की गुणवत्ता मापकों के लिये तथा बी.ओ. 91 x को. 775 की जनसंख्याओं की पेड़ी के परीक्षण में सूखा सहनशीलता के लिये किया गया। बेतरतीब तरीके से लिये गये नमूनों की एस.एन.पी. आधारित जीनोटाइपिंग कर उन्हें ए.ए., ए.बी. और बी.बी. प्रसरण में वर्गीकृत किया गया।

इरिएन्थस से जी.डब्लयू.ए.एस. द्वारा सूखा सहनशीलता लिये नये जेनेटिक संसाधनों की पहचान के कार्य को आगे बढ़ाते हुए 215 इ. अरुंडिनेशियस कृन्तकों और 40 इरिएन्थस जाति कृन्तकों में से 15 इ. अरुंडिनेशियस कृन्तकों को सूखा सहनशील और करीब 20 कृन्तकों को मध्यम सहनशील पाया गया। सूखा सहनशीलता की प्रक्रिया को समझने के लिये चयन किये गये इरिएन्थस कृन्तकों के जड़ों की लक्षण समष्टि करने पर सूखा अनुकूलक शारीरिक विशेषताओं की उपस्थिती इरिएन्थस में पाई गई। इरिएन्थस जर्मप्लास्म के 96 कृन्तकों, जिनमें सूखा संवेदनशील, मध्यम और सहनशील कृन्तक शामिल थे, के अनुक्रमण द्वारा जीनोटाइप पैनल तैयार करने पर 50,000 जव 60,000 बहुरूपी स्थानों को प्रत्येक नमूने में पाया गया, जिनका आगे का विश्लेषण कार्य प्रगति पर है। एक पादप न्यूक्लीयर घटक, एक प्रतिलेखन घटक पहचाना गया जो बहुत सारे तनाव–प्रतिक्रियाशील प्रक्रियाओं, जिसमें सूखा एवं लवणता

तनाव शामिल हैं, में नियन्त्रक भूमिका निभाता है। गन्ने के पच्चीकारी एकलसूत्री संदर्भ जिनोम से एन.एफ.–वाइ.ओं कि लिये जिनोम वृहत खोज द्वारा 9 एन.एफ.–वाइ.ए., 18 एन.एफ. –वाइ.बी. और 24 एन.एफ.–वाइ.सी. जीनों की उपस्थिति का पता चला। इन पहचाने गये एन.एफ.–वाइ. जीन सदस्यों को गन्ने के जिनोम में विभिन्न गुणसूत्रों पर स्थित पाया गया।

भा.कृ.अनु.प. की बीज परियोजना के अन्तरगत अनुरक्षण प्रजनन और केन्द्रक कृन्तकों के बहुगुणन का कार्य, जिसमें संस्थान की बीज चेन में शामिल प्रजातियों, नामशः को. 86032, को. 0212, को. 06030 और को. 09004 और नई लोकार्पित प्रजाति को. 11015 को भी बीज चेन में शामिल किया गया है, जारी है। को. 86032, को. 0212, को. 06030, को. 09004 और को. 11015 के प्रजनक बीज के उत्पादन के कार्य को ऊतक संवर्धन द्वारा प्रारम्भ कर 37,495 टन प्रजनक बीज को कोयम्बत्तूर से चार स्थानों, नामशः सेयूर, माथमपालयम, वेल्लामदाइ और नीलमबुर, और त्रिपुर ज़िलों से प्रशिक्षित प्रगतिशील किसानों को करीब 30 एकड़ में गुणवत्तायुक्त बीज के उत्पादन के लिये दिया गया। इन खेतों से करीब 1200 टन गुणवत्तायुक्त बीज को तमिलनाडू की सहकरी एवं प्राइवेट चीनी मिलों को वितिरित किया गया है। गन्ना फसल की उत्पादक्ता बढ़ानें के लिये गुणवत्तायुक्त बीज के महत्व को समझानें के लिये नये बीज किसानों और तिरूतन्नी सहकारी चीनी मिल के चीनी मिल के कर्मचारियों को व्यक्तिगत प्रशिक्षण दिया गया। जनजाति उप प्लान के अन्तरगत, कोयम्बत्तूर के निकट अनायेकट्टि के कृषक समुदाय को 2,00,000 रुपये टी.एस.पी. निधि का प्रयोग बीज, केले के टी.सी. पौधों और मोटर पम्पसैटों के वितरण के लिये किया गया। इस अवधि के दौरान को. 0212, को. 09004, को. 0238, को. 86032, को.वी. 09356 और को. 11015 प्रजातियों के 48,910 ऊतक संवर्धित पौधों को चीनी मिलों और प्रगतिशील किसानों को बांटा गया।

फसल उत्पादन

हाइड्रोपोनिक्स परीक्षणों में विभिन्न सूक्ष्मजीव विलगनों एज़ोस्पिरिलम, गलुकोनएसिओबैक्टर और बैसिल्लस से को. 09004 और को. 86032 में 90 दिनों के इनाक्यूलेशन के बाद साकारात्मक रूप से उच्चतर जड़ और शाखा की लम्बाई देखी गई। एज़ोस्पिरिलम, गलुकोनएसिटोबैक्टर और स्यूडोमोनास के कारण उच्चतर जड़ और शाखा की लम्बाई देखी गई। जड़ निःस्त्राव नमूनों के एच.पी.एल.सी. द्वारा विश्लेषण करने पर उनमें फिनोलिक अम्लों, नामशः गेलिक, कैफिक, वेनिलिक, सिरिंजिक और फैरुलिक अम्लों, की उपस्थिति दर्ज की गई।

गन्ना बीज टुकड़ों को उपचार यन्त्र का प्रयोग करते हुए जैव समग्रीयों से इनाक्यूलेट करने वाले परीक्षणों में कलिका चिप और एकल कलिका वाले बीज टुकड़ों से पैदा हुए पौधों के प्रदर्शन पर प्रभाव का अध्ययन करने वाले परीक्षण में को. 2001–13 और को. 8371 में सार्वधिक 86.5% अंकुरण प्रतिशत दर्ज किया गया। विभिन्न कल्चरों में से बइजेरिंकिया (बी.इ. 03) से उपचार करने पर एकल कलिका वालों ने 69.5% का सार्वधिक अंकुरण दर्शाया वहीं कलिका चिप में 66.5% अंकुरण दर्ज किया गया।

पांच विशिष्ट गन्ना जीनप्रारूपों (को. 13006, को. 13008, को. 13009, को. 13018 और को. 13020) और तीन मानकों (को. 86032, को.सी. 671 और को. 09004) को उर्वकरों की अनुसंशित मात्राओं के 75%, 100% और 125% साथ मूल्यांकन के लिये रोपित किया गया। पौधा फसल रोपण के 10 महीने बाद पेराई योग्य गन्नों की संख्या में जीनप्रारूप विशिष्ट विभिन्नता देखी गई जिसमें आशावान अगेती जीनप्रारूप को. 13009 ने 71,082 संख्या/हे. की बेहतर संख्या दर्ज की जबकि चैक प्रजातियों को.सी. 671 ने 69,379/हे. और को. 86032 ने 67,450/हे. की संख्यायें दर्ज की।

गन्ने की फसल के जड़ क्षेत्र में कीटरोगजनक कृमि सूत्र (की.रो.सू.) संरूपण को डालने के लिये की.रो.सू. अनुप्रयोजक विकसित किया गया है। इस नये विकसित किये गये अनुप्रयोजक का मूल्यांकन करने के लिये तमिलनाडू के इरोड ज़िले के थालावडी क्षेत्र के बनागाहल्ली में किसान के खेत में एक परीक्षण संचालित किया गया। सामान्यतः बिना उपचारित कन्ट्रोल के मुकाबले की.रो.सू. के उपयोग से सफेद गिंडार की जनसंख्या में कमी देखी गई। उपचार की विभिन्न विधियों में से की.रो.सू. संरूपण का अनुप्रयोजक द्वारा उपचार करने पर सफेद गिंडार की जनसंख्या में 78.79% की सार्वधिक कमी उपचार के 15 दिन बाद देखी गई।

गन्ना फसल की कटाई के लिये एक लटकन टाइप प्रतिघात कटाई यन्त्र का विकास किया गया जिससे कटाई में प्रयुक्त हो रही विशिष्ट ऊर्जा को अनुमानित किया जा सके, ताकि पंक्ति से पंक्ति की दूरी 0.75 मीटर और पौधे से पौधे की 0.35 से 0.45 मीटर दूरी को ध्यान में रखते हुए कटाई बलेड के मापकों, जैसेकि इनकी मोटाई, झुकाव कोण और उपगमन कोण को इष्टतम बनाया जा सके।

सीमित सिंचाई जल की उपलब्द्धता के हालातों में जल उपयोग दक्षता का अध्ययन करने के लिये भूतल से ऊपर स्थित जैवभार में आइ.1 (सिंचाई पानी की मात्रा को आधा किया गया) कारण 20% और आइ.2 (सिंचाई की संख्या को आधा किया गया) के कारण 16% की कमी को. संकरों में निर्माणात्मक प्रवस्था के दौरान देखी गई, जबकि सर्वोत्तम वृद्धि प्रवस्था के दौरान यह गिरावट आइ.1 में उतनी ही रही जबकि आइ.2 में बढ़कर 23% तक पहुँच गई। तीन जीनप्रारूपों, नामशः को. 15015, को. 15018 और को. 85019 ने दोनों प्रकार की सीमित सिंचाई के हालातों में औसत जीनप्रारूप जैवभार से उच्चतर जैवभार दर्ज किये। को. 10026, को. 11015, को. 16018, को. 15015, को. 15018 और को. 85019 ने आइ.1 में उच्चतर जैवभार दर्ज

किया। जाति कृन्तकों ने निर्माणात्मक प्रवस्था के दौरान आइ. 1 और आइ.2 में 9% और 19% की गिरावट क्रमशः दर्ज की जबकि सर्वोत्तम वृद्धि प्रवस्था के दौरान यह गिरावट बढ़कर क्रमशः 20% और 40% तक पहुँच गई। पत्ति क्षेत्रफल सूचकांक को. संकरों में आइ.1 और आइ.2 के कारण 23% और 15% की गिरावट क्रमशः दर्ज की गई। तीन जीनप्रारूपों, नामशः को. 13014, को. 14025, को. 15007, को. 15015 और को. 15018 ने दोनों प्रकार की सीमित सिंचाई के हालातों में औसत जीनप्रारूप से अधिक पत्ति क्षेत्रफल सूचकांक दर्ज किये। जाति कृन्तकों में आइ.1 के कारण 10% और आइ.2 के कारण 20% की गिरावट पत्ति क्षेत्रफल सूचकांक में दर्ज की गई।

उष्णकटिबंधीय हालात में, उष्णकटिबंधीय और उपोष्णकटिबंधीय प्रजातियों में जीवमितीय अवलोकन से निर्माणात्मक प्रवस्था में पत्ति क्षेत्रफल सूचकांक को को. 14012 में 1.20 से को. 06022 में 1.68 तक उष्णकटिबंधीय प्रजातियों में जबकि उपोष्णकटिबंधीय प्रजातियों में इसे को. 0238 में 0.80 से को. 15027 में 1.58 तक दर्ज किया गया। इसी प्रकार कुल सूखा भार उत्पादन उष्णकटिबंधीय प्रजातियों में को. 86032 में 2.15 से को. 11015 में 3.3 किलोग्राम/मीटर^2 के बीच दर्ज किया गया जबकि उपोष्णकटिबंधीय प्रजातियों में यह को. 15023 में 1.65 से को. 15027 में 2.29 किलोग्राम/मीटर^2 के बीच दर्ज किया गया। सर्वोत्तम वृद्धि प्रवस्था के दौरान पत्ति क्षेत्रफल सूचकांक को को. 14012 में 1.75 से को. 06022 में 2.30 के बीच उष्णकटिबंधीय प्रजातियों में जबकि उपोष्णकटिबंधीय प्रजातियों में इसे को. 0238 में 1.25 से को. 15027 में 2.25 के बीच दर्ज किया गया। इसी प्रकार कुल सूखा भार उत्पादन उष्णकटिबंधीय प्रजातियों में को. 13006 में 3.74 से को. 11015 में 4.45 किलोग्राम/मीटर^2 के बीच दर्ज किया गया जबकि उपोष्णकटिबंधीय प्रजातियों में यह को. 15023 में 2.48 से को. 15027 में 4.02 किलोग्राम/मीटर^2 के बीच दर्ज किया गया।

प्रकाश अवरोधन में साकारात्मक विभिन्नता पक्तियों में विभिन्न दूरियों के बीच देखी गई, यानि की कम दूरी पर रोपित कृन्तकों को दो अधिक दूरी पर रोपित कृन्तकों के मुकाबले अधिक प्रकाश अवरोधन करते पाया गया। मई माह के दौरान वैश्विक सौर विकिरण प्रकाश को संस्लेषण के लिये आवश्यक विकिरणों से अधिक पाया गया जबकि इससे उल्ट पैटर्न दिसम्बर माह के दौरान देखा गया। सीमित सिंचाई के हालातों में किये गये परीक्षण में जाति कृन्तकों में आइ.एस.एच. 107 ने बेहतर उत्पादन दर्शाया जबकि खाकई कृन्तकों ने कन्ट्रोल (पूरी सिंचाई अनंशंसित अवधि पर, फसल के वाष्पन उत्सर्जन का 100% प्रतिस्थापन) और मध्यम स्तर की जल कमी (पूरी सिंचाई अनंशंसित अवधि पर, मगर फसल के वाष्पन उत्सर्जन का केवल 50% प्रतिस्थापन) वहीं अत्याधिक जल कमी के हालातों में (सिंचाई अनंशंसित अवधि के बजाय एक छोड़ हर दूसरी बार और वह भी फसल के वाष्पन उत्सर्जन के 50% प्रतिस्थापन के साथ) आइ.के. 7610 और आइ.एस.एच. 107 ने बेहतर जैवभार उत्पादन दर्शाया। खाकई, आइ.एस.एच. 107 और आइ.एस.एच. 111 कृन्तकों को प्रकाश अवरोधन के लिये बेहतर पाया गया जबकि आइ.एस.एच. 9 ने अति कम प्रकाश अवरोधन दर्शाया।

गन्ने के जर्मप्लास्म में जड़ प्रणाली के लक्षण वर्णन के अध्ययन से निर्माणत्मक प्रवस्था में जड़ों की लम्बाई में साकारात्मक विभिन्नता जर्मप्लास्म कृन्तकों के बीच देखी गई। जड़ की लम्बाई को एस. बारबेरी सफेद पिंडारा में 5,799.5 सेंटीमीटर से इ. अरुंडिनेशियस में सार्वधिक 1,70,817.5 सेंटीमीटर दर्ज किया गया जबकि औसत लम्बाई 37,844.3 सेंटीमीटर अनुमानित की गई। इसी प्रकार का प्रचलन जड़ों के सतही क्षेत्रफल, जड़ों के आयतन एवं जड़ों के औसत व्यास, जिनकी औसत क्रमशः 5,566.75 सेंटीमीटर^2, 71.01 सेंटीमीटर^3 और 10.2 मिलिमीटर थी। शारीरिक विज्ञान अध्ययन में जड़ के क्रॉस सैक्शनों ने जर्मप्लास्म में व्यापक विभिन्नता कॉरटैक्स से स्टील के अनुपात, कॉरटैक्स में खाली स्थानों की उपस्थिती और स्टील में मेटाज़ायलम तत्वों की संख्या देखी गई।

खेत में 31 गन्ना जीन प्रारूपों के फसल के नीचे मृदा में कार्बन डाइऑक्साइड प्रवाह को अनुमानित किया गया। रोपण के 300 दिन बाद यह प्रवाह 3.02 से 12.94 μमोलर/मीटर^2/सेकेंड के बीच दर्ज किया गया। सार्वधिक कार्बन डाइऑक्साइड प्रवाह को. 0314 में 12.94 μमोलर/मीटर^2/सेकेंड जिसके करीब ही यह प्रवाह 12.13 μमोलर/मीटर^2/सेकेंड को. 92005 में दर्ज किया गया जबकि को. 7219 में न्यूनतम प्रावह 3.20 μमोलर/मीटर^2/सेकेंड दर्ज किया गया। मृदा पीएच., विद्युत संचालक्ता, मृदा में ऑरगेनिक कार्बन, पेराइ योग्य गन्नों की संख्या और कार्बन डाइऑक्साइड प्रवाह के बीच सहसम्बंध अध्ययन करने पर कार्बन डाइऑक्साइड प्रवाह और मृदा में ऑरगेनिक कार्बन के बीच ऋणात्मक सहसम्बंध पाया गया जबकि यह पेराइ योग्य गन्नों की संख्या के साथ धनात्मक था, मगर यह साकारात्मक नहीं था।

अमरावति कोऑपरेटिव शूगर मिल्लस लिमिटेड के कमान क्षेत्र के अन्तरगत (कृष्णापुरम, जोथमपति, चिन्नाकमपालयम, नरिकलपत्ति, नइक्करापत्ति, पप्पनकुलम और मदाथुकुलम) गन्ना खेती की मृदा परतों का अध्ययन करने पर तमिलनाडू के तिरुपुर और दिंदिगुल ज़िलों ने की मृदाओं की सभी परतों को अलवणीय पाया गया जिनकी विद्युत चालक्ता 0.033 से 0.36 डेसीसीमन/मीटर पाया गया। इनकी पीएच. 6.61 से 8.90 के बीच पाई गई। केवल नरिकलपत्ति में ही मृदा परतों की पीएच. क्षारीय, 8.75 से 8.90 के बीच देखी गई जबकि बाकी क्षेत्रों की सभी मृदा परतों ने विरक्त प्रतिक्रिया दर्शाई। कृष्णापुरम, जोथमपति, चिन्नाकमपालयम, नरिकलपत्ति और चीनी मिल के क्षेत्र में मृदा की कम गइराई जबकि नरिकलपत्ति में मृदाओं का चूनेदार होना अध्ययन किये गये क्षेत्रों के मुख्य अवरोधक थे।

गन्ना बीज टुकड़ों से उत्पादित पौधों को आरोपित करने की प्रौद्योगिकी को प्रदर्शित करने के लिये प्रदर्शन प्लॉट जनवरी 2018 में स्थापित किया गया। इसके लिये उच्च गन्ना उत्पादक प्रजाति को. 11015 के एकल कलिका वाले बीज टुकड़ों से उत्पादित पौधों को जोड़ा पंक्तियों, विस्तृत दूरी (4 फुट x 2 फुट), अन्तरफसलीकरण, टपक सिंचाई, टपक सिंचाई से उर्वरकों को भी देना, कई पेड़ी फसलों का लेना, अवशेषों का मल्च के रूप में उपयोग और मशीनीकरण का प्रयोग किया गया। काला चना, धनिया और लोबिया की अन्तर फसलों ने गन्ने के रस की गुणवत्ता मापकों पर कोई साकारात्मक प्रभाव नहीं डाला। पेड़ी की फसल की शुरुआत के 270 दिन बाद काले चने की अन्तरफसल वाले प्लॉट में सबसे अधिक गन्ना उत्पादन 81.22 टन/हे. दर्ज किया गया जो सांख्यिकी की दृष्टि से धनिया के अन्तरफसल के 68.64 टन/हे. के बराबर मगर लोबिया के अन्तरफसल के 56.63 टन/हे. और बिना अन्तरफसल वाले प्लॉटों 61.08 टन/हे. से साकारात्मक रूप से बेहतर प्रदर्शन था। लोबिया की फसल में अत्याधिक शाखाओं के इधर उधर फैलनें की आदत के कारण गन्ने की फसल में कल्लों के निकलने और पेराइ योग्य गन्नों की संख्या में गिरावट ने अपना प्रभाव गन्ना के उत्पादन में दिखाया। अतः लोबिया की फाल गन्ने में अन्तरफसलीकरण के योग्य नहीं है। काले चने, धनिया और लोबिया की अन्तरफसलीकरण से बिना अन्तरफसलीकरण के मुकाबले क्रमशः 59,992 रुपये, 74,889 रुपये और 4,574 रुपये/हेक्टेयर की अतिरिक्त आय प्राप्त हुई।

फसल सुरक्षा

फसल सुधार विभाग, गन्ना प्रजनन संस्थान अनुसंधान केन्द्रों, कन्नूर और अगली के विभिन्न परीक्षणों से करीब 2,805 कृन्तकों की लाल सड़न रोग प्रतिरोधिता के लिये नियन्त्रित हालातों में सी.एफ.06 (सी.एफ671) रोगजनक के विरुद्ध जाँच कर 1,504 कृन्तकों को लाल सड़न रोग प्रतिरोधी पाया गया।

केयम्बत्तूर और अगली केन्द्र में अनुरक्षित की जा रही विभिन्न जर्मप्लास्म और पैतृक लाइनों की पीली पत्ति रोग की तीव्रता के प्रति मूल्यांकन करने पर रोग की घटना के स्तर को पूरी तरह रोग से स्वतंत्र से लेकर अति तीव्र स्तर तक देखा गया। राष्ट्रीय संकरण उद्यान, जिसमें पैतृक कृन्तक शामिल थे, में 5.21% प्रविष्टियों को पीली पत्ति रोग के प्रति मध्यम प्रतिरोधी पाया गया।

लाल सड़न रोग प्रतिरोधिता के विभिन्न स्तरों वाली 13 प्रजातियों की खेत के हालातों में सहनशीलता के स्तर की जाँच 12 कवक विलगनों, जिनका उग्रता का स्तर विस्तृत था, का प्रयोग कर की गई। संवेदनशील प्रजातियों को.सी. 671 और को. 94012 के साथ साथ को. 06030 ने भी सभी रोगजनक विलगनों से रोग का प्रकटन दर्शाया जबकि को. 09004 और को.वी. 92102 को रोग से स्वतंत्र पाया गया। को. 86032 में इस मौसम के दौरान 8 रोगजनक विलगनों के कारण रोग के लक्षण प्रकट होते देखे गये।

पहचाने गये सुरक्षा सम्बंधित 6 प्रत्याशी एमआइआर.एन.ए.ओं और उनके सम्बंधित एमआइआर.एन.ए. लक्ष्यों का सापेक्ष प्रकटन विश्लेषण, क्यूआर.टी.–पी.सी.आर. का प्रयोग करते हुए, एक अस्थाई पैमाने पर किया गया। संगत अंतःक्रिया में असंगत अंतःक्रिया के मुकाबले एमआइआर.एन.ए.ओं का प्रकटन उच्चतर देखा गया और एमआइआर.एन.ए. तथा उनके लक्ष्यों के बीच पारस्परिक सम्बंध स्पष्ट रूप से स्थापित हुआ पाया गया। परिणामों से विभेदी अभिव्यक्ति के संकेत असंगत अंतःक्रिया में, संगत अंतःक्रिया के मुकाबले, लक्षित जीन ट्रान्सक्रिप्टों के जल्द प्रेरण के रूप में मिले, अतः इन प्रत्याशी सुरक्षा जीन ट्रान्सक्रिप्टों का लाल सड़न रोग प्रतिरोधिता प्रक्रिया के साथ स्पष्ट सम्बंध दिखाई देता है।

काइटोसान से ढके बैंज़ोथायाडायाज़ोल और सैलिसिलिक अमल से संश्लेषित एस.ए.आर. उत्प्रेरक नैनोकणों ने संकेत दिये की संश्लेषित किये गये एस.ए.आर. प्रेरक नैनोकणों, विशेषकर काइटोसान से ढके बैंज़ोथायाडायाज़ोल नेनोकणों को पी.एसआइ के साथ मिलाकर और काइटोसान से ढके सैलिसिलिक अमल से संश्लेषित एस.ए.आर. उत्प्रेरक नैनोकणों को पी.वी.पी से मिलाकर कर प्रयोग करने से इन्हें गन्ने में लाल सड़न रोगजनक के विरुद्ध प्रतिरोधिता उत्प्रेरण में कुशल पाया गया।

रस्ट घटनाओं के महामारी विज्ञानिक अध्ययनों से पता चला की गन्ना प्रजनन सस्थान, कोयम्बत्तूर में पिछले साल के मुकाबले 2019 में रस्ट की तीव्रता कम पाई गई। अधिकतर लोकप्रिय प्रजातियों, को. गन्नों, आइ.एस.एच. कृन्तकों और लोकप्रिय पैतृक कृन्तकों ने रस्ट की कम तीव्रता दर्शाई। खेत में रस्ट रोग की स्थापना में कटौती करने में वर्षा को एक महत्वपूर्ण भूमिका निभाते पाया गया।

गन्ने के साथ सम्बंधित फाइटोप्लास्मा के आणविक लक्षण वर्णन ने गन्ने के घसैले रोग को अधिकतर परीक्षित नमूनों में फाइटोप्लास्मा के साथ सम्बंधित होने को सुनिश्चित कर दिया क्योंकि इनसे उम्मीद अनुसार 1.2 किलोबाइट आकार का विशिष्ट प्रवर्धन प्राप्त हुआ।

गन्ना बीज टुकड़ों को उपचारित करने के यन्त्र को कई नमूनों को विभिन्न निवेषों के साथ उपचारित करने के लिये अनुकूलित किया गया, जिससे न केवल समय की बचत होगी अपितु दक्षता में वृद्धि और इसके परिचालन में भी आसानी होगी। गन्ना बीज टुकड़ों को जैवइनाक्यूलैंट संरूपों, जिसमें 0.5% और 1.0% स्यूडोमोनास अलवेइ और ट्राइकोडरमा हारजिएन्म शामिल थे, ने पादप वृद्धि को साकारात्मक रूप से बेहतर किया जबकि इनका अंकुरण पर कोई प्रभाव नहीं देखा गया।

नैनोकण सक्षम बगल से प्रवाह वाली प्रतिरक्षापरख किट विकसित

कर गन्ने के पच्चीकारी विषाणु और गन्ने के धारीदार पच्चीकारी विषाणु को साइट पर ही पहचान करने के लिये मानकीकृत किया गया। इस प्रतिरक्षापरख किट की तुलना दूसरे परखों के साथ करने पर इसे संवेदशीलता में इ.एल.आइ.एस.ए. के तुलनीय पाया गया। मगर, क्यूआर.टी.–पी.सी.आर. को इससे अधिक संवेदनशील पाया गया क्योंकि इसमें लक्षित जीन को कई गुणा परिवर्धित किया जाता है।

गन्ने के पच्चीकारी विषाणु की जवार के पत्तों के नमूनों में, गन्ने के धारीदार पच्चीकारी विषाणु को मक्का के पत्तों के नमूनों में और बौनी मक्का पच्चीकारी विषाणु की उपस्थिती को गन्ने में आर.टी.–पी.सी.आर. परख द्वारा सुनिश्चित किया गया, जिसके लिये अपने अपने विषाणु कोट प्रोटीन प्राइमरों का प्रयोग किया गया। इसके बाद अनुक्रमण के परिणामों का भी सहारा लिया गया।

एस. साइटेमिनियम एम.ए.टी.–1 अगुणित स्पोरिडिआ को जी. एफ.पी. से टैग किया गया जिस परिवर्तन को, एग्रोबैक्टीरिअम की मध्यस्तता से टी.–डी.एन.ए. बाइनरी वैक्टर पीबी.एच. टी2–जीएफपी का प्रयोग कर किया गया। इसे और भी सुनिश्चित हरी फलुऔरेसेंस को फलुऔरेसेंस सूक्ष्मदर्शी के प्रयोग से देखकर तथा पी.सी.आर. द्वारा भी किया गया।

एस. साइटेमिनियम विलगनों एस.एस97009 और एसएसवी.89101 का प्रयोगशाला और पौधे में इनके विकास चरणों की तुलना एस.इ.एम. का प्रयोग कर की गई। आइ.एस.एस.आर. प्राइमरों का प्रयोग कर आणविक मारकारों आधारित प्रोफाइलिंग की गई ताकि एस. साइटेमिनियम के 5 विलगनों के स्पष्ट संगम प्ररूपों में अनुवांशिक विविधता का पता लगाया जा सके।

एस.एस97009 एम.ए.टी.–1 अगुणित स्पोरिडिआ से प्रोटोप्लास्ट को विलगित करने के लिये एक कुशल विधि का विकास कर प्रोटोप्लास्ट की गुणवत्ता और जीवनक्षमता को सुनिश्चित किया गया।

गन्ने के विभज्योतक ऊतकों से निकल रहे कंडुआ रोग के चाबुक से अपलवक प्रोटीन के निष्कर्षण के लिये स्टैन्डर्ड प्रोटोकॉल विकसित किया गया। परिणामों से संकेत मिले की उपयुक्त बफर के साथ सिरिंज विधि निष्कर्षण के लिये एक आदर्श विधि होगी। अपलवक प्रोटीन का मात्रात्मक प्रोटिओम विश्लेषण, आइटी.आर.ए.क्यू. लेबल का प्रयोग करते हुए एल.सी.–एम.एस. /एम.एस. विधि के साथ मिलकर गन्ने से 51 प्रोटीन और 9 एस. साइटेमिनियम द्वारा स्त्रावित प्रोटीनों को पहचाना गया।

तम्बाकु के पत्तों में, कृषिअन्तःस्यंदन का प्रयोग करते हुए, टैग किये हुए सी.एफ.पी.एल.1 और सी.एफपी.डी.आइ.पी.1 का क्षणिक प्रकटन दर्शाता है की दोनों प्रोटीन अन्तराकोशिकीय स्थानों में स्त्रावित किये गये। सी. फाल्केटम में क्यूपी.सी.आर. द्व ारा सी.एफ.पी.एल.1 और सी.एफपी.डी.आइ.पी.1 की कॉपी संख्या अनुमानित की गई जिसके परिणामों से पता चला की दोनों जीनों की केवल एक कॉपी उपस्थित थी जिसे सी. फाल्केटम के पूरे जिनोम डाटा से भी विधिमान्य किया गया।

एस.सी.बी.वी. आधारित वी.आइ.जी.एस. वैक्टर को विकसित करने के लिये प्रोटोकॉल मानकीकृत किया गया ताकि गन्ने में कार्यात्मक जिनोमिक्स का अध्ययन किया जा सके। इस कार्य को करने के लिये विभिन्न परिवर्तन, जैसेकि बेतरतीब शिखी आर.सी.ए., एस.सी.बी.वी. प्राइमर स्पाइक्ड आर.सी.ए., बेतरतीब शिखी एस.सी.बी.वी. प्राइमर स्पाइक्ड आर.सी.ए., इत्यादि किये गये। परिणामों ने दिखलाया की सभी विलगनों में 80.93 से लेकर 99.68% समानता एस.सी.बी.वी.–बी.आर.यू., इंडिया के, एस.सी.बी.वी.–बी.ओ. 91ए इंडिया के, एस.सी.बी.वी.–वाइ.जी. 40, चीन के और एस.सी.बी.वी.–आइ.एम., ऑस्ट्रेलिया के पूरे जिनोम अनुक्रमों के साथ थी।

विषाणु अनुक्रमण सेवा के अन्तरगत करीब 2,427 ऊतक संवर्धित पौधों, जिन्हें विभिन्न उत्पादन इकाइयों, नामशः मैसर्स इ.आइ.डी. पैरी, पुगालुर, मैसर्स आरएस.सी.एल., थेनी और संस्थान की ऊतक संवर्धन प्रयोगशाला से प्राप्त किया गया था, को एस.सी.वाइ.एल.वी., एस.सी.एम.वी., एस.सी.एस.एम.वी. और घसैला रोग फाइटोप्लास्माओं के लिये मानक प्रचालन विधियों का प्रयोग करते हुए अनुक्रमित किया गया। प्राइवेट ऊतक संवर्धन प्रयोगशालाओं से विषाणु अनुक्रमण सेवा के अन्तरगत शुल्क के रूप में 6,12,800/– रुपये प्राप्त हुए।

शाखा बेधक के आक्रमण को शुरुआती प्रजाति परीक्षण, उन्नत प्रजाति परीक्षण–1 और उन्नत प्रजाति परीक्षण–2 में 0.0 से 41.7% के बीच पाया गया। शाखा बेधक के आक्रमण को पी.आइ. 16131, को.संके. 14102 और को. 13018 में निमन्न स्तर पर देखा गया जबकि को.एम. 16081, को. 14027 और को. 13020 में उच्चतर स्तर पर देखा गया।

लाल छिलके वाले 20 सैकेरम रोबस्टम कृन्तकों में से जी.यू.के. 14–129 और जी.यू.के. 14–836 को पोरी बेधक के विरुद्ध कम से कम संवेदनशील पाया गया जबकि जी.यू.के. 14–48, जी.यू. के. 14–675 और जी.यू.के. 14–829 को मध्यम संवेदनशील, वहीं बाकी 15 कृन्तकों को अतिसंवेदनशील पाया गया।

इरएिन्थस अरुंडिनेशियस जीनप्रारूपों, नामशः आइ.के. 76 78, आइ.के. 76 84, आइ.जे. 76 364, आइ.जे. 76 370, आइ.जे. 76 400, इ.आर.आइ. 2798 और फिजि 55, जिन्हें खेत के हालातों में शाखा बेधक प्रतिरोधी पाया गया था, की प्रयोगशाला में जाँच की गई। डिम्भों कौर प्युपाओं की उत्तरजीविता आइ.के. 76 78, आइ.जे. 76 364 और आइ.जे. 76 370 सबसे कम जबकि आइ.जे. 76 400 के साथ साथ कन्ट्रोल को. 86032 में सार्वधि ाक दर्ज की गई।

पोरी बेधक के अंडों के पैरासिटोयड टेलिनोमस डिगनस की

मौसमी गतिकी के अध्ययन में अंडों के भार के आधार पर कुल मिलाकर 82.6% की परजीविता अनुमानित की गई। अडों के समूहों में करीब सभी अवलोकनों में 100.0% के परजीविकरण दर पाये गये, वहीं अलग अलग अडों के समूहों में से प्रौढ़ों के निकलने को 45.5% से 100.0% के बीच देखा गया।

प्रयोगशाला में शीशे की चिमनियों में बड़े पैमाने पर बहुगुणन के लिये किये गये अध्ययनों में टेलिनोमस ने अंडों का 100% परजीविकरण दर्शाया अंडा समूहों के अन्दर दर्शाया जबकि उनसे प्रौढ़ों के निकलने को 44.2% से लेकर 90.0% तक देखा गया। पैरासिटोयड के बहुगुणन को और अधिक बढ़ाने के लिये, पोलीविनायल के बेलनाकार पिंजरों में पत्तों के छोटे छोटे टुकड़ों पर अंडा समूहों के ऊपर पैरासिटोयड को छोड़ने से 50.8% से 100.0% के बीच परजीविकरण देखा गया। इस विधि से चिमनी विधि के 100 अंडा समूहों के मुकाबले 400 अंडा समूहों को रखा जा सका। पोरी बेधक के अंडा समूहों को जब 10^0सी. पर 2, 4, 6, 8 और 10 दिनों के लिये भंडारित कर टेलिनोमस पर छोड़ा गया तो परजीविकरण को भंडारण की अवधि के साथ कम होते पाया गया।

टेलिनोमस जाति के साथ खेत में आउगमेंटेटिव परीक्षण में, पैरासिटोयडों की मात्रा 3,000/हे. के समतुल्य दो महीने के अन्दर छोड़ने पर, पोरी बेधक की व्यापक्ता और तीव्रता छोड़े गये प्लॉट में 30 दिन बाद कन्ट्रोल के मुकाबले कम पाई गई। जब पोरी बेधक के अंडा समूहों को खेत में चौकीदार के रूप में टेलिनोमस को पकड़ने के लिये रखा गया, तो पैरासिटोयडों को 30% से 50% अंडा समूहों में से पाया गया जबकि इनसे प्रौढ़ों के निकलने में विभिन्नता पाई गई।

कीटरोगजनक कवक के उच्च स्तर पर उत्पादन को कम खर्चीला बनाने के लिये बिनौले की खली को मैटारिज़ियम एनिसोपलि के लिये, तिल की खली के अर्क को ब्यूवेरिया बेसिआना और गेहूँ के चोकर और चावल के चोकर से प्राप्त अर्क को बी. ब्रोंगनिआरटी के लिये, बिजाणु उत्पादन के आधार पर, सर्वोत्तम पाया गया।

कीटरोगजनक कवक से गमलों में मृदा को इनाक्यूलेट करने के बाद 10 दिन के अन्तराल पर मृदा के नमूनों की 10 टोलियों को एकत्रित किया गया ताकि इनकी जीवनक्षमता और रोगजनक्ता का मूल्यांकन किया जा सके। गलेरिया मैलोनैला पर किये गये जैवपरखों में एम. एनिसोपलि के मुकाबले ब्यूवेरिया जातिओं में अधिक अपघटन देखा गया। एम. एनिसोपलि ने इलाक्यूलेशन के 100 दिन बाद 60% कार्यकुशलता दर्शाई।

गमलों में किये गये परीक्षणों में बी. ब्रोंगनिआरटी, बी. बेसिआना, एम. एनिसोपलि, एच. इंडिका, एस. गलासेरी और 6 चयन किये गये कीटनाशियों को, खेत में उपचार के लिये प्रयोग किये जीने वाली अनुसंशित मात्राओं पर, विभिन्न संयोजनों के रूप में दिया गया। सभी कीटरोगजनकों ने संफेद गिंडार में उच्च मृत्युशीलता दर्शाई। कीटरोगजनक कवकों में कवक की प्रभावकारिता और एच. इंडिका संयोजनों से मृत्युशीलता 30 दिनों पर 15.% से बढ़कर 90 दिनों में 59.2% हो गई। कीटनाशियों ने एस. गलासेरी के साथ 90 दिन बाद 0 से 55% तक मृत्युशीलता दर्शाई। एच. इंडिका का इमिडाकलोपरिड के साथ संयोजन सर्वश्रेष्ठ था, जिसमें 90 दिन बाद भी 48% प्रभावी अवशेष देखे गये।

दो क्राई जीनों, नामशः क्राई1डी. और क्राई1इ., जिन्हें बेसिल्स थुरिंजिएंसिस विलगन एस.बी.आइ.–के.के.27 से विलगित किया गया था, की पूरी लम्बाई के अनुक्रमों को कलोनिंग के बाद क्रमशः 3501 और 3531 बीपी का पाया गया।

एस.बी.आइ.–बी.टी41 के पूरे जिनोम अनुक्रम के विश्लेषण से, बी.टी जीवविष नामावली की अन्तरराष्ट्रीय कमिटी के दिशा निर्देर्शों के अनुसार, एक नवीन क्राई8 जीन का पता चला। एस.बी.आइ.–बी.टी721 के पूरे जिनोम अनुक्रम के विश्लेषण से पता चला क्राई3 जीन की पूरी लम्बाई की उपस्थित थी, जिसे पहले रिर्पोट की गई क्राई3सी.ए जीन के साथ 99% से अधिक मिलते पाया गया। इसी विलगन में वानस्पतिक कीटनाशी जीन के आंशिक अनुक्रमों की उपस्थिती देखी गई। इसी प्रकार एक अन्य बी.टी विलगन एस.बी.आइ.–एम.6 के पूरे जिनोम अनुक्रम के विश्लेषण से पता चला की इसने एक नये होलोटाइप क्राई 66 जीन को आश्रय दिया हुआ है, जिसके कार्य का अभी तक पता नहीं है।

काइलो इन्फसकैटेलस (के.एम.453722), साइरपोफेगा एक्सरपटेलिस (के.जे.013411), सेसअमिआ इन्फेरेंस (के.जे.013410), परॉटिस्टा मोएस्टा (के.एक्स.519327), पाइरिल्ला परपुसिला (के.जे.013412), मेलानाफिस सैकेराइ (के.एम.453721), टेटरान्यूरा जेवेंसिस (के.एम.453723), नीओमसकेलिआ बरजाइ (के.एफ.986270), एल्यूरोलोबस बारोडेंसिस (के.एफ.986269), स्टुरमिओपसिस इन्फेरेंस (के.एकस.519323), एपिरिकानिआ मेलानोल्यूका (के.एक्स.519320) और डिफा एफिडिवोरा (के.एक्स.519319) के डी.एन.ए. बारकोड्स विकसित किये गये, जिसके लिये इनका प्रयोग प्राइमरों को डिज़ाइन करने के लिये किया गया, ताकि कीट जातियों के सी.ओ.आइ. जीन घटकों को परिवर्धित किया सके। सी. इन्फसकैटेलस के लक्षित घटकों का आकार 204 बीपी और एस. इन्फेरेंस का 599 बीपी था।

गन्ने के रस को, 5 नाइट्रोजन परिपूरकों, नामशः यूरिआ, अमोनियम कलोराइड, पोटाश्यिम नाइट्रेट, कैलशियम कलोराइड और ईस्ट अर्क को 1% सान्द्रता पर मीडिया में प्रयोग कर, दृढ़ीकृत कर बी.टी–62 स्ट्रेन के उत्पादन को बढ़ाने के लिये इनका मूल्यांकन किया गया। दृढ़ीकृत किये गये मीडिया में से सार्वधिक बिजाणु उत्पादन 6.12 ग 10^{12} सी.एफ.यू./मिलिलिटर गन्ने के रस में ईस्ट अर्क से मिलाकर प्रयोग करने पर पाया

गया जिसके बाद कैलशियम कलोराइड के मिलाने से 3.50 x 10^{12} सी.एफ.यू./मिलिलिटर दर्ज किया गया।

बी.टी 62 के बड़े स्तर पर उत्पादन को मानकीकृत करने के लिये इस बैक्टीरिया को स्टैंडर्ड टी.3 मीडिया और 3% शीरे के साथ, बीज किण्वक पर मैसर्स बन्नारी अम्मन शूगर मिल्लस लिमिटेड, साथ्यामंगलम में, बहुगुणित किया गया। करीब 20 लिटर मीडिया को 2 लिटर मदर कल्चर से इनाक्यूलेट कर बीज किण्वक पर बी.टी की वृद्धि की इनाक्यूलेशन के 4 और 7 दिनों बाद जांच की गई। टी.3 मीडिया से अधिक बैक्टीरिया का उत्पादन शीरे के 3% के मुकाबले देखा गया।

कीटनाशी चयापचयों का शुद्धिकरण और पहचान करने पर सहजीवी बैक्टीरियम, फोटौरहैब्डस ल्यूमिनीसेंस उपजाति अखुरसति (एस.बी.आइ.पी.एल.ए.टी.एन.डी.78) में कीड़े विरोधी जैवक्रियाशील संयोजकों की उपस्थिती दर्ज की गई। जिनोमिक डी.एन.ए. अनुक्रमों का आन्तरिक अनुवादित अन्तरक विशिष्ट प्राइमरों द्वारा विश्लेषण कर 28 कीटरोगजनक कृमि सूत्र विलगनों की आणविक पहचान की गई। पांच की.रो.सू.ओं (हैट्रोरहैब्डाइटिस और स्टेइनरनेमा जातियों), जिन्हें उपोष्णकटिबंधीय गन्ना पारिस्थितिकी तंत्र से विलगित कर उनके आन्तरिक अनुवादित अन्तरक अनुक्रमों को ए.सी.बी.आइ. डाटाबेस को भेजा गया है जिनके अभिप्राप्ति नम्बर एम.के.51969 से एम.के.51973 हैं।

उनतीस उपोष्णकटिबंधीय विलगनों (16 हैट्रोरहैब्डाइटिस और 13 स्टेइनरनेमा जातियों से) की सफेद गिंडार के प्रथम इनस्टार के विरुद्ध जैवपरख ने दर्शाया की सभी विलगनों के कारण सफेद गिंडार की मृत्युशीलता 20 से 100% के बीच रही। स्टेइनरनेमा जाति की तुलना में हैट्रोरहैब्डाइटिस जाति की सार्वधिक संख्या ने 100% मृत्युशीलता दर्शाई। पांच की.रो.सू.ओं जातियों (3 उपोष्णकटिबंधीय विलगनों और 2 उष्णकटिबंधीय विलगनों) की तुलना तीन उपचार विधियों द्वारा नवीन की.रो.सू. संरूपण के प्रभाव का अध्ययन खेत के हालातों में सफेद गिंडार होलोट्राइकिआ सेरेटा बनागाहल्ली गाँव थालावडी क्षेत्र में किया गया। की.रो.सू. जाति और उपचार विधि को ध्यान में रखे बिना सफेद गिंडार की जनसंख्या में गिरावट देखी गई। सफेद गिंडार की जनसंख्या में सार्वधिक 78.79% गिरावट एच. बैक्टीरिओफोरा (एस.बी.आइ.एच.6) और एस. गलासेरी (एस.बी.आइ.एल.एन.1) की.रो.सू. प्रयोजक द्वारा दूसरे कृमि सूत्रों और दूसरे की.रो.सू. उपचार विधियों के मुकाबले देखी गई।

भा.कृ.अनु.प.–गन्ना प्रजनन संस्थान, क्षेत्रीय केन्द्र, करनाल

अ.भा.स.अनु.प. (गन्ना) की प्रजाति पहचान समिति ने करनाल के क्षेत्रीय केन्द्र से को. 13035, एक मध्यम देरी से पकने वाली प्रजाति को पहचाना। को. 19016 (अगेती), को. 19017 (मध्यम देरी) और को. 19018 (मध्यम देरी) कृन्तकों को उत्तर पश्चिमी क्षेत्र में क्षेत्रीय प्रजाति परीक्षण के लिये पहचान कर शामिल किया गया। आइ.एस.एच./आइ.जी.एच. परीक्षण में सूखे के कारण पेराई योग्य गन्नों की संख्या में गिरावट जी.यू.के.00–12226 में 2.6%, 14–50 में 5.7%, कविंगिरे में 9.3% और एच.49–104 में 9.4% कम से कम देखी गई वहीं दूसरी और 2012–124 में 52.8%, एच.81 में 42.6%, सी.एल.47–83 में 41.3%, क्यू.62 में 40.4%, पी.ओ.जे. 28–883 में 40.3% और बी.43–380 में 39.8% में उच्चतर गिरावट देखी गई। लवणता के हालातों में को. गन्नों में को. 98014, को. 15023, को. 0238, को. 0118, को. 06034 और को. 05011 ने 4 तथा 8 डेसीसीमन/मीटर लवणता के स्तरों पर बेहतर प्रदर्शन दर्शाया।

कुल 1084.51 क्विन्टल प्रजनक गन्ना बीज अपने फार्म से बेचा गया जबकि केन्द्र से जुड़े गन्ना बीज किसानों के खेतों से 1098.15 क्विन्टल गन्ना बीज, किसानों की भागीदारी से बीज उत्पादन परियोजना के अन्तरगत शरत्कालीन मौसम के दौरान, देश के विभिन्न साझेदारों को बेचा गया। केन्द्र पर शरत्कालीन गन्ना बीज फसल के अन्तरगत शत प्रतिशत क्षेत्र को गन्ना बीज टुकड़े प्रतिरोपण यन्त्र द्वारा रोपित किया गया, और इन बीज टुकड़ों से को. 0118, को. 0238 और को. 12029 प्रजातियों के कुल 20,630 उत्पादित पौधों को क्षेत्र के विभिन्न साझेदारों को बेचा गया ताकि एस.टी.टी. को प्रोत्साहित किया जा सके। आर.के.वी.वाइ. बीज परियोजना के अन्तरगत 3,00,000 गन्ना बीज टुकड़ों जनित पौधों को किसानों के खेतों में 40–42 एकड़ में स्वस्थ बीज के लिये उगाया गया। एन.एफ.एस.एम. परियोजना के अन्तरगत करीब 8,500 क्विन्टल प्रजनक बीज 10 हेक्टेयर क्षेत्रफल में उत्पादित किया गया।

कुल 786 कृन्तकों, जिनमें सी.1 परीक्षण कृन्तक, पूर्व क्षेत्रीय प्रजाति परीक्षण, प्रारम्भिक और आइ.एस.एच. कृन्तक शामिल थे, की लाल सड़न रोग के सी.एफ.08 और सी.एफ.09 रोगजनकों के विरुद्ध प्लग विधि से जाँच कर 365 कृन्तकों को प्रतिरोधी/मध्यम प्रतिरोधी, 170 को मध्यम संवेदनशील और 251 को संवेदनशील/ अतिसंवेदनशील पाया गया।

दो एक दिवसीय प्रशिक्षण कार्यक्रमों के द्वारा हरियाणा राज्य से आये 165 चीनी मिल अधिकारियों और किसानों को स्वस्थ बीज उत्पादन और गन्ना उत्पादन को अधिकतम बनानें के लिये प्रशिक्षित किया गया। उत्तर प्रदेश से आये 20 किसानों को 5 दिन के लिये प्रशिक्षित किया गया। सरस्वती चीनी मिल लिमिटेड, यमुनानगर से आये 80 प्रगतिशील किसानों और चीनी मिल अधिकारियों ने, संस्थान के करनाल केन्द्र पर आयोजित, एक अति सक्रीय विचार विमर्ष वाले सत्र में भाग आयोजन लिया।

भा.कृ.अनु.प.–गन्ना प्रजनन संस्थान, अनुसंधान केन्द्र, कन्नूर

विश्वभर से संग्रहित किये गये गन्ने के जर्मप्लास्म की 3,373

अभिप्राप्तियां को खेत वाले जीन बैंक में हर साल पुनःरोपण द्वारा मुख्य रोगों से रहित हालातों में अनुरक्षित किया जा रहा है। जर्मप्लास्म का समय समय पर रोग और हानिकारक जीवों के लिये निरीक्षण किया जाता है। अनजानी बाढ़ की स्थिती के कारण जाति कृन्तकों को पोरियों की लम्बाई व मोटाई के लिये बाढ़ से पूर्व व पश्चात और पत्ते के सूखने के लिये मूल्यांकित किया गया। खेत के जीन बैंक के पूरक के रूप में 115 सैकेरम ऑफिश्नेरम और 12 भारतीय संकरों, जिनका खेत में निमन्न प्रदर्शन था, को प्रयोगशाला में विभज्योतक संवर्धन द्वारा बहुगुणित कर उपसंवर्धन द्वारा अनुरक्षित किया जा रहा है। सैकेरम जाति कृन्तकों, नामशः एस. रोबस्टम, एस. साइनेंस और एस. बारबेरी, पर प्रलेखन के एक भाग के रूप में 3 डिजिटल सूचीपत्र लाये गये। रोगों के लिये उपयुक्त जैवनियन्त्रक एजेंट की पहचान के लिये दोहरे कल्चर अध्ययन में, बैक्टीरियल विलगनों पी.एफ.4 और पी.एफ.59 को फुसेरियम सैकेराइ के विरुद्ध सार्वधिक प्रभावी पाया गया, जबकि बैक्टीरियल विलगन बी.सी.29 को सेराटोसिटिस पैराडोक्सा बीज टुकड़े रोगजनक के विरुद्ध सार्वधिक प्रभावी पाया गया।

भा.कृ.अनु.प.–गन्ना प्रजनन संस्थान, अनुसंधान केन्द्र, अगली

अगली अनुसंधान केन्द्र में कुल 611 जर्मप्लास्म अभिप्राप्तियों में पुष्पण देखा गया, जिसकी की तीव्रता 44.28% पाई गई। कुल 170 क्रॉसेस 2019 मौसम के दौरान बनाये गये। अ.भा.स.अनु.प. (गन्ना) के 12 केन्द्रों से गन्ना प्रजनकों ने राष्ट्रीय सदूर संकरण सुविधा का उपयोग किया। कुल 102 कृन्तकों को कलोनल नर्सरीयों में मूल्यांकित किया गया। प्रथम कलोनल नर्सरी से 2 कृन्तकों, ए.जी.12018–27 और ए.जी.12018–35, तथा एक कृन्तक ए.जी.12019एन–42 ने दूसरी कलोनल नर्सरी से 8वें महीने में मानकों से उच्चतर शर्करा : दर्ज की। यह कृन्तक लाल सड़न प्रतिरोधी भी थे। डस परीक्षण स्कीम के अन्तरगत कुल 236 संदर्भ प्रजातियों को अगली केन्द्र पर कलोनली अनुरक्षित किया गया और किसानों की 3 प्रजातियों का डस परीक्षण भी किया गया।

विस्तार विभाग

दूर तक पहुँचने के कार्यक्रमों के अन्तरगत एक गन्ना अनुसंधान और विकास कर्मचारियों की मीटिंग, 9 राष्ट्रीय स्तर के प्रशिक्षण कार्यक्रमों, 20 दो दिवसीय प्रशिक्षण कार्यक्रमों, डी.एस.डी. प्रयोजित एक दिवसीय प्रशिक्षण कार्यक्रम और 6 अनावरण भ्रमणों का आयोजन किया गया। पांच अगली पंक्ति के प्रदर्शन किसानों के खेतों में किये गये।

एग्री इन्टैक्स 2019 को सी.ओ.डी.आई.एस.एस.आई.ए. व्यापार मेला परिसर, कोयम्बत्तूर में आयोजित किया गया जिसमें संस्थान ने एक स्टाल लगाकर गन्ना खेती कार्य प्रणालियों के पैकेज को दर्शाया गया।

गन्ना सलाहकार, गन्ने पर एक एन्डरॉयड मोबाइल एप्प जिसमें राज्य अनुसार प्रजातियों, फसल उत्पादन तकनीकों, फसल सुरक्षा तकनीकों पर सूचनायें उपलब्ध कराई गई हैं। यह एप्प गुगल प्ले स्टोर पर तीन भाषाओं में स्वतंत्र डाउनलोड के लिये उपलब्ध है। संसार भर के 61 देशों में इसे कुल 8761 बार डाउनलोड किया गया है। इसे कुल 1,31,110 हिट्स मिले हैं जिनमें फसल उत्पादन को 49,611 (37.84%), फसल सुरक्षा को 42,166 (32.16%), गन्ना प्रजातियों को 27,182 (20.73%), उर्वरक प्रयोग अनुसूची को 9,227 (7.04%) और सैकेरम जातियों को 2,924 (2.23%) हिट्स मिले हैं।

4. EXECUTIVE SUMMARY

Crop Improvement

Co 11015, a short duration variety, was notified for the state of Tamil Nadu. It recorded a mean performance of 142.72 t/ha of cane yield, 20.22% of sucrose and 20.16 t/ha of sugar yield at 360 days with an increase of 10.23%, 9.66 % and 20.13% over the standard Co 86032 for cane yield, sucrose % and sugar yield respectively. Characterized by early sugar accumulating potential and fast growth, this variety is suitable for harvest from 8 months onwards and its cultivation is expected to improve sugarcane productivity and sugar recovery in the state.

A midlate maturing clone Co 12009 is identified for release in Peninsular zone by the Varietal Identification Committee of AICRP (S). This clone recorded sugar yield of 17.31 t/ha at 360 days across the zone with an improvement of 10.76% over the best midlate standard Co 86032. Increased cane yield and sugar yield both of plant and ratoon crops and resistance to red rot combined with fast growth and early vigour add merit to this variety for wide scale adoption when notified. This variety has a new genetic base involving *S. spontaneum* (SES 91).

The flowering season 2019 was excellent with 85% flowering in the arrowing plot. This opportunity was used to make 402 crosses involving parents with high breeding value as well as new sources for major traits. About 30,000 seedlings were raised in ground nursery from 113 crosses and 22869 progenies, in different stages of selection upto to Prezonal varietal trial, were screened for cane yield and juice quality parameters and selection made. Sixty five test entries were evaluated to identify 'Co' canes and among these, five entries recorded superior sucrose content at 300 days and 48 were resistant to red rot. Botanical description of 'Co' canes of 2019 series and DNA profiling of varieties identified for release by ICAR-SBI and three AICRP centres were carried out.

Drought experiments with promising 'Co' canes progressed at four locations in Maharashtra and Belagavi, Karnataka. In Maharashtra, 18 entries were evaluated in plant and ratoon crops under drought and Co 85019, Co 06022 and Co 98017 emerged as the top performing entries with superior cane yield and sucrose at harvest.

Trials are also in progess at Kolhapur (Maharashtra), Vuyyuru (Andhra Pradesh) and in Tamil Nadu (under Adaptive Research Trial) for identifying location specific varieties. A new research project was initiated along with ICAR-IGFRI, Jhansi for nutritional evaluation, improvement and utilization of newer feed resources for livestock production and the first batch of planting materials were despatched to ICAR-IGFRI for trials on nutritional quality.

Under AICRP(S), an Initial Varietal Trial and three Advanced Varietal Trials were conducted. The entries, Co 11015 and Co 16006 in IVT, Co 14032 in AVT I Plant crop, Co 13002, Co 13018, Co 13004, Co 13013 and CoSnk 13103 in AVT II Plant crop, Co 13004, Co 13002 and Co 13020 in AVT ratoon were identified as the best entries for early high sucrose content. Multiplication and supply of entries for varietal trial as well as for climate resilient intergeneric and interspecific hybrids were progressing well.

Testing of the first set of 20 entries in factory locations through Institute-Industry Participatory Approach was completed. Overall, Co 13014, Co 11015, Co 13018, Co 14016 and Co 06031 performed better than the state variety Co 86032 for cane yield and sugar yield at harvest. Of these, Co 11015 with clear superiority across Tamil Nadu was released as mentioned earlier. In the second set 17 clones are being evaluated at eight private factory locations and 21 clones at six cooperative sugar factory locations in Tamil Nadu.

In the National hybridization garden of 617 parental clones, a high intensity of flowering (91.90%) was observed. Twenty three attended the crossing programme-2019 utilizing 146 females and 104 male parents. The parents Co 775 and CoPant 97222 (male parents) and Co 86032 and Co 0238 were the most utilised parents. The Parental Diversity Index and Parental Utilization Index of crosses effected by the 23

centers revealed that Pune and Perumalappalle recorded maximum values respectively.

In National Active Germplasm, 240 notified and registered genetic stocks were maintained and index numbers were assigned to three clones (Co 12009, Co 13034 and Co 13035). At Agali, 1380 germplasm including 'Co' canes, 'Co' allied clones, exotic clones, inter-specific and inter-generic hybrids, core collection of *Saccharum officinarum,* species clones of *S. barberi, S. sinense, S. robustum, Erianthus* spp., *Sclerostachya* and *Narenga* were clonally maintained in field. Under DUS (Coimbatore and Agali), 233 tropical sugarcane reference varieties were maintained. Eleven *S. officinarum* clones were morphologically characterized in comparison with Farmer's varieties Angangba, Desi I and Desi II. The reference variety 51NG105 was very close with Desi II. Desi I was distinct and did not resemble any of the reference varieties. Two farmers' varieties namely, Sugam Kattari and Jeet Katari were received for DUS test.

Standardization of true seed production technique through developing homozygous parental lines through different approaches is in progress. Characterization of inbreds for cane yield, juice quality, flowering, seed setting, red rot reaction and molecular similarity are being carried out. Based on the results 20 selected inbreds were intercrossed to effect 13 crosses for progeny evaluation. Evaluation of the progenies from crosses involving selfs indicated low variability in the cross involving two sixth generation inbreds (1148-237-S6-2-61 x 1148-S5-242-3-277). For the first time, great progress has been made in anther culture. The right callusing medium from 20 different media and the appropriate age of the arrows were standardised and upto 20% callus induction was realized in the sugarcane variety Co 86032. Characterization of 28 green plantlets for ploidy level through cytology, physiological parameters, marker allelic distribution and flow cytometry is in progress. In the process of identifying CENH3 mutants to enable *en bloc* elimination of chromosomes, TILLING was carried out on EMS treated calli of Co 775. Five putative samples (E2, E5, E6, E10, and E11) were subjected for sequence analyses to identify single nucleotide modification. These mutants were field planted for utilization. This exercise is being extended to two *Erianthus* clones (E.a Sarkandar and SES 153) as well. Wide hybridization of 69 inter-generic crosses were made during Oct-Dec 2019 between sugarcane and sweet corn, sweet sorghum, bajra and fodder type *Sorghum halepense* to generate haploids. Chromosome number of 73 suspected inter-generic hybrids (of bajra, sweet sorghum, sweet corn, *Narenga* and *Erianthus* x sugarcane) were determined, haploid seedlings could not be identified so far. Apomixis regulating genes from sorghum and maize were used as references for retrieving sequences from published mosaic monoploid sugarcane genome data and primers were designed. A few genes were identified, cloned and are being studied for taking up gene editing once the full-length gene sequences from sugarcane are obtained. Phytotoxic effect of fungicide on true seed was assessed and the results did not indicate any negative effect on germination of true seeds and at 90 days after storage Taqat 0.1% treated defuzzed seeds recorded better germination than control. Effective defuzzing of the fluff is possible with red soil powder.

Sugarcane germplasm is maintained, evaluated and new accessions are added. An exploration was conducted in the Western Ghats covering the states of Kerala, Tamil Nadu, Karnataka, Goa and Maharashtra and 39 *S. spontaneum*, 11 *E. arundinaceous,* three *E. bengalense* and two *S. officinarum* were collected and will be added to germplasm bank after quarantine. At present, the wild germplasm collection maintained at Coimbatore has 2140 accessions including *S. spontaneum* (1620), *E. arundinaceous* (215), *Erianthus* spp. (172), allied genera (59), improved *Erianthus* for fibre (48) and *Saccharum* clones (26), while 47 accessions collected from Arunachal Pradesh were maintained at ICAR-IARI, Regional Station, Wellington.

Somatic chromosome number (2n) in 86 clones of *S. spontaneum* collected recently from Punjab, Haryana, Arunachal Pradesh and Jharkhand were determined and one unique clone (IND17-1852) with the basic cytotype of 2n = 40 was

identified. Cytological studies in 10 clones of *E. procerus* indicated the chromosome number of 2n=40 for the species. The meiotic analysis of hybrids involving two commercial hybrids (2n = 108 and 114) and different cytotypes of *S. spontaneum* (2n = 56, 60 and 64) showed predominance of bivalents irrespective of the chromosome number of the F_1 hybrids.

Among the 215 *E. arundinaceus* germplasm clones screened for tolerance to drought 47 clones were identified as tolerant. Ninety one *Saccharum* clones were evaluated for their reaction to CF06 pathotype of red rot and eight accessions *viz*., Nargori, Mangasic, Maneria, IMP 1552, Daur Kinara, Chin, Mungo 254, Kheli and Reha were identified as resistant.

Development and evaluation of prebreeding material are carried out with different objectives. For development of novel drought tolerant genetic stocks, 42 crosses using the drought tolerant ISH and IGH and 13 basic crosses utilising S. *officinarum, S. robustum, S. barberi* and *S. sinense* were made. At Agali, 161 biparental crosses involving commercial canes, *Saccharum* species and related genera were made in the National Wide Hybridization Facility. Forty elite clones with diverse genetic base were evaluated for cane yield and juice quality traits and the wide hybrid, GU15-1586 was remarkable with sucrose of 21.10%. Development of multi-parent advanced generation inter-cross population has reached up to the stage of screening of four-way cross populations and seven drought tolerant and 15 red rot resistant hybrids were identified.

The comparative transcriptomes and small RNA analysis implicated in abiotic stress and sucrose are identified. Under oxidative stress majority of the miRNAs were highly expressed in Co 86032 than in wild species. Significantly high expression of 20 miRNAs in control and nine miRNAs only under stress condition were identified. For drought, the most significant transcripts that were expressed in ten days stress were mined out from the transcriptome data of susceptible (Co 8021) and resistant (Co 06022) varieties. Fifteen genes were upregulated in two days stress in Co 8021 and 19 genes in Co 06022 and as the stress progressed to ten days the upregulation continued and the fold change was higher than that observed in two days stress. Most of the genes that were upregulated in both varieties were involved in different functions thereby indicating varietal differences in stress tolerance mechanisms. A total of 2339 and 4038 differentially expressed salt responsive unigenes between salt stressed and control samples of IND99-907 (resistant) and Co 97010 (susceptible) respectively, were identified, so also 34 differentially expressed salt responsive miRNA in IND99-907 and 371 miRNA in Co 97010. Three miRNA families in the sucrose metabolism (zma-miR169o-3p, vvi-miR396a, smo-miR396) under the control conditions in *Saccharum spontaneum* and three miRNA families miR167i-3p, miR1848, miR159b in Co 86032 were identified.

Genetic control and genomic selection for important traits in sugarcane, and comparison of elite Indian and Australian germplasm under Indo-Australia fund progressed with phenotyping of progeny from the populations of Co canes, Co 86002 x BO 91, CoM 0265 x Co 775 for red rot and cane yield and juice quality traits and the populations from BO 91 x Co 775 for drought tolerance in ratoon trial. SNP based genotyping of randomly selected samples was categorised into AA, AB and BB variance.

Identification of new genetic resources for drought tolerance from *Erianthus* through GWAS progressed with phenotyping of 215 *Erianthus arundinaceus* clones and 40 *Erianthus* sp. clones among which about 15 *E. arundinaceus* clones were tolerant and about 20 clones were moderately tolerant. Root phenotyping in selected *Erianthus* clones to understand the drought tolerance mechanism indicated the presence of drought adaptive anatomical features in *Erianthus*. A Genotype by Sequencing (GBS) panel of *Erianthus* germplasm (96 nos) comprising drought sensitive, intermediate and tolerant clones assembly showed the presence of about two lakh variants with 50000 to 60000 polymorphic sites in each sample and further analysis is ongoing. A plant nuclear factor (NF-Y), a transcription activating factor which plays a key regulatory role in many stress-responsive mechanisms including drought and salinity stresses was identified. Genome wide

search of NF-Ys in mosaic monoploid reference sugarcane genome revealed the presence of 9 NF-YA, 18 NF-YB and 24 NF-YC genes. These identified NF-Y gene members were located on different chromosomes of sugarcane genome.

ICAR Seed Project activities included maintenance breeding and multiplication of nucleus clones of all released varieties in seed chain from the Institute viz., Co 86032, Co 0212, Co 06030 and Co 09004 and the newly released variety Co 11015 has been included in seed chain. Breeder seed production of varieties Co 86032, Co 0212, Co 09004 and Co 11015 was taken up with tissue culture plantlets and 37.495 tons of breeder seed were distributed to trained progressive farmers from four locations (Seyur, Mathampalayam, Vellamadai and Neelambur) in Coimbatore and Tirupur districts for quality seed production in about 30 acres. From these fields around 1200 tons of quality seed has been supplied to both cooperative and private sugar factories of Tamil Nadu. Three hands-on trainings for new seed farmers and factory personnel at Tiruttani Cooperative sugar Mill were provided to realise the importance of quality seed in increasing the yields in sugarcane crop. Under Tribal Sub Plan, Rs.2,00,000 from TSP fund was utilized to distribute seeds, banana TC plants and motor pumpsets to tribal farming communities around Anaikatti near Coimbatore. During the period, 48910 tissue culture plants of the varieties *viz.,* Co 0212, Co 09004, Co 0238, Co 86032, CoV 09356 and Co 11015 were supplied to sugar factories and progressive farmers.

Crop Production

Hydroponic experiments on the application of different microbial isolates *Azospirillum, Gluconacetobacter* and *Bacillus* after 90 days of inoculation showed significantly higher root and shoot length in Co 09004 than Co 86032. *Azospirillum, Gluconacetobacter and Pseudomonas* recorded higher root and shoot fresh weight. HPLC analysis of root exudate samples indicated the presence of phenolic acids *viz.*, galic, caffeic, vanilic, syringic and ferulic acids.

In the experiments to study the effect of sett treatment with bioinoculents by using sett treatment devise on the performance of seedlings raised from chip bud and single bud, overall results indicated that Co 2001-13 and Co 8371 has recorded the highest germination percentage (86.5%). Among the different cultures, Beijerinckia (BE 03) has recorded highest germination of 69.5% in single bud and 66.5 % in chip bud.

In a screening of five elite sugarcane genotypes (Co 13006, Co 13008, Co 13009, Co 13018, Co 13020) and three standards (Co 86032, CoC 671, Co 09004) with three RDF (75, 100 and 125 %) were planted. In the plant crop the NMC (000/ha) recorded at 10th month after planting showed sugarcane genotype specific difference, wherein, promising early genotype Co 13009 (71082 NMC/ha) recorded higher NMC than the check varieties Co 86032 (67450 NMC/ha) and CoC 671(69379 NMC/ha).

Entomopathogenic nematode (EPN) applicator for applying the EPN formulation at the root-zone of the sugarcane crop was developed. A field experiment was conducted to evaluate the newly developed EPN applicator in the farmer's field at Banagahalli, Thalavadi Erode district of Tamil Nadu. In general there was a reduction in white grub population irrespective of the EPN application methods compared to untreated control. However, among the different application methods, EPN applicator recorded maximum reduction (78.79%) of white grubs after 15 days of application of EPN formulation.

For development of sugarcane harvester a pendulum type impact cutting device for measuring specific cutting energy was developed for optimizing the blade parameters like thickness, bevel angle and approach angle by considering row to row spacing of 0.75 m, plant to plant spacing varying from 0.35 to 0.45 m.

In the study on water use efficiency under water limited conditions the above ground biomass registered a reduction of 20 and 16% in I_1 and I_2 respectively in 'Co' hybrids at formative phase, however, during grand growth phase the biomass reduction increased to 23% in I_2 and remained in same pace in I_1. Three genotypes *viz.*, Co 15015, Co 15018 and Co 85019 recorded

higher biomass than the genotypic mean in both the restricted irrigation treatments. Co 10026, Co 11015, Co 16018, Co 15015, Co 15018 and Co 85019 recorded higher biomass in I_1. The species clones registered 9 and 19% reduction biomass in I_1 and I_2 at formative phase while at grand growth phase the reductions were 20 and 40% respectively. Leaf area index (LAI) reduced by 23 and 15% respectively in I_1 and I_2 in Co hybrids. Genotypes Co 15007, Co 15015, Co 14025, Co 15018 and Co 13014 recorded higher LAI than the genotypic mean in both the restricted treatments. In species clones LAI reduced by 10% (I_1) and 20% (I_2) in restricted irrigation treatments.

Experiment at tropical condition on biometric observation of tropical and sub-tropical varieties indicated that at formative phase, LAI varied from 1.20 (Co 14012) to 1.68 (Co 06022) in tropical varieties, while in sub- tropical varieties varied from 0.80 (Co 0238) to 1.58 (Co 15027). Similarly, the variation in TDMP in tropical varieties was 2.15kg/m^2 (Co 86032) to 3.3kg/m^2 (Co 11015), while in sub-tropical it ranged from 1.65 kg/m^2 (Co 15023) to 2.20 kg/m^2 (Co 15027). At grand growth phase, LAI varied from 1.75 (Co 14012) to 2.30 (Co 06022) in tropical varieties, while in sub- tropical varieties, the variation was 1.25 (Co 0238) to 2.25 (Co 15027). Similarly, the variation in TDMP in tropical was 3.74 (Co 13006) to 4.45 kg/m^2 (Co 11015) in tropical varieties, while in sub-tropical it ranged from 2.48 (Co 15023) to 4.02 kg/m^2 (Co 15027).

The significant differences in light interception was observed among different spacing i.e. the clones planted in narrow spacing was recorded more light interception than other two spacing, while the 150cm showed less light interception. The global solar radiation during the month of May month was significantly more than the required radiation for photosynthesis and *vice versa* was recorded in December. In the experiment with species clones under limited irrigated condition revealed better biomass production in ISH 107, and Khakai clones under both control (full irrigation at recommended interval, with 100% crop evapotranspiration replacement) and mild water deficit condition (irrigation at recommended interval, with 50% crop evapotranspiration replacement), while IK 7610 and ISH 107 showed better biomass production under severe water deficit condition (skipping alternate irrigation and irrigation with 50% crop evapotranspiration replacement). ISH 107, Khakai, and ISH 111 clones also recorded better light interception, while ISH 9 showed lesser light interception.

In a study on characterization of root system traits in sugarcane germplasm indicated significant variation in root length among the germplasm clones at formative phase. The root length ranged from 5799.5 cm (*S. barberi* White Pindaria) to 170817.5 cm (*E. arundinaceus* IJ-76-503), with a mean of 37844.3 cm. Similar trend was observed in root surface area, root volume and average root diameter, showing an average of 5566.75 cm^2, 71.01 cm^3 and 10.2 mm respectively. In the anatomical studies cross sections of root revealed wide variation among germplasm with regard to traits such as ratio of cortex-to-stele, number of air spaces in the cortex and number of metaxylem elements in the stele.

Soil carbon dioxide flux under 31 sugarcane genotypes were measured in the field. At 300 DAP the flux ranged from 3.02 to 12.94 µM/m2/s. The CO_2 flux in Co 0314 (12.94 µM/m2/s) was the highest followed by Co 92005 (12.13 µM/m2/s) and the lowest was recorded in Co 7219 (3.02 µM/m2/s). The correlation among soil pH, EC, NMC, soil organic carbon (SOC) and CO_2 flux showed negative correlation of CO_2 flux with SOC and positive correlation with NMC although not significant.

Soil profile study in sugarcane growing soils in the Command Area of Amaravathi Cooperative Sugar Mills Ltd. (Krishnapuram, Jothampatti, Chinnakampalayam, Narikkalpatti, Neikkarapatti, Pappankulam and Madathukulam) in Tiruppur and Dindigul Districts of Tamil Nadu indicated that all the profiles were non-saline and the electrical conductivity ranged from 0.033 to 0.36 dS/m. The pH ranged from 6.61 to 8.90. All the profiles showed neutral soil reaction except the profile at Narikkalpatti which showed alkaline reaction (pH ranged from 8.75-8.90) in all the layers. Shallow soil depth in Krishnapuram,

Jothampatti, Chinnakampalayam, Neikarapatti and Sugar Mill area and calcareousness in Narikkalpatti are the soil constraints identified in the study area.

Demonstration plot was established in January 2018 to demonstrate the Settling Transplanting Technology comprising high yielding new genotype (Co 11015), single-bud settling transplantation in paired row, wide-row spacing (4x2 feet), intercropping, drip irrigation, drip fertigation, multiple ratooning, trash mulching and mechanization. Intercropping of black gram, coriander and cow pea did not affect juice quality parameters significantly. Black gram intercropping (81.22 t/ha) recorded on par cane yield with coriander intercropping (68.64 t/ha) and significantly higher cane yield than that in cow pea (56.63 t/ha) intercropping and no intercropping (61.08 t/ha) treatments at 270 days after ratoon initiation. The cowpea showed profuse branching and trailing habit which resulted in reduction in tillering and NMC, which is also reflected in cane yield. Hence, cow pea is not a suitable intercrop for sugarcane. The net additional income of Rs 59,992, Rs. 74,889 and Rs. 4,574 per hectare was recorded in sugarcane intercropped with black gram, coriander and cow pea, respectively over and above the no intercropping treatment.

Crop Protection

About 2805 clones from different trials of Crop Improvement Division, SBI Research Centres of Kannur and Agali were screened for red rot resistance under controlled conditions against CF06 (Cf671) pathotype and 1504 clones were identified as resistant to red rot.

Assessment of YLD severity on various germplasm and parental lines maintained at Coimbatore and Agali Centre exhibited a broad range of incidence level from apparently YLD free to severity grade of YLD. The incidence recorded in the NHG comprising the parental clones indicated that 5.21% entries were moderately resistant to YLD.

Field tolerance to red rot was assessed in 13 varieties varying in red rot resistance and 12 fungal isolates with different virulence spectrum. The susceptible cvs CoC 671 and Co 94012 along with Co 06030 picked up red rot against all the pathogenic isolates, whereas two cvs Co 09004 and CoV 92102 remained free from disease development. Co 86032 picked up red rot from eight isolates during the season.

Relative expression analysis of the identified defence related six candidate miRNAs and their respective miRNA targets was carried out on a temporal scale employing qRT-PCR. miRNAs expression was higher in the compatible interaction than incompatible interaction and the correlation between miRNA and their targets was established evidently. Results indicated a differential expression in terms of early induction of the target gene transcripts in the incompatible interaction as compared with the compatible interaction, thus an evident association of the above candidate defence gene transcripts in red rot resistant mechanism.

The chitosan (CS) coated benzothiadiazole (BTH) and salicylic acid (SA) nanoparticles (NPs) indicated that the formulated SAR inducer NPs especially, CS- BTH NPs combined with Psi and CS- SA NPs combined with PVP are efficient in inducing the resistance in the host against red rot pathogen.

Epidemiology studies on rust incidence indicated that the rust severity was less in 2019 compared to previous year 2018 at SBI, Coimbatore, however, many popular varieties, Co canes, ISH clones and popular parental clones exhibited rust at low severity. The rainfall was found to play a crucial role in curtailing establishment of rust in the field.

Molecular characterization of phytoplasma associated with sugarcane confirmed association of SCGS phytoplasma in most of the test samples yielding an expected specific amplification in 1.2kb in size.

The Sett Treatment Device is optimized for treating multiple samples with various inputs thus saving time, enhancing efficiency and operational ease. Sett treatment involving bioinoculant formulations comprising 0.5% and 1% of *Pseudomonas alvei* and *Trichoderma harzianum* significantly improved plant growth without affecting the germination.

Nanoparticle enabled lateral flow immunoassay (LFA) kit was developed and standardized for on-site detection for viruses *Sugarcane mosaic virus* (SCMV) and *Sugarcane streak mosaic virus* (SCSMV) causing mosaic disease in sugarcane. Comparison of LFA with other assays indicated that the developed LFA is comparable to ELISA for its sensitivity. However, qRT-PCR is found be more sensitive due to multi-fold amplification of the target gene.

Presence of SCMV in sorghum leaf samples, SCSMV in maize leaf samples and Maize dwarf mosaic virus (MDMV) in sugarcane was confirmed by RT-PCR assays using the respective viral coat protein primers followed by the sequencing results.

GFP tagging of *S. scitamineum* MAT-1 haploid sporidia was done by *Agrobacterium* mediated transformation using T-DNA binary vector pBHt2-gfp and was further confirmed by visualization of green fluorescence under fluorescence microscopy as well as by PCR.

In vitro and *in planta* developmental stages of *S. scitamineum* isolates Ss97009 and SsV89101 were compared using SEM. Molecular marker based profiling using ISSR primers was done to assess genetic variability of distinct mating types of five *S. scitamineum* isolates.

An efficient method for protoplast isolation was developed using Ss97009 MAT-1 haploid sporidia and the quality and viability of the protoplats were also confirmed.

Developed a standard protocol for apoplast protein extraction from smut whip emerging meristematic tissue of sugarcane. Results indicated that the syringe method with appropriate buffer may serve as an ideal method of extraction. Quantitative proteome analysis of apoplastic proteins using iTRAQ labeling coupled with LC-MS/MS method identified 51 proteins from sugarcane and 9 secreted proteins from *S. scitamineum*.

Transient expression of tagged *Cf*EPL1 and *Cf*PDIP1 using Agroinfiltration in *Nicotiana tabacum* leaves indicated that both the proteins were secreted into the intercellular spaces. The copy number of *Cf* EPL1 and *Cf*PDIP1 in *C. falcatum* was assessed by qPCR and the results indicated the presence of single copy for both genes and the same was cross validated with whole genome data of *C. falcatum*.

Protocol standardization for the development of SCBV-based VIGS vector for studying functional genomics in sugarcane was carried out by performing different modifications like, random primed RCA (RP-RCA), SCBV primer spiked RCA (SP-RCA), random primed SCBV primer spiked RCA (RP-SP-RCA) etc. The results showed that all the isolates had 80.93 to 99.68 similarity to the whole genome sequences of SCBV-BRU, India; SCBV-BO 91, India; SCBV-YG 40, China and SCBV-IM, Australia isolates.

As part of the virus indexing service, about 2427 tissue culture raised plants from different tissue culture production units viz., M/s EID Parry, Pugalur, M/s RSCL, Theni and ICAR-SBI tissue culture lab were indexed for SCYLV, SCMV, SCSMV and grassy shoot phytoplasmas by following SOPs. A revenue of Rs 6,12,800/- was generated under virus indexing charges from the private tissue culture labs.

Shoot borer (SB) incidence in IVT, AVT-I and AVT-II trials ranged 0.0-41.7%. Entries PI 16131, CoSnk 14102 and Co 13018 recorded lower incidence whereas CoM 16081, Co 14027 and Co 13020 recorded higher incidence of the borer.

Out of 20 red-fleshed *Saccharum robustum* clones screened under field conditions for resistance against internode borer (INB), the genotypes GUK14-836 and GUK14-129 were found to be least susceptible; while GUK14-48, GUK 14-675 and GUK 14-829 were moderately susceptible, the remaining 15 genotypes were highly susceptible.

Erianthus arundinaceus genotypes *viz.*, IK 76 78, IJ 76 400, IK 76 84, IK 76 88, IJ 76 370, ERI 2798, Fiji 55 and IJ 76 364 identified as resistant to SB in field screening were subjected to laboratory screening. The lowest larval and pupal survival was recorded in the genotypes IJ 76 370, IK 76 78 and IJ 76 364 and the highest in the genotype IJ 76 400 and the control Co 86032.

In seasonal dynamics studies of INB egg parasitoid *Telenomus dignus*, overall parasitism of 82.6% on egg mass basis was observed. Within egg masses, parasitism rates were

100.0% in almost all observations whereas adult emergence from individual egg masses ranged 45.5-100.0%.

In laboratory mass multiplication studies in glass chimneys, *Telenomus* produced 100% egg parasitization within egg masses with moderate to high adult emergence (44.2-90.9%). To further scale-up parasitoid multiplication, egg masses on leaf bits were exposed to the parasitoid in polyvinyl cylindrical cages (30 cm ht) which produced 50.8-100.0% parasitization. This method could accommodate 400 eggs as against 100 eggs in chimney method. When INB egg masses stored at 10°C for 2, 4, 6, 8 and 10 days were exposed to *Telenomus*, percent parasitization decreased with storage duration.

In an augmentative field trial with *Telenomus* sp. at a dosage equivalent of 3000/ha released in a span of two months, INB incidence and intensity were relatively lower in release plot than in control plot 30 d after release. When INB egg masses were placed in the field as sentinel eggs to trap *Telenomus*, parasitoid was recovered from 30-50% egg masses with variable adult emergence.

For economizing mass culture of entomopathogenic fungi (EPF), cotton seed cake was found best for *Metarhizium anisopliae*, sesame seed cake extract for *Beauveria bassiana* and wheat bran and rice bran extracts for *B. brongniartii* based on spore production.

To assess the viability and pathogenicity of inoculated EPF, 10 batches of soil samples were retrieved from pots at 10 day intervals after treatment. Bioassays with *G. mellonella* indicated high degradation of *Beauveria* species compared to *M. anisopliae* with the latter retaining up to 60% efficacy till 100 days after inoculation.

In pot culture experiments with various combinations of *B. brongniartii, B. bassiana, M.anispliae, H. indica*, *S. glaseri* and six selected insecticides at field recommended dose, all the EPF caused high mortality rates of white grub. The effectiveness of the fungi in EPF and *H. indica* combinations increased from 15% mortality at 30 days to 59.2% at 90days. Insecticides with *S. glaseri* showed 0-55% mortality at 90 days while the best treatment for *H. indica* was with imidacloprid which showed 48% residual effect at 90 days.

The full length sequence of two *cry* genes, namely *cry1D* and *cry1E* isolated from the *Bacillus thuringiensis* isolate SBI-KK27 after cloning was found to be 3501 and 3531 bp respectively.

Analysis of the whole genome sequence of SBI-Bt41 revealed the presence of a novel *cry8* gene as per the guidelines of the International Committee on Bt toxin nomenclature. The whole genome sequence analysis of SBI-Bt721 revealed the presence of a full length *cry3* gene having more than 99% similarity to the *cry3Ca* gene reported earlier. The same isolate was also found to contain partial sequences of vegetative insecticidal gene. Similarly, the whole genome sequence of another Bt isolate SBI-M6 was found to harbor a new holotype *cry 66* gene whose function is yet unknown.

DNA barcodes developed for *Chilo infuscatellus* (KM453722), *Scirpophaga excerptalis* (KJ013411), *Sesamia inferens* (KJ013410), *Proutista moesta* (KX519327), *Pyrilla perpusilla* (KJ013412), *Melanaphis sacchari* (KM453721), *Tetraneura javensis* (KM453723), *Neomaskellia bergii* (KF986270), *Aleurolobus barodensis* (KF986269), *Sturmiopsis inferens* (KX519323), *Epiricania melanoleuca* (KX519320) and *Dipha aphidivora* (KX519319) were used to design primers for amplifying specific regions from the *COI* gene fragments of insect species. The target fragments were of 204 (*C. infuscatellus*) to 599 bp (*S. inferens*) in size.

Sugarcane juice fortified with five nitrogen supplements, namely urea, ammonium chloride, potassium nitrate, calcium chloride and yeast extract at 1% was evaluated as media for enhanced production of Bt-62 strain. Among the fortified media, maximum spore production (6.12×10^{12} CFU/ml) was obtained in sugarcane juice containing yeast extract followed by calcium chloride (3.50×10^{12} CFU/ml).

For standardizing large scale production of Bt 62, the bacterium was multiplied on the standard T3 media and molasses 3% in seed fermentor at M/s Bannari Amman Sugar Mills Ltd, Sathyamangalam. About 20 l of media was

inoculated with 2 l of mother culture in the seed fermentor and the growth of Bt was monitored at 4 and seven days after inoculation. T3 media produced higher bacterial population than molasses 3%.

Purification and identification of insecticidal metabolites from symbiotic bacterium, *Photorhabdus luminescens akhurstii* (SBIPLATND78) showed the presence of anti-helminthic and bioactive compounds.

Molecular identification of 28 EPN isolates was done by analysis of genomic DNA sequences with internal transcribed spacer (ITS) specific primers. ITS sequences of five EPN (*Heterorhabditis* and *Steinernema* spp.) isolated from sub-tropical sugarcane ecosystem have been submitted to NCBI Database with accession numbers from MK51969-MK51973.

Bio assay of 29 subtropical isolates (16 *Heterorhabditis* and 13 *Steinernema*) against 1st instar and 2nd instar white grub revealed mortality of the white grub and it ranged between 20 to 100%. Maximum number of *Heterorhabditis* spp recorded 100 % mortality than *Steinernema* spp. Comparison of five EPN species (three subtropical isolates and two tropical isolates) with three different application methods of novel EPN formulation conducted under field condition against white grub *Holotrichia serrata* at Banagahalli village Thalavadi area showed a reduction in white grub population irrespective of the EPN species and application methods. Among the nematodes, *H. bacteriophora* (SBIH6) and *S. glaseri* (SBILN1) recorded maximum reduction (78.79%) of white grubs with EPN applicator than other nematodes and other EPN application methods.

ICAR-SBI, RC, Karnal

From Regional Centre, Karnal, Co 13035, a midlate maturing variety was idenfitied by the variety identification committee of AICRP. Clones Co 19016 (early), Co 19017 (midlate), and Co 19018 (midlate) were accepted for inclusion in ZVT trials of AICRP(S) for testing under North West Zone. In the ISH/IGH trial, clones GUK00-1226 (2.6%), 14-50 (5.7%), Kavingire (9.3) and H49-104 (9.4) had minimum reduction whereas 2012-124 (52.8%), H81 (42.6%), CL47-83 (41.3%), Q62 (40.4%), POJ 28-883 (40.3%), B43-380 (39.8) had higher reduction for NMC under drought condition. Under salinity Co-canes Co 98014, Co 0118, Co 15023, Co 0238, Co 05011 and Co 06034 performed better under 4 dSm^{-1} and 8 dSm^{-1} saline treatment. A total of 1084.51 quintals of breeder seed was sold from on farm and 1098.15 quintals from seed famers attached with centers Farmers Participatory Seed Production (FPSP) programme during autumn season to the various stakeholders of the country. Cent percent area under autumn seed crop at the centre was transplanted using settling transplanter and a total of 20630 settlings of varieties Co 0118, Co 0238 and Co 12029 were produced and sold to the various stakeholders of the region for promotion of STT. Under RKVY seed project a total of 3, 00,000 settlings were raised at farmers field for the planting of 40-42 acres of healthy seed. Under NFSM project nearly 8500 quintals of Breeder seed was produced in 10 ha area.

A total of 786 clones, comprising C_1 trial clones, PZVT, preliminary and ISH clones, were screened against CF08 and CF09 pathotypes by plug method and 365 clones identified as R/MR, 170 MS and 251 S/HS to red rot.

Imparted two training programmes of one day to 165 sugar mill officials and farmers of Haryana state on healthy seed production and maximization of sugarcane yield and five days training to 20 farmers of Uttar Pradesh. A brain storming session was attended by the 80 progressive farmer and Sugar mills officials of SSM, Yamunanagar at ICAR-SBIRC, Karnal.

ICAR-SBI,RC, Kannur

The world collection of Sugarcane germplasm comprising 3373 accessions were maintained free of major diseases of sugarcane in field gene bank at ICAR-SBI, Research Centre, Kannur. The germplasm was monitored regularly for diseases and pest and the species clones were evaluated under the unprecedented flood situation for internode length and thickness under pre- and post flood season and for leaf drying. To compliment the field gene

bank *Saccharum officinarum* (115) and Indian hybrids (12) clones having poor crop stand in the field are multiplied *in vitro* through meristem culture and maintained through sub culturing. As a part of documentation three digital catalogues of *Saccharum* species clones *viz.,1. S. robustum, 2. S. sinense, 3. S. barberi* were brought out. For identifying suitable biocontrol agent for diseases, in dual culture study, bacterial isolates PF 4 and PF 59 was most effective against *Fussariumsacchari*whereasthe bacterial isolate BC 29 was found most effective against set rot pathogen *Ceratocystis paradoxa*

ICAR-SBI, RC, Agali

At Research Centre, Agali, a total of 611 germplasm flowered with a flowering intensity of 44.28%. A total of 170 crosses were made during 2019 season. Sugarcane breeders from 12 AICRP(S) centre utilized the NDH facility. A total of 102 clones were evaluated in clonal nurseries. Two clones in first clonal nursery (Agl2018-27, Agl2018-35) and one clone in second clonal nursery (Agl2019N-42) recorded higher sucrose% at 8m than the standards with R to red rot. Under the DUS testing scheme, a total of 236 reference varieties were clonally maintained at Agali Centre and conducted DUS test for three farmers' variety.

Extension

The outreach programmes included one sugarcane research and development workers meeting, nine national level training programs, thirty-four two-days training programs, DSD sponsored one-day training program and fourteen exposure visits. Five frontline demonstrations were conducted in farmers' fields.

The Institute participated in Agri-Intex 2019 at CODISSIA Trade Fair Complex, Coimbatore by putting up a stall depicting package of practices for sugarcane cultivation.

'Cane Adviser', an android mobile app on sugarcane containing information on state-wise sugarcane varieties, crop production technologies, crop protection technologies was made available in google playstore in three languages for free download. Total downloads are 8716 from 61 countries and the number of hits are 131110 with 49611 (37.84%) on crop production, 42166 (32.16%) on crop protection, 27182 (20.73%) on sugarcane varieties, 9227 (7.04%) on fertilizer schedule and 2924 (2.23%) on *Saccharum* species.

5. RESEARCH ACHIEVEMENTS

5.1 CROP IMPROVEMENT

5.1.1 BREEDING

New Varieties

Co 11015 (Atulya)

Co 11015 is notified for the state of Tamil Nadu as a short duration maturing variety by the Central Varietal Release Committee. This variety was evolved through hybridization and selection from the cross CoC 671 x Co 86011 at ICAR-Sugarcane Breeding Institute, Coimbatore. Performance of Co 11015 was tested in the station trials at ICAR-SBI, Coimbatore and in different factory locations in Tamil Nadu under Institute – Industry Collaborative project supported by SISMA TN, Chennai. In station trials, it recorded a cane yield of 135.70 t/ha, sucrose % of 21.46 and sugar yield of 20.09 t/ha. In trials conducted in Tamil Nadu during 2017-2018 and 2018-2019 seasons, Co 11015 recorded a mean performance of 142.72 t/ha of cane yield, 20.22% sucrose and 20.16 t/ha of sugar yield. The increase over the standard Co 86032 for cane yield, sucrose % and sugar yield were 10.23%, 9.66% and 20.13% respectively and the differences were significant. Co 11015 possesses A_1 quality jaggery. Its high early sugar accumulating potential is expected to benefit the state by improving sugarcane productivity as well as sugar recovery. The first reports of big mill tests conducted by the sugar factories are encouraging with 0.4 to 1.33 units higher sugar recovery over Co 86032 and yield increase of 3-6 t/ac. The variety is characterized by erect medium thick light purple canes with prominent corky patches, light greenish brown dewlap, transitional ligular process, open canopy with erect to tip droopy young leaves and curved older leaves.

Co 12009 (Sankalp)

Co 12009 is identified for release in Peninsular Zone of India as a midlate maturing variety by the Varietal Identification Committee of AICRP(S). This variety was evolved through hybridization of [{(Co 7201 x (Co 62174 x SES 91)} x (Co 88037)] x Co 62198. This is a high yielding midlate maturing sugarcane clone suitable for cultivation in Peninsular zone comprising parts of Andhra Pradesh, Chhattisgarh, Gujarat, Karnataka, Kerala, Maharashtra, Madhya Pradesh, Tamil Nadu and Telengana. This clone recorded sugar yield of 17.31 t/ha at 360 days across the zone with an overall improvement of 10.76% for sugar yield over the best midlate standard Co 86032. Its mean cane yield was 119.65 t/ha and showed an improvement of 9.0% over the best standard Co 86032 (109.73 t/ha). Co 12009 is an excellent ratooner with an improvement of 13.70% and 10.43% for sugar yield and cane yield respectively over Co 86032. The average sucrose % of Co 12009 was 19.91 which was 1.87% higher than of Co 86032 and the mean Pol% in cane was 15.47% which was 2.25% better over Co 86032. The variety has a new genetic base involving *S. spontaneum* clone SES 91. It has an impressive field stand, early vigorous growth, high single cane weight, dark green foliage and tall canes with long internodes and is resistant to red rot (Nodal).

Fig. 2. Field view of Co 11015

Fig. 3. Field view of Co 12009

Breeding superior sugarcane varieties of different maturity with improved cane yield, quality and resistance to biotic and abiotic stresses

Breeding sugarcane varieties for tropical region

(G. Hemaprabha, R.M. Shanthi, S. Alarmelu, P. Govindaraj, A. Anna Durai, K. Mohanraj, C. Appunu, S. Karthigeyan, R. Karuppaiyan, A.J. Prabakaran, C. Mahadevaiah, V. Sreenivasa, S. Sheela Mary, T. Lakshmi Pathy, H.K. Mahadevaswamy and V. Vinu)

Hybridization (2019 season)

The flowering season 2019 was excellent for flowering and 287 clones out of 340 clones housed in the Arrowing Plot flowered. A total of 402 crosses were effected including 280 biparental crosses, 112 poly crosses and 10 selfs. In addition, 73 GCs were collected. The crosses involved promising/ potential tropical and sub-tropical parents, genetic stocks, and exotic clones based on yield, quality and special characters. The more frequently used parents were Co 12009, Co 15027, Co 11015, CoVC 14061, Co 12014, Co 13018, Co 14020, Co 86032, Co 0238, Co 12029, Co 13034, Co 0239, Co 0118 and selected intergeneric and interspecific hybrids, 12 red rot resistant and 10 drought tolerant clones. Two crosses were effected using *S. spontaneum* (IND 08-1500) collection of Rajasthan.

(S. Alarmelu, P. Govindaraj, A.J. Prabakaran, A. Anna Durai, R. Karuppaiyan, C. Appunu, K. Elayaraja and H.K. Mahadevaswamy)

Ground nursery (2019)

Fluff of the crosses effected during 2018 hybridization were raised in large numbers and about 30,000 seedlings from 81 crosses and 32 general collections were field planted in the ground nursery. Growth and establishment of seedlings from 44 crosses are good to assess cross performance for family selection.

(G. Hemaprabha, R.M. Shanthi, S. Karthigeyan, K. Mohanraj, C. Mahadevaiah, V. Sreenivasa, S. Sheela Mary, T. Lakshmipathy and V. Vinu)

Ground nursery (2018)

Twenty thousand seedlings from 90 biparental crosses, four polycrosses and six GCs were planted in the ground nursery. Two thousand seedlings from 18 crosses were assessed for their visual stand, cane diameter, height and HR brix %. Two crosses (Co 86032 x SP 80-185) and (Co 86032 x Co 0238) recorded an overall mean brix of 18.85 % and 18.60 % at 240 days. Four clones which had HR brix in the range of 18.0-19.0 were forwarded for further testing under short duration group. Progenies of two crosses *viz.*, (Co 16001 x Co 10033) and (Co 8371 x CoVc 14061) showed less variation for cane color. Both the crosses had uniform and large proportion (68.0 %) of yellow green colored internodes. The cross Co 86032 x SP 80-185 had more red purple progenies with different purple shades. Canes of cross Co 8371 x CoVc 14061 were thick.

(S. Alarmelu, P. Govindaraj, A.J. Prabakaran, A. Anna Durai, R. Karuppaiyan, C. Appunu, K. Elayaraja and H.K. Mahadevaswamy)

I Clonal Trial

A total of 1360 genotypes are under evaluation. A part of the entries were evaluated for yield and quality parameters at 240 days. Two crosses *viz.* Co 10033 x CoC 671, 81V48 x Co 10015 gave more progenies combining high NMC (>10/ clump) and HR brix (>21.0%).

(G. Hemaprabha, R.M. Shanthi, S. Karthigeyan, K. Mohanraj and C. Mahadevaiah)

II Clonal Trial (Trial -1)

A total of 642 genotypes are under evaluation in second clonal trial along with four checks in Augmented RCBD. The best check at 300 days was Co 11015 with a mean sucrose of 21.46% followed by CoC 671 (20.65%). Among the test clones 37 were superior to Co 86032 (17.65%) and on par with the best standard. Out of 400 clones tested for red rot resistance by CCT method, 182 were R/MR, 100 were MS. The crosses *viz.* Co 86032 x 85 R 186, Co 0240 x ISH 176, Co 0240 x Co 0212 and Co 99006 x Co 06032 had higher proportion of MR progenies. The crosses *viz.* CoSnk 03077 x Co 11015, Co 99006 x

Co 94008, CoSe 95422 x Co 775 and Co 0240 x Co 0218 combined red rot resistance and early high sucrose content.

(G.Hemaprabha, R.M. Shanthi, S. Karthigeyan and K. Mohanraj)

II Clonal Trial (Trial -2)

Seven hundred and fifty entries were evaluated along with three standards in Augmented RCBD. In all, 20 % of clones had thick canes. Thirty nine clones recorded above 18.0% sucrose at 240 days and 19 clones recorded juice sucrose above 20.0 % in comparison with the standard CoC 671(19.26 %) at 300 days. Among 350 clones evaluated for red rot resistance through CCT, 190 were MR and 68 were R types.

(S. Alarmelu, P. Govindaraj, A. Anna Durai, R. Karuppaiyan and C. Appunu)

Pre Zonal Varietal Trial

Cane yield and quality: Sixty-five test entries and four standards (Co 86032, Co 99004, Co 09004 and CoC 671) were evaluated in RBD trial with two replications. Ten clones had good cane population at 300 days. CoC 671 was the best check with juice sucrose of 20.04%. Among the 65 entries, 18-108 recorded the maximum juice sucrose of 20.10% followed by 18-116 (19.91%), 18-158 (19.88%), 18-67 (19.81%) and 18-23 (19.69%) and 48 were R and five were S to red rot by nodal method of inoculation. Twenty-nine clones were R/MR and 23 were MS by plug method. Twenty-eight promising selections were made at 300 days based on quality and yield traits.

(S. Alarmelu and A. Anna Durai)

Multiplications of Pre-Zonal Varietal Trial

A total of 117 entries are under multiplication. Based on juice quality estimation at 300 days, field stand and red rot resistance, selection will be effected to lay out the PZVT (2020-21)

(G. Hemaprabha and V. Sreenivasa)

Screening for diseases

Red rot: From 75 PZVT clones, including 61 clones of 2018 series and 14 clones of 2017 series screened under field conditions with CF06 pathotype by plug and nodal methods, 62 were identified as R by nodal method and 39 as R/MR by plug method.

(P. Malathi)

Smut: Totally, 61 PZVT entries were evaluated against sugarcane smut. Among the 61 entries, nine *viz*., 18-008, 18-020, 18-034, 18-058, 18-067, 18-091, 18-096, 18-108 and 18-161 were identified as resistant, whereas seven clones *viz*., 18-003, 18-072, 18-117, 18-125, 18-134, 18-144 and 18-166 were identified as moderately resistant.

(A. Ramesh Sundar)

Botanical characterisation and DNA Finger printing of elite selections and varieties

Botanical description of 'Co' canes of 2019 (Co 19001 to Co 19015) from Coimbatore was carried out based on 34 morphological traits with their distinguishing features.

DNA fingerprinting: The DNA profiles of Co 12009 and Co 13034 identified to be promising based on AICRP trials in Peninsular Zone and North Western Zone were generated and were included in the release proposals. DNA profiles of CoA 14321 and CoA 14323 from RARS, Anakapalle, G2005-047 from TNAU Sugarcane Research Station Melalathur, CoH 09262 and CoH 11261 from HAU Regional Research Station, Uchani were generated using sugarcane specific STMS primers on payment basis and were sent to the respective centres.

(G. Hemaprabha and H.K. Mahadevaswamy)

Identification and testing of short duration sugarcane clones

In order to identify source of extra early maturing high sugar clones, seven clones of *S. robustum*, 19 *S. sinense* clones, 32 *S. barberi* clones, 38 *S. officinarum* clones, 152 parental clones maintained in arrowing plot and 102 selection maintained in clonal nurseries (total 350 clones) were evaluated for juice quality parameters at 8th month after planting. Among the species clones and parental clones, none qualified the criteria of short duration clones (>18% sucrose and >85% purity at 8th month). Two selections from second clonal nursery (Agl2018-35 and Agl2018-35) recorded 20.58% and 19.27% sucrose at 8th month. The former

was MS and latter was R to red rot. In addition, 56 perspective high sugar extra early maturing clones identified by breeders of ICAR-SBI were pooled and planted in multiplication plot (during July 2019) for further evaluation in the next season.

(R. Karuppaiyan and G. Hemaprabha)

Evaluation of elite clones for identifying promising location specific sugarcane varieties

Maharashtra

Drought experiment: Eighteen drought tolerant clones and standard varieties (Co 86032, CoM 0265 and local standards) were evaluated in RBD with two replications at four locations in Maharashtra *viz.*, M/s Sanjivani Sahakara Sakkara Kharkhana, Kopargaon; M/s Samarth Sahakara Sakkara Kharkhana, Jalna; M/s Bhaurao Chavan Sahakara Sakkara Kharkhana, Nanded and M/s Vasanthdada Sugar Institute, Pune during 2018-19. The drought stress was imposed by withholding the irrigation from 90 days after planting in first plant crop trial and the duration of drought was 60 days (Kopargaon), 42 days (Jalna), 45 days (Nanded) and 30 days (VSI). Among the standards, CoM 0265 recorded the maximum pooled mean yield of 91.77 t/ha followed by Co 86032 (73.21 t/ha) and hence, CoM 0265 is considered as the better standard in the trial. At Kopargaon, test entries *viz.* Co 98017 (69.91 t/ha), Co 85019 (65.12 t/ha), Co 14005 (62.98 t/ha) and Co 92020 (60.62 t/ha) recorded numerically higher cane yield and numerically superior sucrose percent as compared to standard CoM 0265. Similarly, Co 06022 (90.62 t/ha) and Co 98017 (90.09 t/ha) recorded numerically higher cane yield as compared to standard, CoM 0265 (88.06 t/ha) at Nanded. Based on overall mean, Co 85019 recorded superior cane yield of 99.95 t/ha with the mean sucrose of 17.59% at harvest (Table.1).

Plant-II Trial and Ratoon Trial are being evaluated in 2019-20 in all above locations and the drought was imposed for 90 days by withdrawing irrigation from April 01, 2019 to May 30, 2019. Based on overall crop stand during drought and recovery from drought, Co 98017, Co 85019 and Co 14005 exhibited better crop stand compared to the standard Co 86032.

Dalmia Sugars, Kolhapur

New varietal trial: Juice analysis was carried out at 9th month instead of 8th month due to excess

Table 1. Performance of selected best performing entries in Maharashtra

Entries	Yield (t/ha)					Sucrose (360 days)				
	Kopargaon	Jalna	Nanded	Pune	Mean	Kopargaon	Jalna	Nanded	Pune	Mean
Co 85019	65.12	97.13	87.10	150.47	100.00	16.90	18.40	16.80	18.20	17.60
Co 14005	63.00	69.80	-	137.07	90.00	16.40	18.10	-	19.80	18.10
Co 06022	41.90	91.20	90.60	137.64	90.30	16.40	19.90	17.70	19.40	18.30
Co 92020	60.60	88.10	67.70	133.24	87.40	16.20	19.10	17.70	19.90	18.20
Co 98017	69.90	76.70	90.10	104.90	85.40	16.40	19.10	17.70	19.00	18.00
Standards										
CoM 0265	56.70	99.90	88.10	122.50	91.80	16.30	17.40	16.60	16.90	16.80
CoC 671	39.50	80.80	80.80	97.47	74.60	17.00	20.40	17.50	20.20	18.80
Co 86032	47.90	70.20	72.20	102.60	73.20	16.80	18.80	17.60	18.10	17.80
Co 09004	48.10	65.90	-	60.76	58.30	18.90	20.60	18.10	21.30	19.70
Mean	49.00	79.80	78.00	102.70	76.40	16.80	19.00	17.50	18.60	18.00
C.D.	15.90	16.25	19.30	15.96		0.99	0.71	0.80	1.48	
C.V.	16.20	19.70	11.60	7.58		5.94	4.38	2.19	3.75	

rainfall followed by flooding in Kolhapur, Maharashtra.

Second plant trial: Juice quality analysis carried out in second plant trial consisting of 12 test entries and two standards at 270 days revealed that the test entries Co 09004 (16.97%), Co 11015 (16.43%) Co 06030 (16.20%), Co 0212 (16.13%) and Co 06022 (16.11%) recorded numerically higher sucrose% than trial standards Co 86032 (15.34%) and Co 92005 (15.90%). For number of millable canes at 270 days, Co 11015 is the only entry with numerically higher canes than both the standards.

Ratoon trial: In the ratoon trial, Co 09004 (19.36%), Co 13006 (18.42%) and Co 06022 (17.06%) recorded numerically higher sucrose% than standards Co 86032 (17.02%) and Co 92005 (17.23%) at 270 days. For NMC data at 270 days Co 06022 (113.73) and Co 0212 (112.50) were the best entries and were numerically better than trial best standard Co 86032 (105.56).

(C. Mahadevaiah and V. Sreenivasa)

KCP Sugars, Vuyyuru, Andhra Pradesh

Thirteen Co canes along with the check CoV 09356 were evaluated for cane and juice quality traits at 11th month at KCP Sugars, Vuyyuru, Andhra Pradesh. The entry Co 11015 recorded the highest sucrose of 20.47% followed by Co 09004 (19.69%). In addition, five entries showed higher sucrose % than the local check CoV 09356 (19.07%). Highest single cane weight of 1.31 kg was recorded in the entry Co 14008 followed by Co 11015 (1.25 kg) compared to CoV 09356 (0.96 kg).

(K. Mohanraj and T. Lakshmi Pathy)

SNSI, Belagavi, Karnataka

New varietal trials: second plant and ratoon trial: Twenty eight clones viz., 2012-145, 2012-147, 2012-44, 2012-92, 2013-103, 2013-129, 2014-154, 2014-177, 2014-99, Co 13003, Co 13006, Co 14010, Co 14011, Co 15001, Co 15002, Co 15003, Co 15005, Co 15007, Co 15008, Co 15009, Co 15010, Co 15011, Co 15013, Co 15018, Co 15020, Co 15022, Co 18023 and Co 18024 along with standards Co 86032 and CoC 671 were planted in RBD with two replications at SNSI, Belagavi. Juice quality at 240 days was done in November 2019 and analysis of data is under progress. Last year plant crop is maintained as ratoon trial and juice analysis will be done at 300 and 360 days as per schedule.

Drought trials: second plant and ratoon trial: Twenty one clones viz., Co 0303, Co 05001, Co 06015, Co 07015, Co 08020, Co 09004, Co 10033, Co 12007, Co 13003, Co 13006, Co 14011, Co 85019, Co 90003, Co 92002, Co 92013, Co 92020, Co 93009, Co 94005, Co 95020, Co 98008 and Co 98017 along with two standards CoC 671 and Co 86032 were planted in RBD with two replications. Drought was imposed on 65th day old crop by withholding irrigation for 60 days (i.e. upto 125 days). Juice analysis at 240 days was completed and data analysis is in progress. Last year plant crop trial is maintained as ratoon trial.

(V. Sreenivasa and H.K. Mahadevaswamy)

Nutritional evaluation, improvement and utilization of newer feed resources for livestock production ICAR-IGFRI

The planting material was supplied to ICAR-IGFRI for trials on nutritional quality at IGFRI, Jhansi.

(Jhansi- A.K. Misra, S.B. Maity, K. K. Singh, Sultan Singh, Vijay Kumar Yadav, P. Koli ICAR-SBI, Coimbatore- P. Govindaraj and R. Karuppaiyan)

Identification of superior sugarcane varieties suitable for different agro-eco climatic regions of Tamil Nadu (ART/MLT trials in collaboration with TNAU)

Adaptive Research Trial (ART)

The trial was modified with limited number of entries to be tested along with standard variety of Tamil Nadu Co 86032 and recent releases from different sugarcane research institutions located in Tamil Nadu *viz.*, Co 11015 from ICAR-Sugarcane Breeding Institute, Coimbatore, CoC 25 from Sugarcane Research Station (SRS), Cuddalore, TNAU Si 8 from SRS, Sirugamani and CoG 6 from SRS Gudiyatham. Four entries selected for this trial are Co 14016, Co 15007, C 30010 and Si 10-12. Planting of the new trial involving test entries and the standards will be

taken up during the first fortnight of January 2020 at six locations *viz.*, Sathyamangalam, Appakudal, Odapalley, Udumalpet, Theni and Pugalur.

Pilot study on juice quality characters of the 13 test entries including Co 06031, Co 11015, Co 13003, Co 14016, Co 15007, C 30010, C 31098, G 08041, G 08019 and G 08028, SI 10-12, SI 10-02, SI 10-01 and Si 10-027 were analysed for juice quality at 9th month of maturity along with five standards viz., Co 86032, Co 11015, CoC 24, TNAU Si 8 and Co 09004 at Sakthi Sugars, Appakudal. Co 11015 (16.88 %) was the best standard with respect to sucrose content at 9th month of crop duration. None of the entries was superior to Co 11015 with respect to sucrose content. Two entries *viz.*, Co 13003 (15.84) and Si 10-01 (14.74) were superior to Co 86032 for sucrose content. Among the standards, Co 86032 was the best with respect to cane characters with single cane weight of 2.16 kg. Among the test entries, four entries *viz.*, Si 10-27 (2.88 kg), Si 10-02 (2.47 kg), Co 06031 (2.37 kg) and SI 10-12 (2.33 kg) were found superior to the best standard Co 86032. Among the four trials planted in the Coimbatore region, trial could not be established at Amaravathi Cooperative Sugar Ltd., Udumalpet due to severe drought in the region.

Multi-location trial (MLT)

Six entries *viz.*, Co 14004, Co 14012 and Co 18023 from ICAR-SBI, C 2014-516 and C 2014-436 from SRS, Cuddalore and G 10045 from SRS, Gudiyatham were finalized for conducting MLT during the year 2020 at ICAR-SBI, Coimbatore and SRSs, Cuddalore, Gudiyatham and Sirugamani. The trial will be planted during II week of January 2020 at ICAR-SBI Coimbatore. The seed materials of the three nominations from ICAR- SBI *viz.*, Co 14004, Co 14012 and Co 18023 will be supplied to the other centers during the first fortnight of January 2020.

(A. Anna Durai and C. Mahadevaiah)

Enhancement of sugarcane germplasm and development of pre-breeding materials

Cytological behaviour in the interspecific hybrids derived with different cytotypes of *S. spontaneum*

Cytological studies: A total of 26 F_1 hybrids derived from seven interspecific crosses involving two commercial varieties of sugarcane as females (BO 102 with 2n= 108 and Co 1148 with 2n=114) and three cytotypes of *S. spontaneum* (2n=56, 60 and 64) as males were studied for meiotic behaviour. The meiotic analysis indicated predominance of bivalents irrespective of the chromosome number of the hybrids. The rare hybrid (04-1492) obtained with 2n+n transmission (2n=142) exhibited regular meiotic behaviour. However, abnormalities were observed with higher frequency of laggards (5.2) in the hybrids derived with the cytotype 2n=56 of *S. spontaneum*.

The F_1 hybrids derived from cross between commercial varieties and different cytotypes of *S. spontaneum* were back crossed with commercial hybrids and meiotic studies of these six BC_1 hybrids indicated the predominance of bivalents. Predominance of secondary association of bivalents was observed in the BC_1 hybrids derived from the F_1 involving 2n=40 *S. spontaneum* cytotype.

Molecular analysis: Molecular analysis for confirming the hybridity of the putative hybrid 04-1492 with 2n+n transmission was carried out with 14 SSR primers. Among 180 fragments generated by 14 primer pairs, 63 fragments were monomorphic (35%) and 117 fragments were polymorphic (65%). The primers viz., SOMS 116, SOMS 132, SOMS 61, SOMS 154, SOMS 158, SOMS 151, SOMS 103, SOGL 5, SOMS 29, SEGMS 46, SOMS 152 and SOMS 148 generated 13-18 fragments. Among 117 polymorphic fragments obtained from 14 primers, 33 female and 8 male specific fragments were generated (Fig. 4). Five primers *viz.*, SOMS 103, SOMS 116, SOMS 148, SOMS 151 and SOMS 155 generated both male and female specific fragments. The female and male specific fragments were presented in the ratio of 4.1:1. About 80 backcross hybrids were planted for clonal evaluation. Ten backcrosses were established with F_1 hybrids involving the cytotype 2n=40, 60 and 80.

(A. Suganya and R. Karuppaiyan)

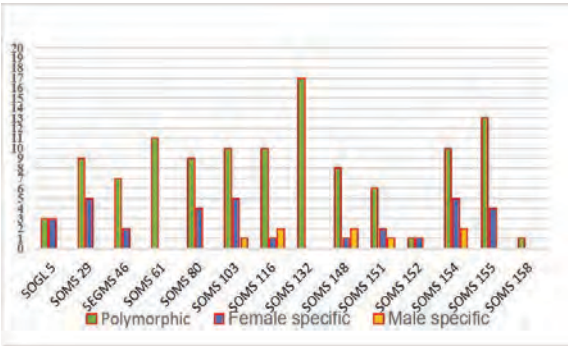


Fig. 4. Male and female specific fragments in the hybrid 04-1492 with 2n+n transmission

Development of Multiparent Advanced Generation Inter-Cross (MAGIC) population for drought tolerance in sugarcane

Evaluation of four way cross population for drought tolerance

Forty clones of fourway cross population along with checks Co 86032, Co 06022 and Co 775 were evaluated for cane and juice quality traits at 10th month. The clones FWC-34 recorded the highest sucrose of 17.56% followed by FWC 17 (16.83%) under drought. Visual scoring of clones under drought showed that the clones *viz.*, FWC-25, FWC-28, FWC-31, FWC-10, FWC-42, FWC-43 and FWC-26 were drought tolerant. The clones FWC-31, FWC-29, FWC-15, FWC-33, FWC-14, FWC-32, FWC-6, FWC-8, FWC-42, FWC-4, FWC-34, FWC-16, FWC-26, FWC-43 and FWC-30 were identified as red rot resistant under CCT.

Planting eightway cross population

A total of 1550 seedlings from eightway cross population were planted in the field for further evaluation.

(*K. Mohanraj, G. Hemaprabha and S. Vasantha)*

Collection, maintenance, evaluation and cataloguing of sugarcane germplasm at Coimbatore

Collection of germplasm

An exploration was conducted in the Western Ghats covering the states of Kerala, Tamil Nadu, Karnataka, Goa and Maharashtra. Wide spread distribution of *S. spontaneum* was observed throughout the Western Ghats in all the states

Fig. 5. IND 19-2020 a S. officinarum clone with tall and thick cane collected from home garden

Fig. 6. A large population of IND 19-2018 (S. spontaneum) in the river bed

Fig. 7. High biomass E. arundinaceus (IND 19-2013) collected from Western Ghats (Kerala)

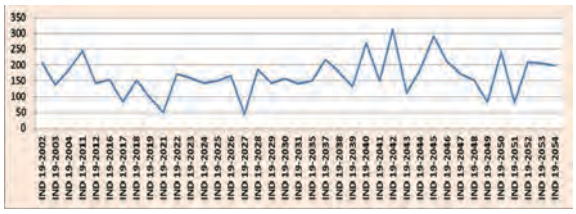


Fig. 8. Variability for plant height (cm) among Saccharum sponteneum collections

while *Erianthus arundinaceus* was mostly found in Kerala and Tamil Nadu. A total of 39 *S. spontaneum* (3 in Tamil Nadu, 5 in Kerala, 9 in Karnataka, 4 in Goa and 18 in Maharashtra), 11 *E. arundinaceous* (3 in Tamil Nadu, 6 in Kerala, 1 in Goa and 1 in Maharashtra), three *E. bengalense* (1 in Tamil Nadu and 2 in Goa) and 2 *S. officinarum* (one each in Tamil Nadu and Karnataka) were collected (Fig. 5-7). High variability was observed among the 39 new *S. spontaneum* collections for different traits like plant height (312 to 45 cm with the Standard Deviation (SD) of 58.89 cm) (Fig. 8), leaf length (102 to 21 cm with the SD of 20.21 cm), leaf width (1.3 to 0.2 cm), peduncle length (59 to 16 cm), arrow length (46 to 14 cm with the SD of 8.14 cm), internode length (15.3 to 4.5) and cane diameter (0.8 to 0.3 cm with the SD of 0.11 cm). A total of 11 *E. arundinaceus* were collected from the Western Ghats covering Tamil Nadu, Goa, Kerala and Maharashtra which showed higher range for plant height (631 to 192 cm with the SD of 140.17 cm), leaf width (5.7 to 3.8 cm with the SD of 0.51 cm) and internode length (8.5 to 17 cm with the SD of 2.79 cm). All the 55 collections were planted in glasshouse for quarantine.

(P. Govindaraj and H.K. Mahadewaswamy)

Maintenance at Coimbatore and Wellington

At Coimbatore, 2140 accessions were maintained which included *S. spontaneum* - 1620, *E. arundinaceous* - 215, *Erianthus* spp. - 172. (*Erianthus* spp. total = 387 Nos.), Allied Genera - 59, improved *Erianthus* for fibre – 48 and *Saccharum* clones 26 and 47 accessions from Arunachal Pradesh at IARI Regional Station, Wellington. Fifty-five new collections *viz.*, *S. spontaneum*-39, *E. arundinaceous* - 11, *Erianthus* spp. – 3. and *S. officinarum* types - 2 from the exploration in Western Ghat areas of Tamil Nadu, Kerala, Karnataka, Goa and Maharashtra states were replanted in pots and maintained in glasshouse for quarantine (Fig. 9).

Fig. 9. Establishment and growth of new collections from Western Ghat areas of Tamil Nadu, Kerala, Karnataka, Goa and Maharashtra

(S. Karthigeyan, S. Sheelamary and M. Sivaswamy-IARI, RC Wellington)

Maintenance of commercial hybrids and genetic stocks

A total of 1868 'Co' canes are maintained under commercial hybrids and genetic stocks. The individual composition of clones under each group is as follows:

Group	No of clones maintained
Co canes	1313
Co allied	17
Foreign hybrids	52
ISH	284
PL 480	58
CD	86
IGH	38
IA	13
GU	1
IND	6
Total	1868

(R.M. Shanthi and C. Appunu)

National Active Germplasm maintenance

The seed materials received from different centres were submitted to quarantine process and periodical monitoring was done for their growth. During this period 240 notified and registered genetic stocks were maintained in the field (2018-19). Index numbers were assigned to three clones namely Co 12009 (Coimbatore), Co 13034 and Co 13035 (Karnal). The clones CoN 13072, CoC 13335, G 2005044, CoH 13263, CoH 14261 and CoH 06266 were submitted to quarantine process for inclusion in NAG

(C. Jayabose and S. Alarmelu)

Characterization, Evaluation and Cataloguing

Flowering behaviour of S. Spontaneum

Characterization of germplasm: Disease free 24 clones collected from Assam and West Bengal states were characterized using 39 morphometric traits. Among the characterized clones IND 18-1939 showed the highest HR brix of 15.2% while the lowest (5.0%) was observed in IND 18-1980 and 1986. Ligule hair was present in all clones except IND18- 1984 and 1986. The cross section of internodes in 15 clones were found to be hallow in IND 18- 1990, IND 18–1989, IND 18-1987 and IND 18-1986, IND 18- 1985 having pithy internodes and clones like IND 18 1994 and IND 18 1993 exhibited solid internodes. Regarding internodal shapes 11 clones with conoidal, 8 with bobbin shaped, four with cylindrical internodes (IND18-1940,1948, 1958 and 1962) and one with rambhoid type (IND 18-1989) were observed.

Out of the 1620 *S. spontaneum* planted in the field at Coimbatore (Fig. 10), 925 clones flowered during this season; Out of which 295 accessions flowered from November 15th to December 15th, 215 accessions flowered from October 15th to November 14th, 159 accessions flowered from 15 September to 14 October^{h}, 181 accessions flowered from August 15th to September 14th and 75 accessions flowered from 15 July to 14 August 2019.

Flowering behaviour of Allied Genera: Studies on the flowering behavior of allied seven genera a total of 58 clones were flowered till 2nd week of December and the short blade stage was noticed in some clones. Among the 172 Erianthus species clones 145 were flowered till December 2nd week.

Fig.10. Profuse flowering in Saccharum spontaneum accessions under Coimbatore condition during the year 2019

(C.Jayabose and S. Karthigeyan)

Cryopreservation

Standardization of suitable media composition for regeneration of S. spontaneum: In vitro multiplication of *S. spontaneum* plantlets at various concentrations (100 µl/L, 200 µl/L, 400 µl/L, 500 µl/L, 1000 µl/L) of BAP and (15 µl/L, 133.2 µl/L) of kinetin were amended in the meristem culture medium. The time taken for shoot initiation in different hormonal concentration were studied and initiated shoots were transferred to shoot multiplication medium and the observation was recorded.

Cryo treatment for various explants of S. spontaneum: Different procedures (vitrification) were followed for the different germplasm acessions with shoot apices, nodal buds and meristem derived axillary buds of *S. spontaneum*. The control samples of nodal buds showed growth and the samples treated in Liquid Nitragen showed only the phenolic excretion. And it was known that the most intensive period of phenolic excretion preceded the most intensive period of shoot formation. Thus, the culturing time should be needed more for the buds to show growth. In case of shoot apices, even the control smaples failed to show growth and thus, the composition of media should be improved and optimized beforetesting for cryopreserved samples. The control samples of meristem derived axillary bud showed a good growth but the colour changed for the samples treated with LN from green to white.

(C.Jayabose)

Cytological studies in *Saccharum* and allied genera – *S. spontaneum*

Somatic chromosome number (2n) in 86 clones of *S. spontaneum* collected from Punjab and Haryana (IND 16), Arunachal Pradesh (IND 90) and Jharkhand (IND 17) were determined (Fig.11 and Table.2).

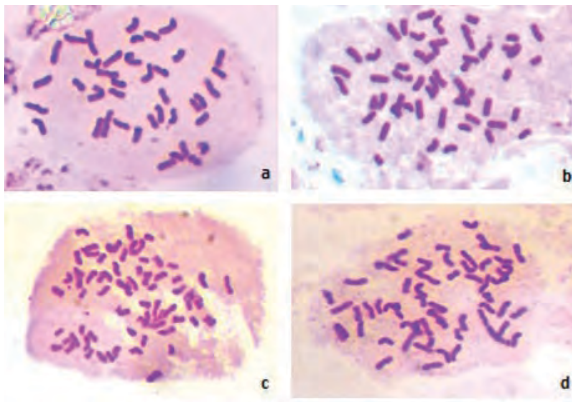


Fig.11. Somatic cell of a) IND 17-1852 (2n=40), b) IND 16-1841 (2n=54), c) IND 17-1861 (2n=70), d) IND 90-811 (2n=64)

(V.P. Sobhakumari)

Floral biological and cytological characterization of *Erianthus*

Symptom stage of flowering was observed in *E. arundinaceus* clones from 10.8.2019 onwards. Selfs were made to study seed set in 15 clones *viz.* Mythan A, C, Mindana, Fiji 10, Eri. 2384, IND 84-478, NG 77-182, EA Sarkender, EA Munja, EA Layalpur, SES 153, SES 288, EA Thornless, Kwangdong and SES 293 and fluffs were sown to raise seedlings. Cytological studies in 10 clones of *E. procerus* indicated the chromosome number of 2n=40.

(A. Suganya)

Evaluation of sugarcane germplasm for biotic and abiotic stresses at Coimbatore

Erianthus arundinaceus: Second year field trial with 215 *E. arundinaceus* germplasm clones along with standards *viz.*, SES 288 and IS 76 - 219 were screened for water deficit stress tolerance related traits. The clones were exposed to stress by withholding irrigation at the formative

Table 2. Somatic chromosome number (2n) of *S. spontaneum* clones

Clones	No. of clones	Chromosome number (2n)
IND 17-1852	1	40
IND 16-1830	1	52
IND 16-1841, 1783, 1836, 1849, 1772, 1775, 1806, 1824, 1771, IND 90-782, IND 17- 1902, 1906, 1908, 1909, 1920, 1923, 1864, 1873, 1895, 1876	20	54
IND 16- 1815, 1837, 1754, 1766, 1764, 1781, 1816, 1843, 1767, 1834, IND 90-802, IND 17-1892, 1885, 1834	14	56
IND 90-788, 795	2	58
IND 17- 1854	1	60
IND 90-822	1	62
IND 16-1845, IND 90-780, 787, 804, 769, 797, 796, 804, 811, 813, 815, 844, 807, 803, IND 17- 1913, 1925, 1926, 1928, 1930, 1871, 1865	21	64
IND 17-1862	1	66
IND 17-1911, 1914, 1915, 1861, 1866	5	70
IND 16-1835, 1848, 1770, IND 17-1891, 1917, 1929, 1863, 1853, 1857, 1859, 1858	11	72
IND 17-1867	1	74
IND 16- 1780	1	76
IND 90-755	1	90

phase and the stress progression was monitored through soil moisture content. After 80 days of withholding irrigation, 'Co' canes were found to be completely dried compared to the *Erianthus* clones. *E. arundinaceus* clones were categorised based on the leaf drying and about 11 clones were found to be highly tolerant with 0% leaf drying and 18 clones each in tolerant and moderately tolerant with 10-20% leaf drying. The tolerant clones maintained a high chlorophyll fluorescence (Fv/Fm), low canopy temperature (24°C -25°C), higher leaf relative water content (75- 80%) and a lower leaf rolling index. Data on biomass, leaf area index and single cane weight were collected at the maturity phase to analyse the stress tolerance index among the clones. Maximum Stress Tolerance Index (STI) was recorded in IND and SES clones (0.60 - 3.45), whereas IS and IJ collections showed STI in the range of 0.10 - 0.50.

Saccharum spontaneum: Plant height, number of tillers per plant, SPAD index and total biomass were recorded in the thirty *S. spontaneum* (ratoon crop) accessions. The SPAD index ranged from 16.40 to 36.50 having total chlorophyll content (mg/cm^2) of 0.009 to 0.033 respectively. Number of tillers per plant ranged from 24.30-247.50/ plant. The total fresh biomass ranged from 0.585 kg/plant to 11.980 kg/plant. The SPAD index of the 95 *S. spontaneum* clones planted during 2019 ranged from 12.0 to 39.3 having total chlorophyll content (mg/cm^2) of 0.005 to 0.037 respectively. In general the SPAD index of 35 and above is considered as healthy plant with green leaves having better chlorophyll content for photosynthesis.

(V. Vinu, T. Lakshmi Pathy, H.K. Mahadevaswamy, R. Valarmathi and R. Arun Kumar)

Developing trait specific genetic stocks with biotic and abiotic stress tolerance, quality and yield traits in sugarcane through pre-breeding

Identifying multi trait genetic stocks with improved *Saccharum* genetic base

One hundred clones were evaluated for yield and quality parameters at 240 and 300 days for their utilization in breeding. Forty five clones were high tillering types in comparison with the checks Co 86032 and CoC 671. At 240 days, 28 clones recorded HR brix in the range of 17.50-18.50%. Genetic stocks with appreciable cane weight and height were identified for further studies. Sixty five clones recorded more NMC and estimated cane yield above 70.00 kg/ row. Preliminary physiological observations recorded in the improved species derived interspecific clones (174) showed wide variations for relative water content (RWC), SPAD index and chlorophyll content. RWC ranged from 54.5% (PIO 88-79) to the highest of 85.2% (PIO 14-100) with a mean of 73.3%. SPAD index ranged from 19.5 (PIO99-141) to 38.7 (PIR 07-776) while chlorophyll content varied from 0.013 mg/cm^2 (PIO99-141) to 0.036mg/cm^2 (PIR 07-776) with a mean of 0.028mg/cm^2.

(S. Alarmelu, S. Sheela Mary and S. Vasantha)

Developing trait specific genetic stocks for biotic and abiotic stress tolerance utilizing novel *Saccharum* germplasm

Germplasm maintenance: A total of 293 clones consisting of 96 *S. officinarum*, 28 *S. barberi*, 9 *S. sinense*, 28 *S. robustum* and 132 interspecific hybrids and their derivatives were obtained from SBIRC, Kannur and SBIRC, Agali and planted in the field at Coimbatore for further utilization.

Red rot

At Coimbatore: Ninety-one *Saccharum* species clones were evaluated for their reaction against CF 06 pathotype of red rot pathogen *Collectotrichum falcatum.* Majority of the accessions (52) showed susceptible (S) reaction while two accessions *viz.,* NG 77-94 and 57 NG 203 exhibited highly susceptible reaction. Fifteen accessions showed moderately resistant reaction and 14 were moderately susceptible. Eight accessions *viz.,* Nargori, Mangasic, Maneria IMP 1552, Daur Kinara, Chin, Mungo 254, Kheli and Reha showed resistance reaction. Similarly, 120 inter-specific hybrids developed at SBIRC, Kannur which were found flowering were raised at Coimbatore and evaluated for resistance against red rot pathogen (CF 06).

Most of the hybrids were MR (72), while three hybrids exhibited R reaction. Other reactions observed in these hybrids were S (29), MS (11) and HS (5).

One thousand two hundred and seventy six seedlings of the crosses *viz.*, 51NG 036 x Co 88025, 51NG 159 x CP 62-23, Uber White x Co 88028, Awela Green sport x CoSe 92423, Manjuria x Co 13007, Uba white x SP 80-1848, S.O hybrid x Co 12009, Laukana15 x Co 0233, Nargori x Pathri, Dhaur Kalig x Pathri and IJ 76470 x IJ 76436 effected during 2018 flowering season were planted to raise a ground nursery in order to study these crosses for red rot resistance. Ten crosses involving four *S. officinarum* clones *viz.*, Monget gayam, Naz, IJ 76-274, and Otaheite and seven new collections of *S. spontaneum viz.*, 04-1351, 17-1920, 07-1457, 04-1369, 04-1327, 05-1416, 04-1374, and 04-1381 and eight crosses involving red rot resistant interspecific hybrids were hybridized with high quality 'Co' and 'Co' allied canes during 2019 flowering season for further improvement.

At Kannur: A total of 22 seedlings from two crosses involving Pathri were evaluated in ground nursery at SBIRC, Kannur. The HR brix ranged from 13.20 (GUK 18-527) to 18.60 % (GUK 18-520) in the cross Daur Kalig x Pathri and 9.0 (GUK 18-532) to 19.20% (GUK 18-538) in the cross Pathri x Co 62175. During the flowering season 2019, four new crosses using *S. officinarum* clones *viz.*, NG 77 221, Oramboo and NG 77-142 were made.

Drought: Forty-two crosses were made during the crossing season 2019 using the drought tolerant ISH and IGH as one of the parents. In addition, fresh crosses were attempted using basic species namely, S. *officinarum, S. robustum, S. barberi and S. sinense* clones viz., Co 12014 x NG 77-146, Co 0303 x NG 77-146, Co 17003 x Kheli, Co 89003 x IJ 76-412, Co 10017 x Gunjera, Co 8371 x IJ 76-564, Co 8371 x Kheli, Co 06022 x 77 NG 23, CoC 671 x Kheli, Co 0118 x Kheli, Co 0118 x IJ 76-564, Co 8371 x IJ 76-564, Coc 671 x IJ 76-564.

(A. Anna Durai, A.J. Prabakaran, V. Sreenivasa, H.K. Mahadevaswamy, C. Mahadevaiah, K. Mohanraj, R. Viswanathan, K. Chandran and R. Arunkumar)

Developing trait specific genetic stocks with *Erianthus* genetic base

Hybridization: Thirty-five backcrosses were made using BC_1 progenies involving *E. procerus viz.*, GU 12-16, GU 12-17, GU 12-19, GU 12-25, GU 12-37, GU 12-41, GU 12-50, and GU 12-51 as parents during the crossing season 2019. From 2018 crosses, 178 BC2 seedlings were transplanted in the field.

Maintenance of distant hybrids: A total of 580 distant hybrids and their derivatives developed over the years are planted for maintenance and further utilization.

Clonal evaluation: Forty elite clones with diverse genetic base were evaluated for cane and juice quality traits. The clone GU 15-1586 recorded the highest sucrose of 21.10% and twenty six clones recorded higher sucrose than the standard Co 86032 (18.10%). Four clones *viz.*, GU 15-96, GU 15-100, GU 15-1697 and GU13-84 recorded a single cane weight of more than 2.0 kg.

(K. Mohanraj, H.K. Mahadevaswamy and A. Suganya)

Improvement of elite interspecific hybrids derived from different cytotypes of *S. spontaneum* through nobilisation with typical clones of *S. officinarum* (2n=80)

Chromosome number of 40 clones were redetermined to confirm typical clones of *S. officinarum* with 2n=80 for further studies.

(A. Suganya, A. Selvi, P. Govindaraj and R. Karuppaiyan)

Sugarcane genomics and molecular markers

Oxidative stress tolerance in light of climate change: Gene discovery and regulation by micro RNAs in *Erianthus* sp. and *Saccharum spontaneum*

miRNA expression and validation under oxidative stress: Identified three miRNA family in the sucrose metabolism (zma-miR169o-3p, vvi-miR396a, smo-miR396) under the control conditions in *S. spontaneum,* and for the Co86032, three miRNA families miR167i-3p, miR1848, miR159b were identified. The analysis of miRNA related to sucrose metabolism showed

that miR1848 targeted sucrose-phosphate synthase and beta-fructo furanosidase; ppt-miR160e targeted the trehalose 6-phosphate synthase. Upregulation of sbi-miR397 in *S. spontaneum*; down regulation in *E. arundinaceus* and neutral regulation in Co 86032 was observed. For miRNA validation, stem loop primers were used for cDNAs preparation. MicroRNAs expression were validated using qRT-PCR.

The highest number of targets observed in Co 86032 under control conditions. Numerous miRNAs involved in the oxidative stress responsive in wild and cultivated sugarcane were also identified. Novel miRNAs showed significant changes in expression after stress treatment. Under oxidative stress, majority of the miRNAs were highly expressed in Co 86032 than wild species.

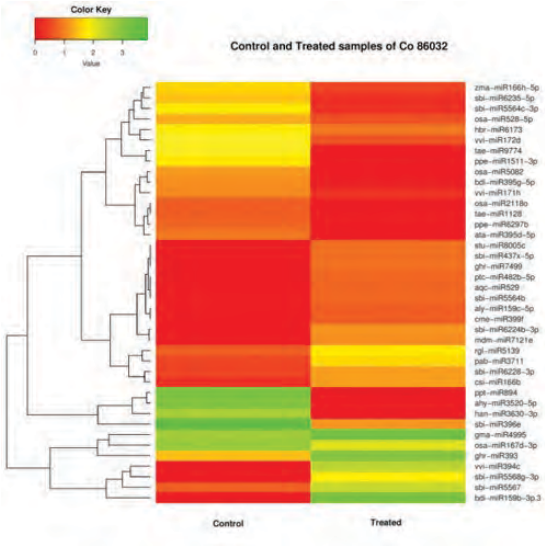


Fig. 12. Differential expression of miRNAs under Control and treated samples of Co 86032

Differential miRNA expression in Co 86032 under oxidative stress: Significantly expressed miRNAs were identified by log2fold change and below 0.05 p-values. The expression results showed 29 miRNAs up-regulated and 32 miRNAs down-regulated in both the control and oxidative stress conditions. Thus, 20 miRNAs were highly expressed in control while 9 miRNAs were highly expressed only under stress conditions (Fig.12).

(R. Manimekalai, A. Selvi and R. Gomathi)

Precise genome editing system in sugarcane CRISPR-Cas: Altering the flowering behavior of sugarcane

Isolation and expression of miRNA genes: miRNAs expression analysis at flower initiation stage showed differential expression between flowering and non flowering clones. The 20 bp region in the flowering gene to develop CRISPR-Cas construct was identified. Oligos were synthesised for the 20 bases. The vector plasmid was revived and cultured for cloning the 20 base sequence.

(R. Manimekalai, A. Selvi, S. Vasantha, K. Mohanraj and B. Deva Kumar)

Transcriptome guided mining and validation of genes, miRNAs and their potential targets for water deficit stress

Validation and identification of genes involved in stress tolerance mechanisms in tolerant and susceptible cultivars: Most significant transcripts that were expressed in 10 days stress were mined out from the transcriptome data of both varieties Co 06022 and Co 8021 which are tolerant and susceptible to water deficit stress, respectively. The candidates that were significantly up and down regulated in Co 06022 and Co 8021 as compared to their controls were identified (Fig. 13). A set of 35 genes were mined from 10

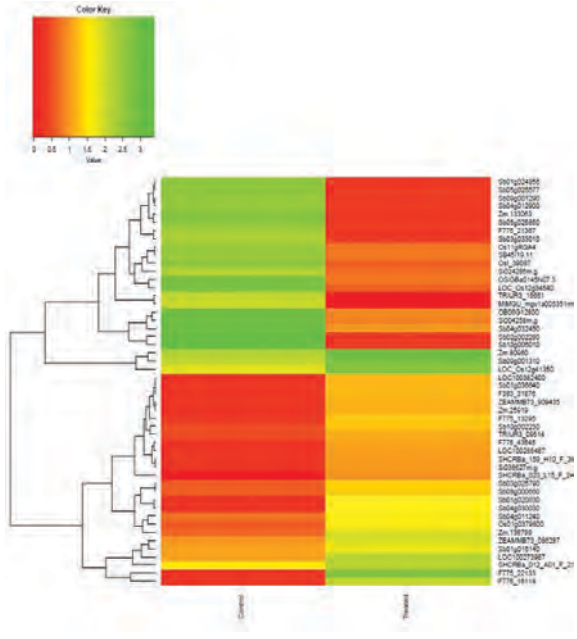


Fig. 13. Transcripts that are significantly expressed in 10 days stress in the tolerant cultivar Co 06022

days stress. In order to know their expression levels in the tolerant and susceptible cultivars at the beginning and end of stress period a comparison of expression levels at two and 10 days was performed. Of the 35 genes selected, 15 genes were upregulated in two days stress in Co 8021 and as the stress progressed to 10 days, the upregulation continued and the fold change was higher than that observed in two days stress. Significant among them were the stress related protein, putative heat stress transcription factor, bidirectional sugar transporter, NAC domain containing protein, disease resistant protein and ABA domain responsive factor. The experimental validation and comparison was carried out in the tolerant variety Co 06022 along with its control for the same set of 35 genes. Nineteen genes were upregulated in two days stress and continued to be upregulated on the 10th day of stress with increased fold change as compared to their expression in two days. Significant genes that were several fold expressed in 10th day compared to two days were ABA responsive element binding factor, disease resistant protein, growth regulating factor, abscisic acid and DREB. While some of the genes showed similar pattern of upregulation in both the varieties at two days and 10 days stress, most of the genes that were upregulated in both varieties were involved in different functions thereby indicating varietal differences in stress tolerance mechanisms. The comparison and validation of the expression levels of these genes with the transcriptome data was also done.

Identification of miRNA and their targets for water stress: miRNAs that are differentially expressed in drought were selected. Based on their fold change and p values miRNAs that were significantly expressed in water stress tolerance was identified. p significant miRNA that were identified in Co 06022 included gma-miR166k, osa-miR171h, osa-miR444b.2, ppt-miR390c-5p, cpa-miR167d, ath-miR394b-5p and sbi-miR6235-5p. p significant miRNA in Co 8021, sbi-miR396d, csi-miR166a, cme-miR156j, osa-miR393b-3p, sbi-miR397-3p and zma-miR393c-3p. The selected miRNAs were used to design stem loop primers and primers synthesized for real time validation. PCR conditions are being standardized for real time validation of miRNAs. Data mining for identifying target transcripts of miRNA significantly expressed in water stress is being carried out.

(A. Selvi, R. Manimekalai, P.T. Prathima and R. Gomathi)

Sucrose regulating genes in sugarcane – analysis of transcript diversity and identification of isoforms / transcript variants

Sugarcane genotypes consisting of commercial genotypes and wild species differing in sucrose content were planted in a RBD in February 2019. From this planting, internode and leaf samples were collected from 3rd month of planting. Juice analysis was conducted at 200 days in 19 'Co' canes, among which Co 09004 (16.89 %) and Co 11015 (16.76 %) were found to have highest sucrose content, whereas lowest was recorded in TWC-28 (8.4). An expression profiling of sucrose transporters was performed at 3rd, 6th, and 9th month of planting using internode samples from a set of high sugar and low sugar genotypes. A transcriptome sequencing for selected genotypes is in progress.

(P.T. Prathima, T. Lakshmipathy and Avinash Singode (Indian Institute of Millets Research, Hyderabad)

Isolation and characterization of genes associated with high water use efficiency (WUE) in sugarcane cultivars

Twenty-four heterologous primers designed from WUE genes identified in crops such as maize, *Sorghum* and rice were screened for their amplification in twenty different cultivars of sugarcane. Gradient PCR was carried out at different temperatures and out of these 24 primers,10 primers for the genes (EPF-3, EPF-5, GTL1c, SLAC, EPF-4, STAYGREEN, EPF-9, EPF-2, CER1 and WIN1) showed multiple band amplification while 14 primers did not show any amplification at all. The gene fragments corresponding to correct size of WUE genes was eluted out and reamplified and sent for sequencing. RNA isolation was carried out for 3 genotypes with high WUE and 2 genotypes with low WUE. The cDNA was synthesized from

the isolated total RNA and primer screening is being done.

(K. Deva Kumar and P.T. Prathima)

MULTI-DISCIPLINARY PROJECTS

Standardization of true seed production technique through developing homozygous parental lines and apomixes

(Bakshi Ram and G. Hemaprabha)

Inbreeding

Among the 143 inbreds evaluated for red rot resistance two inbreds *viz.,* 1148-S4-242-1-69 and ms 68/47-39 were resistant while majority were either MR (59) or MS (47) or S types (34). One inbred (1148-13-11-2-252-22-367) showed highly susceptible reaction to red rot. In all, 155 inbreds at different stages of selfIng (S0 to S7) were studied for flowering behaviour, early sucrose accumulation potential at 240 days and red rot resistance in order to choose the inbreds in crossing programme. H.R. Brix at 240 days was above 22% in nine inbreds, the highest being in the sixth generation inbred of Co 1148 *viz.* 1148-13-11-2-237-2-360 (25.2%) and 17 inbreds combined red rot resistance and early high Brix (>20% at 240 days).

At 300 days, 224 inbreds were screened for juice quality traits at 300 days along with CoC 671 and Co 86032. Among the inbreds, 1148-13-11-2-150 (20.19%) was on par with CoC 671 (20.45%) and ten inbreds viz.,1148-13-11-2-252-33-361 (19.84), 1148-13-11-2-252-180 (19.99), 1148-13-11-2-242-3-80 (19.71), 1148-13-11-2-242-1-56 (19.58), 1148-13-11-2-242-5-249 (19.44), 1148-13-11-2-1-42 (19.35), 86032 – 127 (19.21), 1148-13-11-2-242-5-263 (18.95), 775-5-102 (18.79 and 775-12-35 (18.51) were better than Co 86032 (18.40%).

Based on flowering synchrony, 20 selected inbreds were intercrossed to effect 13 crosses for progeny evaluation. Fifteen 'Co' canes and 25 inbreds of early and advanced generations were selfed in order to attempt development of near homozygous populations.

(G. Hemaprabha, A, Annadurai and T. Lakshmi Pathy)

Anther culture

Sugarcane anthers were cultured in 20 different callusing media. The arrows/spikes were sampled at mid short blade stage, approximately 10-20 cm distance between the symptom and

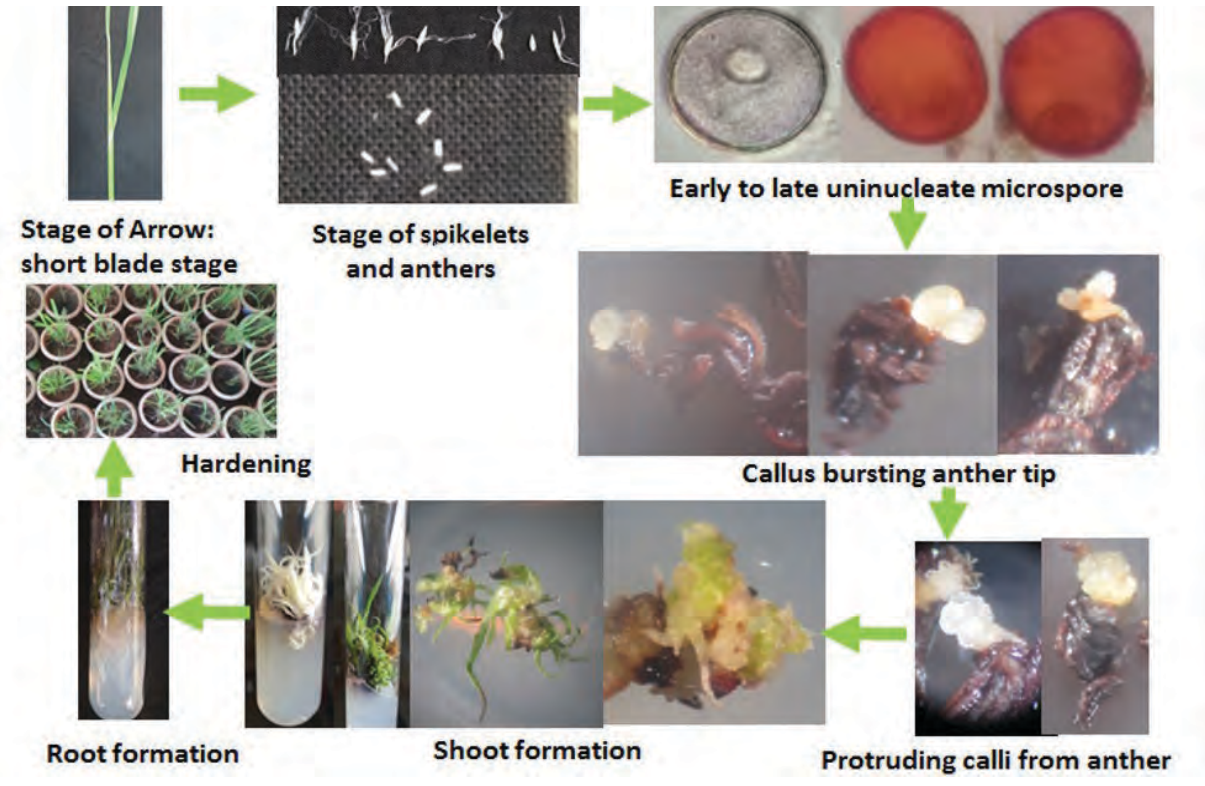


Fig. 14. Flow chart indicating the various stages of anther culture studies in sugarcane

short blade stage. At this stage, the most of the microspores were in mid to late uninucleate stage and were cultured in nutrient rich media. Around 20% callus induction in sugarcane variety Co 86032 and around 10% callus induction in Co 16001 was reported. Callusing was observed even after 140 days and among 400 calli obtained, 46 calli were regenerated, 28 were green plantlets and remaining were albinos. Further characterization for ploidy level through cytology, physiological parameters, marker allelic distribution and flow cytometry is in progress. During the flowering season of 2019-20, seven clones *viz.*, Co 16001, Co 62198, Co 0209, Co 775, CoC 671, Co 0238 and Co 86032 were selected for optimization of media for callus induction. Among them, Co 16001 and Co 86032 were responding for callus induction with multiple callus induction and other clones were accumulated with high level of polyphenols (Fig. 14).

(C. Mahadevaiah, Sanghamitra Samantaray (ICAR-NRRI, Cuttack) and H.K. Mahadevaswamy)

Chromosome elimination

The genomic DNA has been isolated from the plants regenerated from EMS treated calli of Co 775. TILLING has been done with 4x pools of genomic DNA. The hybridized products were treated with Nuclease S for cleavage at mutated region of CENH3. These products were analyzed by PAGE and four pools (pools 8, 9, 10 and 11) were showing additional bands (Fig.15). Hence the individual genomic DNA (16 samples) which consists of these pools were analyzed for the point mutation for the gene CENH3. The PCR product of these 16 samples were analyzed for individual point mutation through S1 nuclease treatment and out which five samples showed multiple bands and these five samples (E2, E5, E6, E10, and E11) were amplified (Fig.16) and the PCR products are subjected for sequencing analyses to identify single nucleotide modification. These five putative mutants were transferred to field from glass house. These clones were not flowered during this season. Mutated calli of two *Erianthus* clones (*E.a* Sarkandar and SES 153) were regenerated and the putative mutant clones are being maintained in the glass house. Genomic DNA has been isolated from 95 clones and stored. Genomic DNA from twenty eight *Erianthus* clones were quantified and prepared into 4x pools. These pools are being standardized for PCR amplification of CENH3 with high fidelity polymerase enzyme.

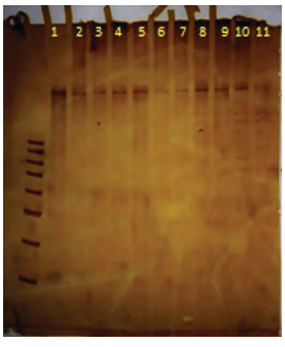


Fig.15. PAGE analysis of 11 pools after S1 nuclease treatment

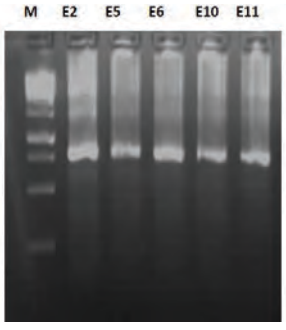


Fig.16. CENH3 amplification in 5 putative mutants of Co 775. Pools 8,9,10 and 11 show cleaved bands

(V.P. Sobhakumari and K. Lakshmi)

Wide hybridization

A total of 69 inter-generic crosses were made during October-December 2019 between sugarcane (as female and male) and sweet corn, sweet sorghum, bajra, fodder type *Sorghum halepense* to generate haploids. Chromosome number of 73 suspected inter-generic hybrids (of bajra, sweet sorghum, sweet corn, Narenga and *Erianthus* x sugarcane) were determined. It ranged from 2n=14-100. A hybrid with 2n=60 from the cross of *S. officinarum* and maize was found. In the cross of sugarcane cv. CoJ 64 x sweet sorghum, four hybrid seedlings with 2n=70-75 were identified. Haploid seedlings were not yet identified.

(R. Karuppaiyan, K. Mohanraj and A. Suganya)

Apomixis

Apomixis regulating genes from sorghum and maize were used as references for retrieving sequences from published mosaic monoploid sugarcane genome data and primers were designed. Genes for which sequence information were not available from sugarcane, sequences from sorghum and maize were used as such. Some of the genes viz., Baby boom 1, somatic embryogenesis receptor-like kinase 1, ameiotic 1, DMT102 methyl transferases, suppressor of

gene silencing 3 were identified, cloned and are being studied currently. Gene editing will be taken up as and when the full-length gene sequences from sugarcane are obtained.

(P.T. Prathima and C. Appunu)

Evaluation of hybrids

Tropical (Coimbatore): Extent of variability was studied in crosses involving advance inbred lines for cane yield and juice quality traits. Of the nine combinations evaluated, S6 x S6 (1148-237-S6-2-61 x 1148-S5-242-3-277) recorded lesser magnitude of variability compared to other combinations. Cane diameter registered least variation (7.70%) followed by H.R brix (11.1%), cane height (14.2%) and number of millable canes/clump (35.6%). Screening of four biparental crosses in ground nursery revealed that the cross Co 99008 x CoPant 97222 exhibited least variation for cane yield and juice quality traits comprising of uniform individuals with yellow green stalk colour. Overall, cane diameter was found to be the most stable trait registering minimum variability (12.8%) as evident by the presence of moderately thick canes in both populations. Number of millable canes per clump was the least stable trait that recorded the highest variability of 43.7%.

(R.M. Shanthi, S. Alarmelu, R. Karuppaiyan and V. Vinu)

Evaluation for diseases

Assessing phytotoxic effect of fungicide on true seed: The effect of fungicide treatment on germination of true seeds was tested. The fungicide Taqat 0.1% (Captan + Hexaconazole) was treated on defuzzed seeds of Co 1331, stored and assessed for their germination at monthly interval. The results so far indicated that fungicide treatment did not affect germination of true seeds. At 90 days after storage Taqat 0.1% treated defuzzed seeds recorded 48% germination, while it was 40% in control.

Assessing diseases of true seed: The inflorescence of sugarcane crop in National Hybridization Garden and other experimental fields of SBI, Coimbatore were observed in this flowering season for diseases of true seed. The visual observations showed no disease development in any of the inflorescence.

(V. Jayakumar and K. Nithya)

Agronomic practices for seedlings

Weed management experiment in split plot design in three replications was initiated in April 2019 consisting 18 treatment combinations with three planting materials (true seed seedling, bud chip settling and setts) in main plot and six integrated weed management practices in sub-plot. Seedling nursery was raised from the fluff. In main field, 45 days old true seed seedlings were transplanted along with bud chip settlings and setts at 120 cm row spacing. The project is in progress and so far the new herbicide molecules like topramezone, tembotrione were found effective in managing the weeds like *Cynodon dactylon* L., *Brachiaria reptans*, *Cyperus rotundus*, *Trianthema portulacastrum Parthenium hysterophorus, Euphorbia hirta, Datura metel, Phyllanthus niruri, Digera arvensis, Commelina benghalensis Cardiospermum helicacabum* and *Portulaca oleraceae*.

(A.S.Tayade, S. Anusha, P. Govindaraj, P. Geetha and C. Palaniswami)

Seed processing, packaging and storage

During 2018-19 hybridization season, open pollinated fluff collections of 270 clones were made. Of the four media *viz.* fine sand, clay soil powder, red soil powder and chalk powder tested for seed defuzzing, red soil powder has been found to be more effective for defuzzing.

(N. Rajendra Prasad)

All India Coordinated Research Project (Sugarcane)

(Bakshi Ram and P. Govindaraj)

Peninsular Zone

Initial Varietal Trial

Eighteen test entries and three standards (Co 86032, CoC 671 and Co 09004) were planted in RBD with three replications. Juice quality analysis at 8th month among the standards indicated that Co 09004 recorded the highest sucrose content (17.64%) followed by CoC 671 (16.16%). Among the test entries, Co 11015 recorded the highest sucrose content (17.70%) followed by CoVSI 16121 (17.41%). At 10th month, standard Co 09004 recorded the highest sucrose content (19.52%) followed by CoC 671

(19.32%) and Co 86032 (17.44%). Among the test entries, Co 11015 (19.64) and Co 16006 (19.13%) were identified as the best entries with better crop stand and superior sucrose content.

(C. Mahadevaiah and S. Sheelamary)

Advanced Varietal Trial (I Plant)

Fifteen entries along with three standards *viz.,* Co 86032, CoSnk 05103 and CoC 671 were evaluated for cane and juice quality traits at 240 and 300 days. None of the entries recorded higher sucrose than the best standard CoC 671 (16.99%) at 240 days. However, the entries Co 14027 (16.26%), Co 14030 (15.86%) and Co 14002 (15.19 %) recorded higher sucrose compared to the standard Co 86032 (15.15%). At 10th month, the entry Co 14032 recorded the highest sucrose of 19.83% and CCS of 13.92 % compared to the best standard CoC 671 (19.33% sucrose and 13.63% CCS).

(K. Mohanraj and A. Anna Durai)

Advanced Varietal Trial (II Plant)

Seventeen entries along with three standards (Co 86032, CoC 671 and CoSnk 05103) were evaluated for juice quality and yield traits at 240 and 300 days. Co 13002 (19.30 %) was found to be the best for juice sucrose compared to the best check CoC 671 (18.17 %). The entries Co 13018 (17.70 %), Co 13004 (17.69 %), Co 13013 (17.53 %) and CoSnk 13103 (17.39 %) were the other best entries for juice sucrose. CoSnk 05103 (103.82) was the best for check for NMC ('000 ha^{-1}) at 300 days, and four entries *viz.,* Co 13002 (89.47), Co 13018 (85.65), PI 13132 (82.52) and CoSnk 13103 (82.52) recorded more than 80,000 NMC/ha.

(H.K. Madevaswamy and S. Karthigeyan)

Advanced Varietal Trial- Ratoon

Seventeen entries and three standards *viz.,* Co 86032, CoC 671 and CoSnk 05013 were evaluated for cane and juice quality traits. None of the entries was better than the standard CoC 671 for sucrose% at 9th month. Ten entries recorded higher sucrose than Co 86032 (16.59%). Among the entries, Co 13004 recorded the highest sucrose 18.84% followed by Co 13002 (18.83%) and Co 13020 (18.80%). The entry Co 13014 recorded the highest single cane weight of 1.30 kg followed by Co 13009 (1.22 kg) compared to the standard Co 86032 (0.97 kg).

(K. Mohanraj and K. Elayaraja)

Multiplication and exchange of seed material

Eleven entries *viz.,* Co 18001, Co 18002, Co 18003, Co 18009, Co 18012, Co 18013, Co 18024, CoVC 18061, CoN 18071, CoN 18072, CoVSI 18121 were supplied to three AICRP(S) *centres viz.,* Rudrur, Perumalapalle and Manya.

(R. Karuppaiyan and C. Appunu)

Evaluation and identification of climate resilient ISH and IGH genetic stocks

Supply of new set of clones: Twenty four ISH (ISH 501, ISH 502 ISH 512, ISH 513, ISH 516, ISH 519, ISH 524 , ISH 526, ISH 528, ISH 534, ISH 535, ISH 536, ISH 542, ISH 545, ISH 548, ISH 554, ISH 558, ISH 564, ISH 567 , ISH 584, ISH 585, ISH 587, ISH 590 and ISH 594) and six IGH (IGH 806, IGH 816, IGH 823, IGH 829, IGH 833 and IGH 834) clones were supplied to SRS, Cuddalore for testing against red rot.

(P. Govindaraj and H.K. Mahadevaswamy)

Fluff Supply and National Hybridization Programme

Maintenance of parents and their database: National breeding gene pool of sugarcane having 617 parental clones was maintained at National Hybridization Garden (NHG) - 2019 in healthy and pest and disease free condition. Database on parents in NHG were updated by adding the information on red rot resistance of 36 parental clones with respect to their reaction to *CF06* pathotype of *Collectotrichum falcatum*. The flowering advanced by a week compared to the years of normal flowering and the first flowering was noticed in LG 99122 on 16th October, 2019 followed by NCo 310 on 20th October 2019. Data collected on flowering of parental clones in NHG were uploaded and updated at weekly intervals in institute website. Out of 617 parents, 567 (91.90%) flowered during 2019, against 67.90 % during 2018 flowering season.

Hybridization: Among 24 participating centers of Fluff supply / National Hybridization

Table 6. PDI and PUI of crosses effected by the fluff receiving centers at NHG during 2019

Centre	No. of bi-parental crosses	Parental Diversity Index	Parents Utilization Index
Peninsular Zone		**(PDI)**	**(PUI)**
Mandya	21	69.05	51.79
Navsari	22	79.55	79.55
Padegaon	21	69.05	51.79
Perumalapalle	26	84.62	84.62
Powarkheda	14	75.00	65.63
Pune	23	89.13	66.85
Rudrur	31	64.52	56.45
Sankeshwar	27	64.81	56.71
Thiruvalla	21	61.90	54.17
Sub-total	206		
North West Zone			
Faridkot	19	68.42	68.42
Kapurthala	34	76.47	66.91
Lucknow	34 *	45.59	28.49
Shahjahanpur	33	65.15	57.01
Pantnagar	15	83.33	52.08
Uchani	24	70.83	61.98
Sub-total	159		
East Coast Zone			
Anakapalle	28	66.07	66.07
Cuddalore	26	57.69	50.48
Nayagarh	22	79.55	69.60
Vuyyuru	22	81.82	71.59
Sub-total	98		
North Eastern Zone			
Buralikson	16	75.00	65.63
North Central Zone			
Motipur	22	77.27	48.30
Pusa	36	69.44	69.44
Seorahi	27	66.67	50.00
Subtotal	85		
Grand total	564		

* Including 5 selfs

programme, 23 centres attended the crossing programme 2019. Hybridization work commenced on 26 October 2019 and concluded on 5 December 2019. Out of 567 parents flowered, 146 females and 104 male parents were utilized for generating genetic variability for different agronomic traits. Co 775 was the most frequently used male parent (42 cross combinations), followed by CoPant 97222 (34 crosses) and Co 1148 (31 crosses). Similarly, Co 86032 was the most frequently used female parent (in 34 cross combinations) followed by CoC 671 (33), Co 0238 (16), CoVC 14062 (16) and MS 68/47 (14).

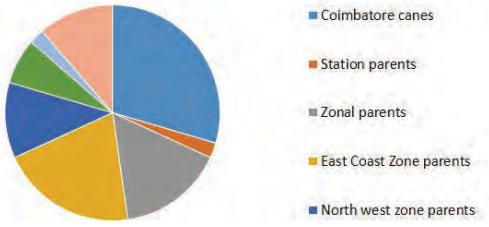


Fig. 17. Utilization of different sources of parents in NHG by Perumallapalle centre

Utilization pattern of parental clones in NHG: The Parental Diversity Index (PDI) and Parental Utilization Index (PUI) of crosses effected by the 23 centers were analyzed by classifying the source of the parental clones in to eight categories *viz.*, Parents developed by ICAR-SBI (Coimbatore Canes), parents from the particular center, parents from the zone in which the respective center is located, parents from other four zones, exotic parents and interspecific hybrids. Accordingly, the PDI ranged from 45.59 % (Lucknow) to 89.13 % (Pune). Overall the PDI of the crosses affected during 2019 flowering season was significantly higher than that of crosses effected during the normal years of flowering. Pattern of utilization of parents by the Perumallapalle with higher PDI (84.62) and PUI equal to PDI. Number of bi-parental crosses and the PDI and PUI of the crosses facilitated by ICAR-SBI to the participating centers during 2019 flowering season is presented in Table 3. Five centers *viz.*, Anakapalle, Faridkot, Navsari, Perumallapalle and Pusa had PUI equal to PDI which indicated the utilization of all the classes of parents by these centers (Fig. 17).

(A.Anna Durai and V. Sreenivasa)

Agronomic performance of elite sugarcane genotypes

A new experiment entitled "Agronomic performance of elite sugarcane genotypes" was initiated during February 2019. The experiment was laid out in split plot design with two replications. In all, five elites sugarcane genotypes Co 13006, Co 13008, Co 13009, Co 13018, Co 13020 and three standards Co 86032, CoC 671, Co 09004 with three RDF (75, 100 and 125 % RDF) were planted. In the plant crop, the NMC (000/ha) recorded at 10 months after planting showed difference due to sugarcane genotypes, wherein, promising early genotype Co 13009 (71082 NMC/ha) recorded higher NMC than the check varieties Co 86032 (67450 NMC/ha) and CoC 671(69379 NMC/ha).

(A.S.Tayade, S. Anusha, P. Govindaraj, P. Geetha and C. Palaniswami)

Evaluation of fodder values and ethanol production for AVT-I plants

Jaggery analysis of 17 samples with three standards of AVT I plants showed Brix values between 12.0 and 11.7 without sharp difference. The maximum Pol value of 45.3 was recorded for Co 13009 and the minimum value of 42.0 for CoSnk 13101. The Brix values of juices obtained from the cane samples, used for fermentation for ethanol were recorded in the value ranged from 10.4 to 11.6. The Sikes values fell between 95.0 and 97.0 for all samples.

The analysis of P and K values for green top of AVT I Plant revealed the low K value of 32.2 for Co 13013 and high of 70.2 for Co 13002 and low P value of 0.248 for PI 13132 and high of 0.795 for Co 13009 among 17 samples with three standards.

(I. Rajendran and A.Vennila)

Identification of pathotypes / races of red rot pathogen

Two new isolates (Cf86027- Vellalapalayam and Cfc24- Mandagapattu) along with 6 old isolates (Cf2001-13-Perambakkam, Cf06022-Kuttalam, Cf99006-Mundiampakkam, Cfc24-

Thandavarayanpatti, Cf06022-Pennadam and Cf0265-RK pet) and 2 reference pathotypes (CF06 and CF12) were inoculated on 19 sugarcane differentials and the disease intensity was rated. Among these, two old isolates *viz*., Cf06022-Kutalam and Cf06022-Pennadam exhibited more virulence followed by an old isolate Cf2001-13-Perambakkam and a new isolate Cfc24-Mandagapattu. Another new isolate Cf86027-Vellalapalayam exhibited least virulence. The isolate Cfc24-Thandavarayanpattu showed distinct differential reaction on two varieties, i.e., R reaction on Co 975 (while all other isolates exhibited I reaction) and S reaction on Baragua (while all other isolates exhibited either R or I reaction). The isolates Cf99006-Mundiampakkam and Cfc24-Thandavarayanpattu showed distinct R reaction on CoJ 64, while all other isolates showed I reaction. The isolate Cf06022-Kuttalam exhibited I reaction on CoS 8436 (while all other isolates exhibited R reaction) and Cf06022-Pennadam exhibited S reaction on CoSe 95322 (while other isolates exhibited I reaction).

(V. Jayakumar and R. Selvakumar)

Evaluation of IET / Zonal varieties for resistance to red rot, smut and YLD

About 20 IVT entries were evaluated for red rot resistance by plug and nodal methods under field conditions against *C. falcatum* pathotype CF06. Based on disease severity and rating score 17 and 19 entries were identified as resistant in plug and nodal methods, respectively. Three entries behaved as moderately susceptible in plug method and only one entry CoSnk 13158 behaved as susceptible by nodal method of inoculation. Among the 15 IVT entries evaluated for smut, four entries viz., Co 16018, CoVc 16062, CoM 16081 and CoR 16142 were identified as resistant, whereas one entry, CoM 16082 was identified as moderately resistant.

(R. Viswanathan, A. Ramesh Sundar and K. Nithya)

Evaluation of zonal varieties/genotypes for their reaction against major insect pests

Shoot borer: Overall shoot borer (SB) incidence recorded on 60th day after planting in IVT, AVT-I and AVT-II trials ranged from 0.0 to 41.7%. In IVT, the entry PI 16131 was free of SB incidence whereas CoM 16081 recorded 26.7% incidence. In AVT-I Plant, lowest incidence (2.9%) of SB was noticed in the entry CoSnk 14102 whereas the highest incidence (41.7%) was recorded in Co 14027. In AVT-II Plant trial, Co 13018 recorded the lowest incidence (2.5%) while the entry Co 13020 recorded the highest incidence (38.2%).

Survey and surveillance of sugarcane insect pests: In July 2019, white grub was moderate in Thalavady with the numbers in the range of 0-10 per meter length. The numbers were slightly lower in August. At Sathyamangalam, the incidence was lower with 0-3 grubs in September 2019. The numbers further decreased in October 2019 with pupal and adult occurrence in the root zone of the crop.

Monitoring of insect pests and bio-agents in sugarcane agro-ecosystem: In monitoring plot, shoot borer incidence was 2.23%, 4.69%, 4.11% in the months of April, June and July 2019 respectively. Pyrilla, mealybug and sheath mite were found in traces during June-July. Internode borer incidence of 2.64% was recorded in July 2019.

Standardization of simple and cost effective techniques for mass multiplication of sugarcane bio-agents, Beauveria brongniartii *and* Metarhizium anisopliae: For economizing mass culture of EPF, media based on agricultural by products and several grains were assessed with and without addition of peptone at different concentrations (5, 10 and 15%). For production of *M. anisopliae*, no differences among the concentrations used was observed among the byproducts *viz*., extracts of rice bran, wheat bran, red gram husk, sesame seed cake, groundnut cake, cotton seed cake along with peptone supplement which were compared with Jaggery and SD medium. The spore production ranged between 2.13 x 10^9/100ml (cotton seed cake) to 8 x 10^9/100ml (wheat bran). When the media were assessed without peptone supplement, irrespective of the concentration, the effect of media showed overlapping levels of significant variation. Cotton seed cake was the best (7.3 x 10^9/100ml)

which was on par with Jaggery, wheat bran, groundnut cake (4.8 x 10^9/100ml) and SD broth (5.2 x 10^9/100ml). Similar tests with *Beauveria* spp., showed that production of *B. bassiana* was higher in sesame seed cake extract (2.81 x 10^8/ml) than other media including standard SD (0.77 x 10^8/ml). Several media including sesame seed cake extract were cost effective at 5% concentration. For *B. brongniartii*, irrespective of concentrations tested many media *viz.*, coconut seed cake (11.93 x 10^7 /ml), rice bran extract (11.02 x 10^7 /ml), wheat bran (11.67 x 10^7 /ml),red gram husk (8.27 x 10^7 /ml) and cotton seed cake (5.8 x 10^7 /ml) were on par and significantly better than others. Wheat bran at 15% and rice bran extract at 15% were most cost effective.

(K.P. Salin, J. Srikanth, P. Mahesh, N. Geetha, B. Singaravelu, T. Ramsubramanian, M. Punithavalli and L. Saravanan)

Externally Funded Projects

Identification, characterisation and verification of new sugarcane varieties for DUS testing at Coimbatore

(R. Karuppaiyan)

Maintenance breeding: A total of 233 tropical sugarcane reference varieties (RV) were maintained in field through clonal propagation and in disease free condition.

Re-characterization of reference varieties: Reference varieties maintained at Coimbatore Centre (30 varieties) were re-characterized (old data were verified).

Conduct of DUS test for FV: DUS test for three farmers' varieties namely, Desi 1, Desi II, and Meitei Chu Angangba is in progress. Three farmers' varieties were morphologically characterized as by DUS guidelines. SBI, RC centre Kannur was visited and 11 *S. officinarum* clones were morphologically (DUS) characterized in comparison with Farmer's varieties Angangba, Desi I and Desi II. The reference variety 51NG105 was very close with Desi II. Desi I was distinct and did not resemble any of the reference variety.

(S. Alarmelu and C. Jayabose)

ICAR Seed Project: Seed production in agricultural crops and fisheries – sugarcane

The period was most favourable to undertake quality seed production by the seed unit both at the Institute and the seed villages. Overall, the indents for both breeder seed cane and tissue culture plants received in advance from farmers and sugar factories were considered for supply to the maximum extent possible. All the new activities initiated during previous years had strengthened the seed programme so as to deliver large quantity of seeds with high genetic purity and adequate quality to the indenters.

Maintenance Breeding: Maintenance breeding and multiplication of nucleus clones of all released varieties in seed chain from the Institute *viz.*, Co 86032, Co 0212, Co 06030 and Co 09004 were continued and the newly released sugarcane variety Co 11015 has been included. The nucleus clones are being maintained under the direct supervision of the breeders as a continuous activity. The selected canes from each variety were micropropagated to supply disease free plantlets for further multiplication as breeder seed.

Breeder Seed production: Breeder seed multiplication was taken up using the initial source of the tissue culture plants produced from the nucleus clones at the Institute. The varieties included were Co 86032, Co 0212, Co 09004 and the newly released variety Co 11015. Production of breeder seed using TC plants for further multiplication in farmers' fields in 2019-1 had also been taken up at ECC farm. About 37.495 tons of breeder seed thus produced have been supplied to the selected farmers to undertake the quality seed production during July 2019 under the guidance from ICAR-SBI in addition to the seed indents from sugar factories. Further, a total of 67,000 settlings of Co 11015 have been produced with the participation of a trained seed farmer and supplied for further multiplication.

Farmers' participatory quality seed production: It is a demand-driven activity due to the awareness on the need for quality seed material which has increased manyfold in recent times. The need

Fig. 18. Training for seed farmers held at Veeranathur on December 09, 2019

Fig. 19. Training for seed farmers held at Kesavarajakuppam on December 10, 2019

to produce a large quantity of quality seed cane coupled with the limited availablity of resources in the Institute provided an opportunity to explore the farmers' participatory mode under ICAR Seed Project. Seed requests received from farmers and sugar factories have been processed and about 1200 tons of quality seed has been finalised as target for 2019-1 seed season. However, a huge indent of about 2300 tons of quality seed has been received from Director of Sugar, Govt of Tamil Nadu could not be entertained as time and basic seed availability were limited. Progressive seed farmers have been selected to undertake farmers' participatory seed production from Seyur, Mathampalayam, Vellamadai and Neelambur and seed production was undertaken in about 29 acres. The seed crops were strictly monitored and the supply is scheduled from the second fortnight of January 2020 to both cooperative and private sugar factories as per allotments received from Directorate of Sugar, Govt of Tamil Nadu.

Training and Extension: In order to enhance the number of participation in training for seed farmers, three hands-on trainings for seed farmers and factory personal of Tiruttani Cooperative sugar Mill were conducted during 9-11 December 2019 at three different villages *viz.,* Veeranathur, Mamandoor and Kesavarajakuppam villages and a large number seed farmers participated. Several fields planted with ICAR-SBI seeds have been visited and the farmers have been interacted to record the feedback on the quality of seed received. All the farmers were happy and realised the importance of quality seed in increasing the yields in sugarcane crop (Fig.18-19).

(A.J. Prabakaran and S. Karthikeyan)

Tribal Sub Plan under ICAR Seed Project

Utilized Rs.2,00,000 from TSP fund, seed of jowar, bajra, gingelly, minor millets, grand naine TC plants and motor pumpsets were purchased for distribution to tribal farming communities around Anaikatti, Coimbatore.

(A.J. Prabakaran, N. Rajendra Prasad and S. Karthikeyan)

Production of tissue culture plants

Through apical meristem tip culture, the varieties Co 86032, Co 0212, Co 09004, Co 0238, Co 0118, CoV 09356 and Co 11015 were multiplied. In vitro cultures of varieties Co 0212, Co 09004, Co 0238, Co 86032, CoV 09356 and Co 11015 were virus indexed and found to be free from SCYLV, SCMV, SCSMV and GSD. A total of 48,910 tissue culture plants were supplied to private and co-operative sugar factories of Tamil Nadu, sugar factories from other states, breeder seed production and progressive farmers. An amount of Rs.6,32,768 has been generated through supply of tissue culture seedlings.

(D. Neelamathi, R.Valarmathi and C. Jayabose)

Enhancing sugar productivity in Tamil Nadu through institute-industry participatory approach (SISMA funded)

(Bakshi Ram and C. Appunu)

Variety released: Evaluation of first set of clones was carried out during 2017-2019. Pooled data analysis for yield and quality traits was performed based on data of two plants and one ratoon crop. Overall, Co 13014, Co 11015, Co 13018, Co 14016 and Co 06031 performed better than Co 86032 for cane yield and sugar yield at harvest. Of these, Co 11015 recorded 10.23%, 20.13% and 9.66% improvement over Co 86032 for cane yield, sugar yield and sucrose content across Tamil Nadu. Hence, it was identified as best performing variety combining yield and quality. ICAR-SBI Institute Research Committee and SISMA TN committee members recommended Co 11015 for release in Tamil Nadu for the benefit of sugar factories and farming community.

Based on the recommendation Co 11015 (Atulya) was proposed and released as short duration sugarcane variety for commercial cultivation in Tamil Nadu and subsequently this variety was notified by Central Variety Release Committee (CVRC). Salient features of this variety are as follows:

- High yielding and high quality short duration sugarcane variety suitable for Tamil Nadu for normal and drought prone areas.
- Recorded 10.23 per cent improvement in yield (142.72 tha^{-1}) over the check Co 86032 (129.48 tha^{-1}) in trial conducted across Tamil Nadu.
- Improvement of 20.13 per cent recorded for sugar yield (20.16 t ha^{-1}) compared to the check Co 86032 (16.78 t ha^{-1}) in trial conducted across Tamil Nadu.
- This is a short duration maturing clone with >17 % sucrose at 240 days thereby sugar recovery during the early crushing season can be improved. Further, the juice quality improves upto 12 months, hence can be harvested from 8 to 12 months.
- This clone fits well in realizing three crops in two years, hence highly suitable to regions with water scarcity.
- This variety is also suitable for special season harvest as it recorded an improvement of 8.98, 6.93 and 9.15 per cent sucrose over Co 86032 at 240, 300 and 360 days respectively in July planted trials.
- Co 11015 has the ideal plant characters of height (> 250 cm) with erect plant type, excellent field stand with medium thick canes.
- It is a good ratooner and registered 9.61 per cent, 18.57 per cent and 8.62 per cent increase in cane yield, sugar yield and sucrose per cent respectively over Co 86032.
- This clone responds well with single bud settling planting under wider row spacing and hence suitable for SSI technology.
- Co 11015 produces A_1 quality jaggery of golden yellow colour.

Evaluation of second set of clones

Performance of varieties: Eighteen varieties were evaluated along with Co 86032 and local standards in a replicated trial (Fig. 20). Very good germination was recorded in evaluation trial plot. Data were compiled and analyzed for sucrose % and juice Brix % at 240 days. Of

Fig. 20. SISMA trail at Dharani Sugar and chemicals Ltd., Polur, Thiruvannamalai

the eight locations, Co 17003 recorded higher sucrose % than Co 86032 at five locations followed by Co 12008, Co 12009 and Co 16010 recorded better sucrose % than standard at three locations each. There were nine entries that showed better sucrose content than Co 86032 at VV Sugars while five clones at Bannariamman Sugars Ltd. The clone Co 16010 recorded more than 2 units higher sucrose over the standard at E.I.D. Parry (India), Nellikuppam. Over all, Co 17003 recorded better mean sucrose (15.09 %) and Brix (17.46%) than standard Co 86032 for sucrose (15.03 %) and Brix (17.17%).

Monitoring visit of ICAR-SBI Team to factory trial locations

1. ICAR- SBI Coordination committee visited and monitored the seed cane multiplication plots of Co 11015 at Bannari Amman Sugars Ltd., Sathyamangalam and Sakthi Sugars Ltd., Apakoodal on 05.07.2019 (Fig. 21).

2. Visited and interacted with cane officials conducting location specific varieties trial at Ponni Sugars Ltd., Odapalli, Erode on 29.08.2019 (Fig. 22).

Fig. 21. Field stand of Co 11015 at Sakthi Sugars Ltd, Appakudal

Fig. 22. Quality seed multipication of Co 11015 at Ponni Sugars Pvt Ltd. Erode

3. ICAR- SBI Coordination committee visited and monitored the seed cane multiplication plots of Co 11015 at Ponni Sugars Ltd., Erode on 26.09.2019.

4. ICAR- SBI Coordination committee visited and monitored the seed cane multiplication plots of Co 11015 at Dharani Sugars and Chemicals Ltd., Polur on 12.10.2019.

(G. Hemaprabha, A.J. Prabakaran, R.M. Shanthi, S. Alarmelu, P. Govindaraj, D. Neelamathi, S. Karthigeyan, A. Anna Durai, R. Karuppaiyyan, K. Mohanraj, C. Appunu, C. Mahadevaiah, V. Sreenivasa, Adhini S Pazhani, S. Sheela Mary, H.K. Mahadevaswamy, T. Lakshmipathy, V. Vinu, K. Elayaraja, R. Viswanathan, A. Ramesh Sundar, P. Malathi, C. Sankaranarayanan, R. Selvakumar, V. Jayakumar, K. Nithya, R. Gopi, K.P. Salin, J. Srikanth, N. Geetha, B. Singaravelu, T. Ramasubramanian, M. Punithavalli and P. Mahesh)

Identification of location specific sugarcane varieties suitable for different agro-climatic zones of Tamil Nadu (Cooperative sugar factories)

First plant crop trial was laid out in replicated trial with 21 clones (Co 09004, Co 11015, Co 12009, Co 14002, Co 14005, Co 14016, Co 14025, Co 15007, Co 15015, Co 15018, Co 16009, Co 16010, Co 16018, Co 17001, Co 17003, Co 17004,

Table 4. Region wise varietal testing centres under ICAR-SBI and TNCSF trial

Trial evaluation location	Region
Kallakurichi-I Cooperative Sugar Mill, Moongilthuraipattu 605 702, Villupuram	Interior Tamil Nadu
Amaravathy Cooperative Sugar Mills Ltd., Krishnapuram, Udumalpet, Tirupur 642 111	Interior Tamil Nadu
Subramaniya Siva Cooperative Sugar Mills Ltd., Alapuram, Gopalapuram 636 904, Dharmapuri	Interior Tamil Nadu
Salem Cooperative Sugar Mills Ltd., Mohanur, Namakkal 637 015	Interior Tamil Nadu
Arignar Anna Sugar Mills, Kurungulam, Thanjavur 613 303	Delta Tamil Nadu
Tiruttani Coop. Sugar Mills Ltd., Tiruvalangadu 631210 Thiruvallur	Interior Tamil Nadu

Fig. 23. Field view of Co 11015 ratoon crop at Kallakurichi - I. Co operative Sugar Mills, Moongilthuraipattu

Co 17012, Co 17013, Co 17014, Co 18009 and Co 18024) along with standard Co 86032 in six cooperative sugar factory locations for evaluation. Trial evaluation locations are given in Table 4. Juice quality analysis is in progress.

Other activities: ICAR- SBI Coordination committee visited and monitored the seed cane multiplication plots of Co 11015 at Kallakurichi-I Cooperative Sugar Mill, Moongilthuraipattu on 11.10.2019. Large quantity of Co 11015 seed materials were supplied to other cooperative factories for further multiplication and spread of the variety for the benefit of farmers and sugar factory. A very good ratoon potential of Co 11015 was observed in the farmers field (Fig. 23).

(Bakshi Ram, G. Hemaprabha, S. Alarmelu, S. Karthigeyan, A. Anna Durai, R. Karuppaiyyan, K. Mohanraj, C. Appunu, C. Mahadevaiah, V. Sreenivasa, S. Sheela Mary, H.K. Mahadevaswamy, T. Lakshmipathy and K. Elayaraja)

Genetic control and genomic selection for important traits in sugarcane, and comparison of elite Indian and Australian germplasm

The population BO 91 x Co 775 was planted in RBD for red rot phenotyping (plug method). The populations ('Co' canes, Co 86002 x BO 91, CoM 0265 x Co 775) were phenotyped for red rot (CCT method) number of tillers, plant height, number of millable canes and Brix).

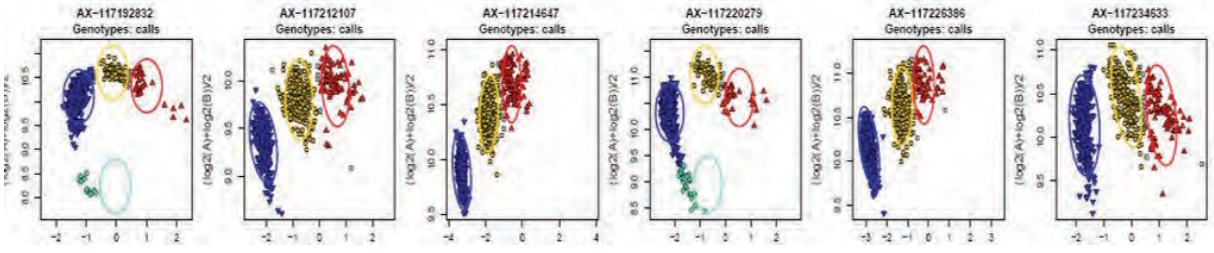


Fig. 24. Clustering of genotypes for variance calls

Table 5. Performance of the population BO 91 x Co 775 in control and drought for physiological and yield parameters

	Control population mean	Drought population mean	Reduction %
Fv/Fm (early)	0.675	0.654	-
Fv/Fm (peak)	0.752	0.632	15.96
Fv/Fm (recovery)	0.680	0.664	-
SPAD (early)	20.7	21.1	-
Total chlorophyll content (early)	0.014	0.015	-
SPAD (peak)	18.07	14.20	21.42
Total chlorophyll content (peak)	0.011	0.007	-
SPAD (recovery)	23.53	26.11	-
Total chlorophyll content (recovery)	0.017	0.020	-
Cane height at 7th month	125.42	66.65	46.86
Cane height at 9th month	188.32	105.34	44.06

Ratoon crop trial (BO 91 x Co 775)

The population BO 91 x Co 775, CoM 0265 x Co 775 and Co 1148 x Co 775 are in ratoon trial. Drought was imposed at 60 days of crop age. SPAD, Leaf temperature and chlorophyll fluorescence were taken at three phases *i.e.*, early stress phase (May and Jun), peak drought stress period (July-August 2019) and recovery phase (Oct 2019). Cane height at 7th month and number of millable canes in October 2019, Brix at 10th month were recorded and flowering details were recorded. The observed data were statistically analyzed. The juice analysis and yield estimation will be performed at 360 days (Table 5) (Fig. 24). The results are as follows

Fig. 25. Field view of ratoon crop trial (BO 91 x Co 775)

Genotyping with SNP markers: 640 DNA samples were genotyped with SNP markers. The average cluster rate was 98.6 %. The number of samples passed the genotyping was 95.4 %. The polymorphic markers were categorized into AA, AB and BB variance (Fig. 25).

High Resolution markers

	Number of markers
Number of markers	15,040
AA variance X	61
AA variance Y	165
AB variance X	230
AB variance Y	130
BB variance X	127
BB variance Y	130

(R. Manimekalai, G. Hemaprabha, R. Viswanathan, A. Selvi, K. Mohanraj and S. Vasantha)

Identification of new genetic resources for drought tolerance from *Erianthus*, A related wild genus of sugarcane through GWAS

A second year field evaluation of about 215 *E. arundinaceus* clones and 40 *Erianthus* sp. clones were carried out to identify new genetic resources for drought tolerance. Drought stress was imposed by withholding irrigation at the tillering phase. After 65 days of drought

exposure at 30-40% soil moisture content about 15 *E. arundinaceus* clones were found to be tolerant and about 20 clones to be moderately tolerant. Data on biomass, leaf area index and single cane weight was collected to ascertain the drought tolerance levels among the clones.

A Genotype by Sequencing (GBS) panel of *Erianthus* germplasm was constructed based on the data obtained from *Erianthus* genetic diversity and the drought phenotyping data. A panel of 96 *Erianthus* germplasm comprising of drought sensitive, intermediate and tolerant clones were included in the panel and DNA samples were sent for sequencing. GBS raw data for all the samples were obtained and analysed for quality using the software FASTQC. The data showed the presence of 150k tags with 43% GC content and about seven to eight lakh sequences with more than 40 Phred score. A De novo assembly was carried out using the STACKS pipeline and SNP tags and popmap was created as output. The assembly showed the presence of about two lakh variants with 50000 to 60000 polymorphic sites in each sample and further analysis is ongoing. Root phenotyping in selected *Erianthus* clones to understand the drought tolerance mechanism indicated the presence of drought adapted anatomical features in *Erianthus*.

(R.Valarmathi and H.K. Mahadevaswamy)

Identification of salt responsive genes and micro RNA targets from salt tolerant *Erianthus arundinaceus* through transcriptome analysis

Salt tolerant *E. arundinaceus* accession IND99-907 and sensitive sugarcane genotype Co 97010 were grown in controlled condition. The sixty days old plants were irrigated with 16 dSm^{-1} saline water containing Sodium chloride, Calcium chloride and Sodium sulphate in 2:2:1 proportion. The young growing roots of stressed and control of Co 97010 and IND99-907 were sampled from both tolerant and sensitive genotype on 10th day after the salinity stress with three biological replicates and total RNA was isolated from Trizol method. Sample purification and QC check was done by using Agilent Bio Analyser and only samples with RIN value more than 6 were used library preparation using Tru-seq RNA sample preparation kit v2 (Catalog No. RS 122-2001). After library preparation and library quality check, sequencing was done using Illumina HiSeq 2500 with 2x100 bp paired end format. Total of 538,554,479 raw reads were processed for all 12 samples, after pre-processing a total of 522,075,939 cleaned reads were obtained which were used for further processing. After rRNA removal, the cleaned reads were assembled using the *de novo* assembler Trinity for both pooled and individual assembly for all samples. For pooled assembly, a total of 873866 transcripts were assembled, a total of 251235 contigs were obtained with the largest contig having a length of 18797 bp and Contig N50 of 1289 bp. Annotation and differential gene expression analysis is in progress. For small RNA library preparation, same total RNA was used and small RNA library was prepared by using Tru-Seq Small RNA library Prep Kit and quality check was done using Agilent Bio Analyser. Samples with RIN value with more than six were sequenced by using Illumina HiSeq 2500 platform with 1x50 bp single end format. Total of 865,218,680 raw reads were processed and both 5′ and 3′ adapter sequences were removed for all 12 samples. Ribosomal RNA and transfer RNA has been removed for all 12 samples by aligning the adapter removed sequences with RNA sequences obtained from databases using bowtie2 program.

(C. Mahadevaiah)

Isolation, functional characterization and evaluation of water deficit stress tolerance responsive genes from high drought tolerant *Erianthus arundinaceus* by comparative drought transcriptome analysis

Around 6.0 gigabase pairs (Gb) of comparative raw data were obtained for each of stressed and nonstressed samples of leaves and roots from ninety days grown plants of *E. arundinaceus* and sugarcane commercial variety Co 86032. Detailed analysis is in progress. Based on preliminary analysis of data, plant nuclear factor (NF-Y), a transcription activating factor, consisting of three subunits, which plays a key regulatory role in many stress-responsive mechanisms including

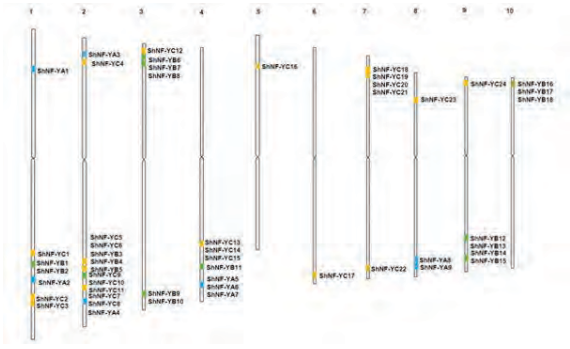


Fig. 26 Location of NF-Y genes on chromosomes of sugarcane genome

drought and salinity stresse was identified. Hence, this gene member was characterised at genome level of *Saccharum* spp. In general, NF-Ys function both as complex and as individual subunits. NF-Y is a heterotrimeric CCAAT box binding plant transcription factor comprising of three subunits *viz*., NF-YA (CBF-B), NF-YB (CBF-A) and NF-YC (CBF-C). In animals, NF-Ys are encoded by a single gene whereas in plants NF-Ys are encoded by multiple gene members. NF-Ys play crucial role in many vegetative, developmental and reproductive processes in plants. Genome wide search of NF-Ys in mosaic monoploid reference sugarcane genome revealed the presence of 9 NF-YA, 18 NF-YB and 24 NF-YC genes. These identified NF-Y gene members were located on different chromosomes of sugarcane genome (Fig. 26). *In silico* analysis predicted the physio chemical properties and functionally important domains in NF-Y genes. Multiple sequence alignment of NF-Y proteins showed high conservation of functional domains. Phylogenetic analysis of NF-Y genes predicted orthologies which would assist in determining functional conservation and translation between species. Synteny analysis of ShNFY genes with *Arabidopsis thaliana* genome showed collinearity of NFY genes in sugarcane and *Arabidopsis* (Fig. 27).

(C. Appunu, G. Hemaprabha and G.S. Suresha)

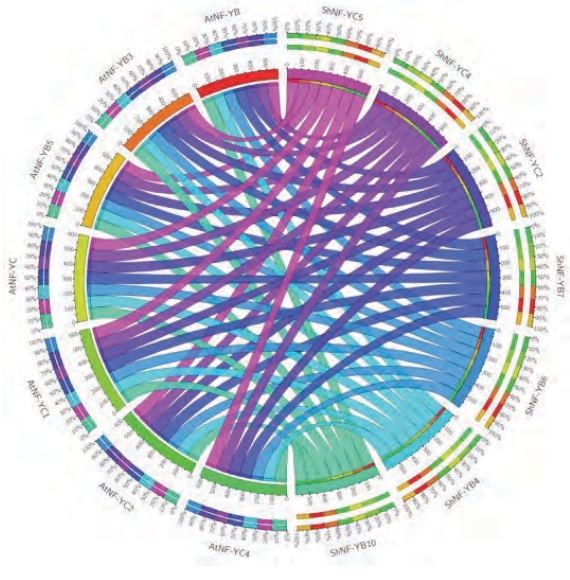


Fig. 27. Synteny analysis of ShNFY genes with Arabidopsis thaliana genome showed collinearity of NFY genes in sugarcane

Network project of transgenics in crops - Transgenic development in sugarcane

The most popular tropical sugarcane variety Co 86032 was chosen for genetic transformation with idea to enhance the performance under water deficit stress conditions. In response to abiotic stresses, plants produce low molecular weight compound known as Glycine betaine (GB), compatible solutes, to cope with stresses by increasing water potential and in turn protect the plants against the damaging effects of secondary stresses such as osmotic and ionic stresses. Transformation work was continued with *codA* gene as suggested by expert members in the progress review meeting held during June 2018 and November 2019. Now, the *codA* transgenic events are in different stages of development (Fig. 28). As suggested by expert

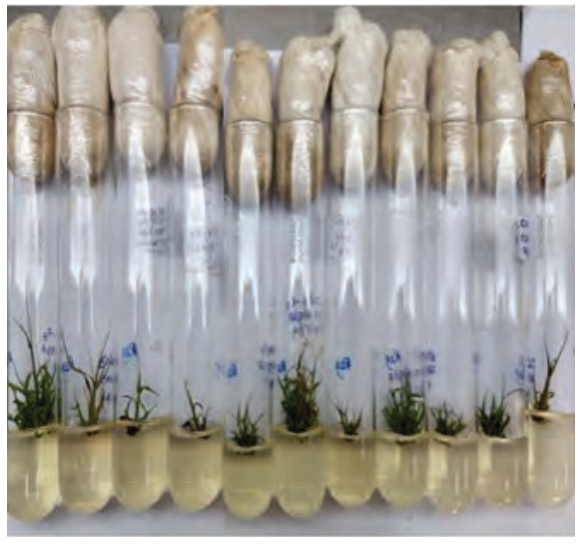


Fig. 28. Shoot regeneration of coda putative transgenic events

members new construct was developed for *EaDREB2* gene. In this construct the candidate gene is driven by stress inducible RD29 promoter. The cloning was confirmed through PCR using gene specific primers. Sugarcane transformation was initiated and events are in different stages of developments and work is in progress.

(C. Appunu and R. Valarmathi)

5.2 DIVISION OF CROP PRODUCTION

5.2.1. Agronomy, Microbiology and Farm Machinery and Power

Development of cropping systems and improved agronomic practices to enhance sugarcane productivity

Characterization of rhizosphere of selected sugarcane genotypes

Selected isolates of *Bacillus, Beijerinkia, Derxia, Azospirillum, Gluconacetobacter* and *Methylobacterium* were inoculated to Co 86032 and Co 09004 planted under hydroponic conditions. Overall results on 90 days of inoculation indicated that among the isolates, *Azospirillum, Gluconacetobacter and Bacillus* inoculated plants recorded significantly higher root and shoot length in Co 09004 while in Co 86032. *Azospirillum, Gluconacetobacter* and *Pseudomonas* recorded higher root and shoot fresh weight. The root exudate samples were concentrated using lyophilizer and analysed using HPLC. HPLC analysis of root samples indicated the presence of phenolic acids *viz.*, galic, caffeic, vanilic, syringic and ferulic acids. Most of the samples gave large amounts of interfering substances.

(K. Hari, S. Vasantha, A. Anna Durai and G.S. Suresha)

Development and promotion of tools and machinery for sugarcane mechanization

Development of EPN (Entomopathogenic nematode) applicator: Initially a conceptual design for EPN (Entomopathogenic Nematode) applicator for applying the EPN formulation at the root-zone of the sugarcane crop was prepared (Fig. 29). This was designed to apply around 50 ml of formulation at the root-zone which is below

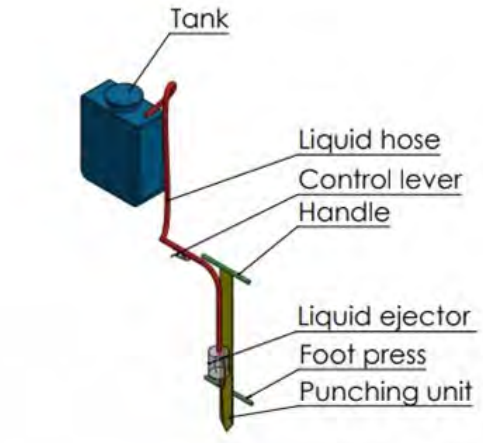


Fig. 29. Conceptual design of manually operated EPN applicator

15-20 cm depth from the surface by using a lever by the operator. Based on the conceptual design, the fabrication of the unit was carried out at ICAR- Central Institute of Agricultural Engineering, Regional Centre, Coimbatore. A knapsack spraying unit having a tank capacity of 16 litres with the working pressure of 3 bar (3 kg/) was used for the manual application of EPN solution. The outlet of knapsack spraying unit was further connected with the injector unit through a lance having cut-off valve. Cut-off valve is used for controlled release of pressurised EPN solution from the knapsack unit. The injector unit includes handle, injector frame, pedal press and an injecting mechanism and this injector unit was made up of mild steel material. Injecting mechanism is transparent and graduated with volumetric scale upto 50 ml. It works on the Siphon principle. A siphon works because of gravity pulling down on the taller column of liquid causes reduced pressure at the top of the siphon (formally, hydrostatic pressure). As gravity pulls down the fluid, the velocity of the fluid increases, resulting in lower pressure. The applicator handle was made up of Mild steel hollow pipe of 25.48 mm outer diameter and 22.61 mm inner diameter with 460 mm length. Flat mild steel of 50 mm wide was used for the preparation of injector main frame and its length was 980 mm. At the end of the main frame, 80 mm long triangular section is provided for easy penetration of the tool in to the soil to a depth of 15 cm approximately. A 460 mm long mild steel hollow pipe of 25.48 mm outer diameter and 22.61 mm inner

diameter was used as a pedal. The pedal was fixed in a way such that it can be easily pressed by everyone for smooth penetration of the injector main frame into the soil. Flexible plastic tubes having 8.08 mm inner diameter and 11.17 mm outer diameter is used for the delivery of the solution from the injecting mechanism to the root zone. The different components namely knapsack tank, lance, injecting mechanism and delivery tube were made of plastic to avoid corrosion.

Working of EPN applicator: With all the connections made appropriate and the tank is filled with EPN solution, the knapsack unit has to be pressurised by pumping the handle. Once the pressure reaches its maximum the injector unit has to be inserted into the soil near root zone of the sugarcane crop. The injector unit can be inserted by pressing the handle with hand and pedal with leg together until it reaches 15 cm depth approximately. After inserting the injector unit, cut-off valve should be pressed to release the EPN solution to the injecting mechanism until it reaches its maximum capacity of 50 ml. Once the injecting mechanism reaches its maximum the solution drains automatically to the root zone through delivery tube (Fig. 30).

Fig. 30. Prototype of manually operated EPN applicator

Field testing of EPN applicator: Initially field testing of EPN applicator was carried out in the field at ICAR-Central Institute of Agricultural Engineering, Regional Centre, Coimbatore (Fig. 31). Further, a field experiment was conducted to evaluate the newly developed EPN applicator in the farmer's (Sh. K. Loganathan) field at Banagahalli, Thalavadi (Fig. 32). Three different application or delivery methods for five EPN species against white grub *Holotrichia serrate* were studied in the first ratoon crop of sugarcane variety Co 86032. Totally 16

Fig. 31a. Field testing of EPN applicator at ICAR-CIAE, RC, Coimbatore - 2
Fig. 31b. Field testing of EPN applicator at ICAR-CIAE, RC, Coimbatore - 1

Fig. 32. Farmer experiencing EPN applicator in his field at Thalavadi

treatments including control was maintained with two replications. The EPN was applied at the rate of $1x10^9$ per acre. White grub population was observed randomly in six places per treatment by counting dead and alive white grub population in one m^2 area. In general there was a reduction in white grub population irrespective of the EPN application methods

compared to untreated control. However, among the different application methods, EPN applicator recorded maximum reduction (78.79 %) of white grubs after 15 days of application of EPN formulation.

(T. Arumuganathan, C. Palaniswam and V. Venkatasubramanian)

Development of improved planting material of sugarcane by priming with plant growth promoting bacteria and other substances

Priming sugarcane with plant growth promoting bacteria: Free living, root associated and phyllosphere bacteria belong to genera *Beijerinkia, Derxia, Azotobacter, Azospirillum, Gluconacetobacter* and *Methylobacterium* were isolated from sugarcane varieties. Experiments were conducted to study the effect of sett treatment with bioinoculents by using sett treatment devise on the performance of seedlings raised from chip bud and single bud. Overall results indicated that Co 2001-13 and Co 8371 have recorded the highest germination percentage (86.5%). Among the different cultures, Beijerinckia (BE 03) has recorded highest germination of 69.5% in single bud and 66.5 % in chip bud. The treated setts recorded higher population of the inoculated bacteria on the day of planting and at 30 days after planting compared to uninoculated. Highest colonization was also observed with *Beijerinka* (1.8×10^4 cfu/g fresh root) and *Methylobacterium* (1.6×10^4 cfu/g fresh root).

(K. Hari, P. Geetha, P. Malathi, D. Neelamathi, G.S. Suresha and N. Rajendra Prasad)

Weed management in sugarcane under wide row planting

A field experiment was commenced during February 2019 to study the effect of herbicide molecules like metribuzin, ametryne, ethoxysulfuron, topramezone, halosulfuron methyl and tembotrione in sugarcane. The experiment consisted of 10 treatments laid out in RBD with three replications. Treatments are (1)Three hand weeding 30, 60 and 90 DAP (2) Unweeded control (3) Metribuzin 1.25 kg ha^{-1}early post emergence (EPOE) *fb*topramezone 21 g ha^{-1} + atrazine 250 g ha^{-1} at 65 DAP *fb* one hand weeding at 120 DAP(4) Metribuzin 1.25 kg ha^{-1} EPOE *fb*topramezone 25.2 g ha^{-1} + atrazine 250 g ha^{-1} at 65 DAP *fb* one hand weeding at 120 DAP (5) Metribuzin 1.25 kg ha^{-1} EPOE *fb*topramezone 29.4 g ha^{-1} + atrazine 250 g ha^{-1} at 65 DAP *fb* one hand weeding at 120 DAP (6) Metribuzin 1.25 kg ha^{-1} EPOE *fb*ethoxysulfuron 60 g ha^{-1} at 65 DAP *fb* one hand weeding at 120 DAP (7) Metribuzin 1.25 kg ha^{-1} EPOE *fb*tembotrione 120 g ha^{-1} + atrazine 250 g ha^{-1} at 65 DAP *fb* one hand weeding at 120 DAP (8) Metribuzin 1.25 kg ha^{-1} EPOE *fb*ametryne 2.4 kg ha^{-1} + 2,4-D 1 kg ha^{-1} at 65 DAP *fb* one hand weeding at 120 DAP (9) Metribuzin 1.25 kg ha^{-1} EPOE *fb*ametryne 2.4 kg ha^{-1} at 65 DAP *fb* one hand weeding at 120 DAP (10) Metribuzin 1.25 kg ha^{-1} EPOE *fb*halosulfuron methyl 67.5 g ha^{-1} + metribuzin 750g ha^{-1} at 65 DAP *fb* one hand weeding at 120 DAP. The mean germination in all plots at 45 DAP was more than 50 per cent. Major weed flora observed in the field *was Daturametel, Digeramuricata, Cleome gynandra, Parthenium hysterophorus, Trianthema portulacastrum, Commelina benghalensis, Cyperus rotundus, Brachiaria reptans, Dactyloctenium aegyptium and Cyanadon dactylon*. All the weed management practices led to significant reduction in density and dry matter of weeds when compared to weedy check. The project is in progress and the herbicide molecules at the tested dose did not exhibit any phytotoxic symptoms in sugarcane variety Co 86032.

(S. Anusha and P. Geetha)

Doubling income of small farms through sugarcane based farming system (NADP/ RKVY)

This project has been sanctioned by Government of India under the National Agriculture Development Programme/ Rashtriya Krishi Vikas Yojana for the year 2019-20 with the objectives of setting up a model farm to demonstrate the extent of diversification and possibility of varied agro-based enterprises at ICAR-Sugarcane Breeding Institute, Coimbatore and for empowering human resource for sustenance of the proposed activities through on-farm capacity development programs. The farm layout for establishment of sugarcane

based farming system model with various components such as intercropping of pulses, trash mulching for organic matter addition and weed control and allied enterprises like dairy, goat/ sheep, mushroom production using sugarcane trash, apiary, jaggery production has been prepared. For cropping system component, cultivation of short duration paddy has been planted. The paddy was harvested with the yield of 2300 t/ac. The sugarcane settlings were raised with the variety Co 11015 for planting under drip irrigation.

(P. Geetha, T. Rajula Shanthy, C. Palaniswami, A.S. Tayade and L. Saravanan)

NFSM demonstration of pulses intercropping with sugarcane

With the objective of enhancing sugarcane farmer's income, a project on diversification of sugarcane based cropping system with short duration pulses like black gram was initiated in six villages *i.e.*, Vellode, Aval Poondurai, Erode, Modakuruchi, Ganapathypalayam and Chennimalai from Erode and Kangeyam. These villages come under the Sakthi sugars unit-4. Under this project, Sugarcane + black gram intercropping comprising improved black gram variety BG 6, foliar spray of Pulses wonders, weed management and integrated nutrient management were demonstrated on 50 ha of sugarcane farmer's field.

(A.S. Tayade, P. Geetha and S. Anusha)

INTER INSTITUTIONAL COLLABORATIVE RESEARCH

Inter Institutional Collaborative Research Project on Testing and evaluation of IISR sugarcane machineries under tropical condition

Fabrication work of two machineries namely IISR-Ratoon Management Device and IISR-Sugarcane planter was completed at the Division of Agricultural Engineering, ICAR-Indian Institute of Sugarcane Research, Lucknow. These two machineries fabricated under this inter institutional collaborative project were brought to ICAR-SBI, Coimbatore during December 2019 from ICAR-IISR, Lucknow forits testing and evaluation under tropical condition.

To evaluate the IISR model disc type ratoon management device, a harvested field of plant crop in Field No. 22 has been identified and selected. The harvested field of field experiment on 'Agronomic performance of elite sugarcane genotypes' which was concluded this year was found suitable for this study.

(A.K. Singh – ICAR-IISR, Lucknow, T. Arumuganathan, A.S. Tayade, T. Senthil Kumar - ICAR-CIAE RC, CBE)

Development of tractor operated whole cane harvester

Development of experimental set up for measuring specific cutting energy: A Pendulum type impact cutting device for measuring specific cutting energy was developed for optimizing the blade parameters like thickness, bevel angle and approach angle for development of sugarcane harvester by considering row to row spacing of 0.75 m, plant to plant spacing varying from 0.35 to 0.45 m. The moisture content of the collected sugarcane stems varied from 60 to 75 percent and it was maintained almost at constant level by keeping the stems under shade till the completion of the investigation (Fig. 33).

From the results, it was observed that the specific cutting energy was influenced by the thickness of blade, bevel angle and approach angle. It was concluded that with 8mm blade thickness, 15˚bevel angle and 20˚ approach angle required minimum specific cutting energy of 26994 J/ m^2 followed by 8mm blade thickness, 35˚ bevel

Fig. 33. Experimental set up for measuring specific cutting energy

angle and 40˚ approach angle required specific cutting energy of 28146 J/m^2.Eight mm blade thickness, 35˚ bevel angle and 0˚ approach angle required maximum specific cutting energy of 61310 J/m^2. Hence the cutting blade parameters *viz*., 8mm blade thickness, 15˚ bevel angle and 20˚ approach angle have been standardized for development of sugarcane harvester.

(T. Senthilkumar - ICAR-CIAE RC, Coimbatore, T. Arumuganathan, A.K. Singh and M.K. Singh - ICAR-IISR, Lucknow)

5.2.2. PLANT PHYSIOLOGY

Enhancing physiological efficiency of sugarcane

Evaluation of physiological efficiency of commercial hybrids and species clones of *Saccharum* for water use under water limited conditions

Two separate trials in split plot design were initiated with irrigation treatments as main plot and varieties (20 'Co' hybrids in the first trial and 15 representatives from species clones in the second trial) as sub plot. Recommended cultural practices followed up to 60 DAP. The treatments were imposed during formative phase and to continue up to harvest. Soil samples were drawn during irrigation cycle in all the treatments.

Growth and biomass: The above ground biomass registered a reduction of 20 and 16% in I_1 and I_2 respectively in Co hybrids at formative phase, however, during grand growth phase the biomass reduction increased to 23% in I_2 and remained in same pace in I_1. Three genotypes *viz*., Co 15015, Co 15018 and Co 85019 recorded higher biomass than the genotypic mean in both the restricted irrigation treatments. Co 10026, Co11015, Co16018, Co 15015, Co 15018 and Co 85019 recorded higher biomass in I_1. The species clones registered 9 and 19% reduction biomass in I_1 and I_2 at formative phase while at grand growth phase the reductions were 20 and 40%.

Leaf area index (LAI) reduced by 23 and 15% respectively in I_1 and I_2 in Co hybrids. Genotypes Co 15007, Co 15015, Co 14025, Co 15018 and Co 13014 recorded higher LAI than the genotypic mean in both the restricted treatments. In species clones LAI reduced by 10 (I_1) and 20% (I_2) in restricted irrigation treatments.

Physiological traits: Chlorophyll SPAD index reduced by 18% in restricted irrigation treatments during formative phase and Co 15007, Co 15018, Co 12009 and Co 13014 had higher SPAD index for both the treatments (I_1&I_2). SPAD index did not vary significantly among the species clones and among irrigation treatments suggested that restricted irrigation doesn't influence the chlorophyll pigment in species clones unlike Co hybrids.

At formative phase the chlorophyll fluorescence declined in both the restricted irrigation treatments in 'Co' hybrids and the differences smoothened during grand growth phase, perhaps due to rainfall and conducive climate experienced during the period. In species clones the variations for chlorophyll fluorescence were marginal and irrigation treatments effects were not pronounced. Canopy temperature increased by 2-4 units in I_1 and I_2 during formative phase in Co hybrids as well as species clones (Fig. 34). However, the differences vanished during grand growth phase. The climate influence could be observed in reducing the canopy temperature in restricted irrigations.

Juice sucrose: Sucrose % juice at 11th month of the crop showed reduction by 7% in I2 and 4% in I1

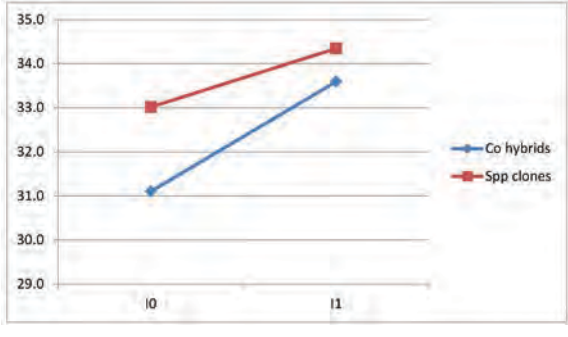


Fig. 34. Leaf temperature at formative phase in irrigation treatments

as compared to 'Co' hybrids. Among the 'Co' hybrids studied Co 09004, Co 10026, Co 12009, Co 11015, Co 14002 and Co 15007 registered higher juice sucrose over the genotypic mean (Fig. 35a). Species clones showed better stability with minor reduction in juice sucrose (Fig. 35b). ISH clones ISH 107, ISH 111, ISH 23, ISH 58, ISH 9 and Khakai, Nargori and Lalri recorded comparable sucrose % in all the treatments.

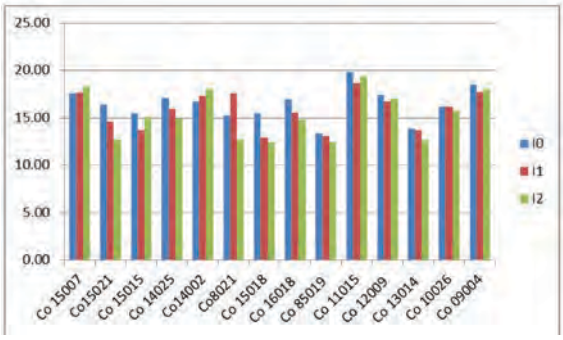


Fig. 35a. Sucrose % Juice in commercial genotypes at 11 months

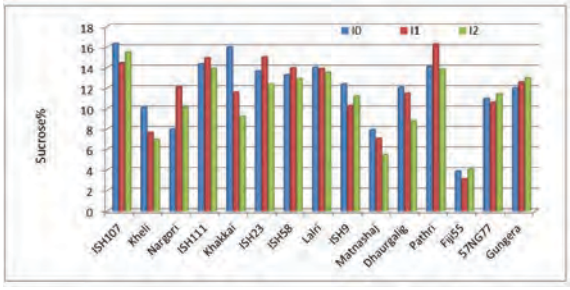


Fig. 35b. Sucrose % Juice in species clones

(S. Vasantha, A.S .Tayade, R. Arun Kumar, S. Anusha and G. Hemaprabha)

Comparative physiological analysis of tropical and sub tropical varieties of sugarcane

Experiment at tropical condition: During 2017-18 planting season, 10 tropical and eight sub- tropical varieties were planted for multiplication. Initiated field experiment by using six tropical (Co 86032, Co 0212, Co 14012, Co 06022, Co 11015 and Co 13006) and six sub-tropical varieties (Co 0238, Co 15023, Co 98014, Co 15027, BO 91 and Colk 8102) in FRBD design and germination was found good (more than 90%) in both tropical and subtropical varieties.

Biometric observation at formative phase of tropical and sub-tropical varieties: At 90 DAP, variation in shoot population in tropical varieties was 38,000 ha^{-1} (Co 06022 to 61, 000 ha^{-1} (Co 0212) and sub - tropical varieties was 44, 000 ha^{-1} (Co 0238 to 65,000 ha^{-1}(Co Lk 8102). At 70 DAP, data on total chlorophyll content in tropical varieties was varied from 1.25 mgg^{-1} (Co 06022) to 1.85 mgg^{-1} (Co 14012) and sub-tropical varieties was 1.30 mgg^{-1} (Co 0238) to 1.70 mgg^{-1} (Co 15023). At 70 DAP, Nitrate reductase (NR ase) activity varied from 19.5 (Co 86032) to 26.5 μg^{-1} $frwt^{-1}$ h^{-1}(Co

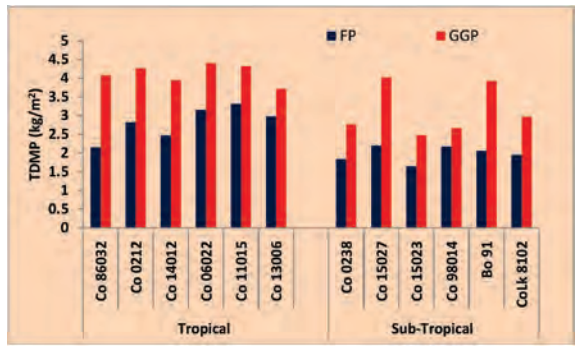


Fig. 36. LAI in tropical and sub-tropical varieties during formative and GGP phases of the crop

0212) in tropical varieties and in subtropical varieties, the variation was 17.6 (Co 15023) to 24.5μg^{-1} $frwt^{-1}$ h^{-1} (Co 15027). At formative phase, LAI varied from 1.20 (Co 14012) to 1.68 (Co 06022) in tropical varieties, while in sub-tropical varieties varies 0.80 (Co 0238) to 1.58 (Co 15027). Similarly, the variation in TDMP in tropical was 2.15kg/m^2 (Co 86032) to 3.3kg/m^2 (Co 11015) in tropical varieties, while in sub-tropical it ranged from 1.65 kg/m^2 (Co 15023) to 2.20 kg/m^2 (Co 15027) (Fig. 36).

Biometric observation at GGP of tropical and sub-tropical varieties: The variation in shoot population in tropical varieties was 52,000 ha^{-1} (Co 06022) to 81, 000 ha^{-1} (Co 0212) and sub - tropical varieties was 44, 000 ha^{-1} (Co 0238 to 65, 000 ha^{-1} (CoLk 8102). In tropical varieties, plant height varied from 80.15 cm (Co 11015) to 140 cm (Co 14012) and sub tropical, the variation was 60.0 (Co 0238) to 102.0 cm(Co 15027). Generally, tropical varieties recorded higher shoot population, plant height and TDMP compared to sub tropical varieties. SPAD value of tropical varieties, varied from 32.58 (Co 0212) to 41.21

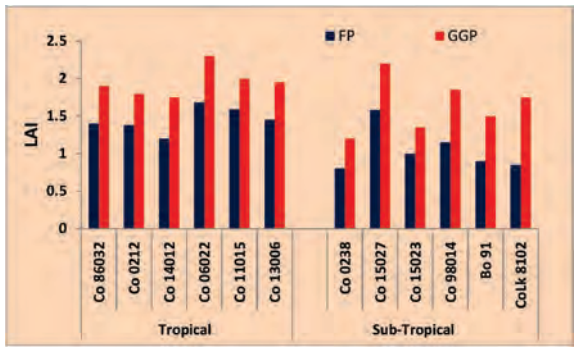


Fig. 37. TDMP (kg/m2) in tropical and sub-tropical varieties during formative and GGP phase of the crop

(Co Co 06022) and sub-tropical varieties was 33.10 (BO 91) to 44.18 (Co 15027). Subtropical varieties comparatively recorded higher SPAD of 37.83 values than the tropical varieties (35.43. Nitrate reductase (NR ase) activity varied from 28.5 (Co 86032) to 36.5 μg^{-1} fr.wt^{-1} h^{-1}(Co 06022) in tropical varieties and in subtropical varieties, the variation was 27.6 (Co 15023) to 38.5 fr.wt^{-1} h^{-1} (Co 15027). Variation for total phenolics was 95.1 (Co 86032) to 105.2 μgg^{-1}frwt^{-1} (Co 0212) in tropical varieties and was 98.0 (BO 91) to 110.2 μgg^{-1}frwt^{-1} (Co 15027) for sub-tropical varieties. At grand growth phase, LAI varied from 1.75 (Co 14012) to 2.30 (Co 06022) in tropical varieties, while in sub- tropical varieties, the variation was 1.25 (Co 0238) to 2.25 (Co 15027) Similarly, the variation in TDMP in tropical was 3.74 (Co 13006) to 4.45 kg/m^2 (Co 11015) in tropical varieties, while in sub-tropical it ranges from 2.48 (Co 15023) to 4.02 kg/m^2 (Co 15027) (Fig. 37).

Experiment at sub-tropical condition: Ten tropical varieties namely Co 0212, Co 06022, Co 09004, Co 11015, Co 13006, Co 14008, Co 14012, Co 14027, Co 14028 and Co 15007 were planted for multiplication with objectives to elucidate physiological growth characters associated with phenotypic behaviors of promising varieties in tropical and subtropical conditions.

(R. Gomathi, V. Krishnapriya, R. Arun Kumar, Pooja, N. Kulshrestha and K. Elayaraja)

Radiation use efficiency of sugarcane genotypes as influenced by water levels and crop geometry

An experiment is being conducted in ICAR-SBI during 2019 with five 'Co' canes *viz*., Co 62175, Co 85019, Co 86032, Co 86249 and Co 99004 planted under three different spacing (Row to row:75 cm, 90 cm and 150 cm) for studying radiation use efficiency. Line quantum sensors (LICOR) along with digital data logger (LI-1400) were used to record the light interception data. The cumulative global photosynthetically active radiation (PAR) was recorded during the germination, formative, grand growth and maturity phases. Under 90 cm spacing and 75 cm

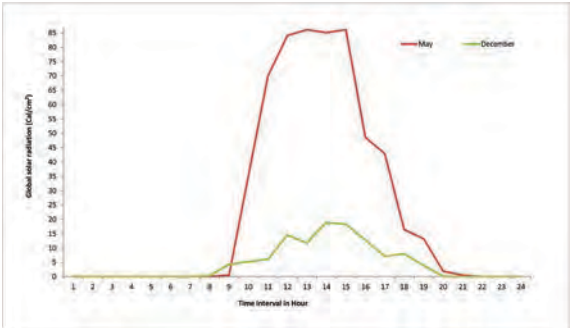


Fig. 38. Global solar radiation during May and December months

spacing, Co 86249 and Co 62175 were recorded with better dry matter production along with light interception at grand growth phase, while under the 150 cm row to row spacing the Co 86032 registered better biomass. Significant differences in light interception was observed between different spacing i.e. the clones planted in narrow spacing was recorded with more light interception than other two spacing, while the 150 cm was observed with less light interception. Mostly the global solar radiation during May month was observed significantly more than the required radiation for photosynthesis and *vice versa* was recorded during December month (Fig. 38). Dry matter production was recorded at three intervals during 95 days after planting (DAP), 217 DAP and 304 DAP. At maturity phase (304 DAP) the range of biomass at 90cm, 75cm and 150cm were 3503-5040, 2759-6124, and 2448-3320 g.dwt/m^2 respectively. Another experiment with species clones under limited irrigated condition for studying radiation use efficiency has revealed better biomass production in ISH 107 and Khakai clones under both control (full irrigation at recommended interval, with 100% crop evapotranspiration replacement) and mild water deficit condition (irrigation at recommended interval, with 50% crop evapotranspiration replacement), while IK 7610 and ISH 107 showed better biomass production under severe water deficit condition (skipping alternate irrigation and irrigation with 50% crop evapotranspiration replacement). ISH 107, Khakai, and ISH 111 clones also recorded better light interception, while ISH 9 showed lesser light interception.

(R. Arunkumar and P. Geetha)

Deciphering the physiological basis of nutrient use efficiency in sugarcane

Preliminary observations were recorded in Co 86032 raised in gravel media with nutrient solution and subjected to increasing concentration of N, P and K (0 to 2000 µM). The set-up was placed in glass house under controlled condition. The plants were grown till visible deficiency symptoms appeared, upon which the plant was harvested to record the observations. With increasing concentration of N, P and K the SPAD chlorophyll index, plant height, leaf area and total plant biomass showed a general increasing trend. The experiment is in progress and data from three replications will be pooled to arrive at critical threshold values for N, P and K in sugarcane using Cate-Nelson analysis.

(V. Krishnapriya, S. Vasantha, R. Arunkumar, S. Anusha and V. Vinu)

Characterisation of root system traits in sugarcane germplasm

Root system architecture and morphology is one of the least studied traits in most agricultural crops including sugarcane (*Saccharum* sp.). It is of prime importance as roots are the primary conductors of water and nutrients which in turn determine crop growth and yield. This research work was attempted with the aim to characterise root system traits in sugarcane germplasm to gain knowledge about its relationship with above-ground biomass and physiology.

Root trait (length, surface area, volume and average root diameter) of an entire clump was captured in a root scanner (Epson) and integrated using image analysis software (WinRhizo Pro). Length of all the roots constituting an individual clump was summed up to derive the root length presented here, with significant variation among the germplasm clones at formative growth stage, ranging from 5799.5 cm (*S. barberi* White Pindaria) to 170817.5 cm (*Erianthus arundinaceus* IJ-76-503), with a mean of 37844.3 cm. Similar trend was observed in root surface area, root volume and average root diameter, showing an average of 5566.75 cm^2, 71.01 cm^3 and 10.2 mm respectively. Physiologically active roots of about 10 cm length (excised at 10 mm from the root tip) were preserved in fixative solution (formaldehyde:acetic acid:ethanol::2:2:1) for anatomical studies. Cross sections of root revealed wide variation among germplasm with regard to traits such as ratio of cortex-to-stele, number of air spaces in the cortex and number of metaxylem elements in the stele (Fig. 39).

With regard to above-ground biomass during formative stage, green leaf area ranged between 722.7 cm^2 to 16077.5 cm^2 with an average of 5073.2 cm^2. Leaf dry weight varied from 2.507 to 99.567 g, mean being 32.602 g. Highest sheath dry weight (43.291 g) and cane dry weight (14.354 g cm) was recorded in *S. officinarum* clone Hawaii Original and *Pennisetum sp.* clone IS 76-166, respectively. Chlorophyll content and epicuticular wax deposition in the leaves observed at formative stage varied significantly among clones. Total chlorophyll was highest in GUK 14-530 (2.747 mg g^{-1} FW) and lowest in IJ 76-503 (1.699 mg g^{-1} FW), with a mean of 2.185 mg g^{-1} FW. Epicuticular wax content on the leaf surface ranged from 15.018 µg cm^{-2} in GUK 14-530 to 5.006 µg cm^{-2} in Reha, with an average of 9.211 µg cm^{-2}.

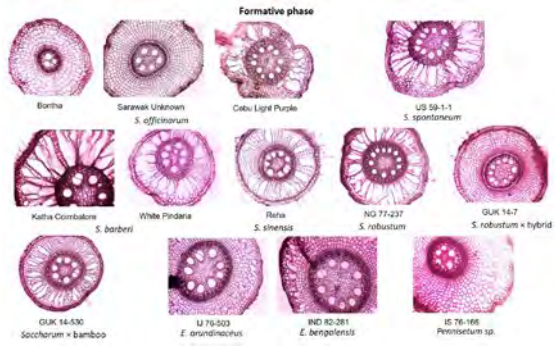


Fig. 39. Cross section of sugarcane germplasm roots

At maturity, the canes were harvested to record the yield attributing traits. Average cane height among the clones was 110.1 cm, with highest recorded in IS 76-166 (208.0 cm) with maximum number of internodes (24). White Pindaria had the shortest cane (52 cm) with least number of internodes (9). Sarawak Unknown and Bontha has thick canes of 2.6 cm and 2.5 cm girth, respectively. Internode length was highest in US 59-1-1 (11.6 cm), followed by IS 76-166 (11.2 cm). *S. spontaneum* clone US 59-1-1 recorded

the highest number of tillers per clump (48) and least single cane weight (25.1 g), while *S. officinarum* clone Sarawak Unknown had two tillers per clump but exhibited highest single cane weight (477.8 g) among the germplasm.

(V. Krishnapriya)

5.2.3 SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

Natural resource management for enhancing productivity and sustainable sugarcane production

Development of a decision support system for sugarcane soil management

The post-harvest analysis of soil samples from Plant crop II is completed. The post-harvest soil fertility did not vary significantly among the treatments at p=0.05. The mean pH, EC, organic carbon, available N, available P, and available K were 9.10, 0.53 dS/m, 0.73%, 105.41 kg/ha, 50.49 kg/ha, 674 kg/ha. The initial soil pH, EC, organic carbon, available N, available P, and available K was 8.94,0.49 dS/m, 0.83%, 190.40 kg/ha, 53.61 kg/ha and 665.84 kg/ha respectively. The reduction in organic carbon, and nitrogen to an extent of 12.27 and 44.64% was observed over the initial status. The DS4M software was validated with the soil test results of 105 soil samples from Amaravathi Cooperative Sugar Mills Ltd, and generated soil health cards and package of practices.

(A. Vennila and C. Palaniswami)

Assessment of carbon sequestration in sugarcane growing soils with reference to substrate dynamics

Carbon dioxide flux under 31 sugarcane genotypes was measured in the field at 300 DAP. The flux ranged from 3.02 to 12.94 µM/m^2/s. The CO_2 flux under Co 0314 (12.94 µM/m^2/s) was the highest followed by Co 92005 (12.13 µM/m^2/s) and the lowest was recorded with Co 7219 (3.02 µM/m^2/s) (Table. 6). The correlation among soil pH, EC, number of millable canes (NMC), soil organic carbon (SOC) and CO_2 flux was analysed. CO_2 flux showed negative correlation with SOC and positive correlation with NMC although not significant (Table. 7). Soil organic carbon content in the 105 soil samples collected from the command area

Table 6. Carbon dioxide flux (µM/m^2/s) under different sugarcane genotypes at 300 DAP

Genotype	CO_2 Flux	S. No.	Genotype	CO_2 Flux
Co 0112	3.84	16	Co 6806	4.89
Co 0113	6.68	17	Co 7219	3.02
Co 0115	6.98	18	Co 8021	7.18
Co 0212	7.81	19	Co 8338	4.46
Co 0218	3.60	20	Co 85019	7.00
Co 0238	4.64	21	Co 86032	5.87
Co 0240	5.85	22	Co 87025	3.98
Co 0314	12.94	23	Co 91010	5.78
Co 0403	9.35	24	Co 92005	12.13
Co 06022	5.71	25	Co 94008	7.81
Co 06027	8.88	26	Co 97010	6.96
Co 06030	5.98	27	Co 99004	8.22
Co 09004	6.87	28	Co 99006	7.45
Co 11015	4.78	29	CoC 671	5.83
Co 62175	7.27	30	CoM 0265	6.49
		31	CoM 86249	9.56

Table 7. Correlation among soil pH, EC, CO_2 flux, NMC and SOC under different sugarcane genotypes (n=31)

	pH	EC	CO_2 Flux	NMC	SOC
pH	1				
EC	0.278	1.000			
CO_2 Flux	-0.212	0.086	1.000		
NMC	-0.078	-0.006	0.219	1.000	
SOC	0.140	0.074	-0.503	0.041	1

of Amaravathi Cooperative Sugar Mills Ltd in Tiruppur and Dindigul Districts of Tamil Nadu ranged from 0.19 to 1.50%. 20% of the soils showed low organic carbon status (<0.5%) and 43% showed medium status (0.5-0.75%). These soils need to be managed to improve/maintain the organic carbon stock so as to attain the sustainable production.

(C. Palaniswami and A. Vennila)

Development of soil inference system for the management of sugarcane soils using pedotransfer function approach

Soil profiles were excavated in sugarcane growing soils in the Command Area of Amaravathi Cooperative Sugar Mills Ltd. (Krishnapuram, Jothampatti, Chinnakampalayam, Narikkalpatti, Neikkarapatti, Pappankulam and Madathukulam in Tiruppur and Dindigul Districts of Tamil Nadu (Fig. 40). Collected disturbed and undisturbed samples from different horizons from each soil profile for further analysis. The depth of soil profile varied very widely. The profile in Krishnapuram showed three layers and lateritic parent material was found at 0.77 m depth. The profile in Jothampatti showed only one layer up to 0.25 m depth and below that lateritic parent material was observed. The profile in Chinnakampalayam showed two layers and the gneissic parent material was observed at 0.40 m. Profile excavated in Narikkalpatti showed five layers and parent material was observed at 1.16 m. The profile at Neikkarapatti showed three soil layers and the lateritic parent material at 0.43 m. Three layers were observed in the profile excavated at Pappankulam and parent material was not reached even at 1.8 m depth. The profile in the Mill site at Madathukulam showed two layers and lateritic parent material was observed at 0.44 m depth. Non-calcareousness was observed in the profiles excavated at Jothampatti, Chinnakampalyam and Neikkarapatti. First horizon in Krishnapuram profile showed moderate calcareousness and other two layers showed 0-1 rating of calcareousness. The profile at Narikkalpatti showed moderate

Fig. 40. View of soil profiles excavated in the command areas of Amaravathi Cooperative Sugars, Udumalpet

calcareousness in the first layer, and strong to very strong calcareousness in the layers 2, 3 ,4 and 5. The profile in Pappankulam showed

weak, moderate and very strong calcareousness in the layers, 1, 2 and 3, respectively. The profile excavated in the sugarcane field of Amaravathi Cooperative Mills showed weak calcareousness. All the profiles were non-saline and the electrical conductivity ranged from 0.033 to 0.36 dS/m. The pH ranged from 6.61 to 8.90. All the profiles showed neutral soil reaction except the profile at Narikkalpatti which showed alkaline reaction (pH ranged from 8.75-8.90) in all the layers. Shallow soil depth in Krishnapuram, Jothampatti, Chinnakampalayam, Neikarapatti and Sugar Mill area and calcareousness in Narikkalpatti are the soil constraints identified in the command area of Amaravathi Cooperative Sugar Mills Ltd.

(A. Vennila and C. Palaniswami)

Demonstration of crop production technologies for sugarcane

The demonstration plot was established in 2018 to demonstrate the Settling Transplanting Technology comprising high yielding new genotype (Co 11015), single-bud settling transplantation in paired row, wide-row spacing (4x2 feet), intercropping, drip irrigation, drip fertigation, multiple ratooning, trash mulching and mechanization (Fig. 41 and 42).

The crop was ratooned in December 2018. Black gram (Co BG 6, 3 rows) coriander (Co CR 4, 5 rows) and cow pea (Co CP 7, 2 rows) were sown as intercrops. Coriander was harvested for leaf purpose at 35 days after sowing (DAS). Coriander II crop was sown again in the same interspaces and harvested for leaf purpose at 35 DAS. Sugarcane was harvested in September 2019 *i.e.* 270 days after ratooning (DAR). Intercropping did not affect the cane height and single cane weight (SCW). The mean cane height and SCW was 1.42 m and 0.81 kg, respectively. The weather condition such as high temperature accompanied with low relative humidity prevailed during March to July 2019 affected the cane growth adversely. Cane intercropped with coriander showed significantly lower cane diameter and number of internodes than that with black gram, cow pea and no intercropping.

Fig. 41a. Ratoon I 180 DAR

Fig. 41b. Ratoon II 90 DAR

Fig. 42a. Black gram 65 DAS

Fig. 42b. Coriander 35 DAS

Fig. 42c. Cowpea 65 DAS

Intercropping of black gram, coriander and cow pea did not affect juice quality parameters significantly. The mean Brix, sucrose, purity and CCS were 20.28%, 18.85%, 92.98% and 13.34%, respectively at 270 DAR. Effect of intercropping was significant with respect to number of millable canes (NMC) per hectare, cane yield and commercial cane sugar (CCS) yield. Cow pea intercropping (68957) recorded significantly lower NMC per hectare than that of black gram (86968) and coriander (83741) but was on par with no intercropping (79522) treatment. Black gram intercropping (81.22 t/ha) recorded on par cane yield with coriander intercropping (68.64 t/ha) and significantly higher cane yield than that in cow pea (56.63 t/ha) intercropping and no intercropping (61.08 t/ha) treatments at 270 DAR (Table. 8.) CCS yield in cane intercropped with black gram (11.08 t/ha) was significantly higher than that of coriander (8.98 t/ha) and cow pea (7.64 t/ha) intercropping and no intercropping (8.11 t/ha). The cowpea showed profuse branching and trailing habit which resulted in reduction in tillering and NMC, which is also reflected in cane yield. Hence, cow pea is not a suitable intercrop for sugarcane.

The net additional income of Rs. 59992, Rs. 74889 and Rs. 4574 per hectare was recorded in sugarcane intercropped with black gram, coriander and cow pea, respectively over and above the no intercropping treatment (Table. 8). However, caution should be taken into account when additional income from coriander intercropping is concerned as the leaf purpose coriander will be profitable only when cultivated in small area nearer to the cities in suitable season.

The Ratoon I was harvested and initiated second ratooning on 20 September 2019. Trash shredding using tractor drawn shredder was carried out. Broadcasted urea @ 50 kg per hectare and then broadcasted *Trichoderma viride* @ 10 kg/ha mixed with 100 kg FYM immediately after trash shredding to stimulate trash decomposition. Ratoon operations and basal application of nutrients were carried out. Sowing of intercrops was taken up. The germination of intercrops especially coriander was poor. Later on due to continuous rainfall, waterlogging and excessive moisture resulted in complete loss of coriander. The excessive vegetative growth of black gram and green gram with less profuse flowering was observed. Seed settling was very poor and hence pods were not harvested. Second crop of coriander was sown in the same coriander interspaces on 22 November 2019. The germination was

Fig. 43. Field stand of Ratoon II (at 90 DAR) in the demonstration plot of settling transplanting technology for sugarcane (Co 11015)

Table 8. Sugarcane yield and returns under different intercropping per hectare in Ratoon crop I

	Sugarcane			Intercrops			Sugarcane + intercrops	
	Cane yield (t/ha)	Income (Rs/ha)		Yield (kg/ha)	Income (Rs/ha)		Over all net income (Rs/ha)	Additional income (Rs/ha)
		Gross	*Net		Gross	**Net		
Blackgram	81.23	212213	57213	347	17350	7350	64563	59992
Coriander	68.64	179322	24322	3257†	65138	55138	79460	74889
Cowpea	56.63	147946	-7054	318	26200	16200	9146	4574
No intercrop	61.08	159572	4572	-	-	-	4572	-

*Cost of cultivation@ Rs 155000/ha; ** Cost of cultivation @ Rs 10000/ha; †Two crops for leaf purpose in the same interspaces

again affected by rainfall and yielded only 340 kg green leaves/ha. The regular drip irrigation, fertigation, monitoring and maintenance is being carried out for the second ratoon crop (Fig. 43).

(A. Vennila, S. Anusha, C. Palaniswami and Bakshi Ram)

Development of simulation model for sugarcane production system

Statistical analysis of weather parameter on sugarcane flowering: A detailed analysis of the weather data (2000-2018) with sugarcane flowering (National Hybridization Garden) revealed that the minimum temperature during April, May, June, July, August and September months had significant negative correlation with flowering. Among the observed months the July month minimum temperature was recorded with high negative correlation (r= -0.654**) for flowering in sugarcane. It has been observed that minimum temperature of ≥23°C had negative impact on sugarcane flowering and the years with better rainfall results with optimum temperature thereby providing conducive microclimate for flowering in sugarcane. The changing climate with more atmospheric drought and warming of night plausibly leads to reduced flowering.

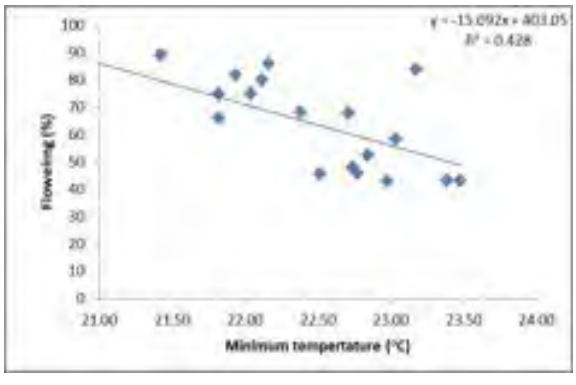


Fig. 44. Correlation between July month minimum temperature with sugarcane flowering

Correlation between July month minimum temperature with sugarcane flowering: The flowering observation data of National Hybridization Garden in main farm and Arrowing plot in ECC farm were utilised to calculate cumulative thermal time for flowering in different sugarcane genotypes. Thermal time for planting to flowering was calculated using the base temperature 9°C. This ranged from 5141 to 5920°C day. Out of 320 genotypes observed, about 50% of genotypes required 5500-5750 °C day for flowering (Fig. 44).

(C. Palaniswami, G. Hemaprabha, A. Vennila, S. Vasantha, K. Hari, R. Gomathi, I. Rajendran, A. Anna Durai, A.S. Tayade, P. Geetha, S. Anusha, G.S. Suresha, R. Arun Kumar, V. Krishnapriya, R. Valarmathi and T. Arumuganathan)

Sub-cellular targeting of invertase inhibitory proteins: a novel approach to enhance sucrose yield in sugarcane

Invertase inhibitor genes construct development: In order to develop ShINH1 and ShINH2 gene constructs for vacuolar targeting, pCAMBIA1302 plasmid DNA was used as template along with the gene specific primers having 5'SpeI and 3'BstEII overhangs. The amplified products were gel eluted and restricted from SpeI and BstEII. The same enzymes were used to generate 5' and 3' overhangs in the MF42 vector to replace cloned somatotropin gene. Plasmids were isolated from recombinant colonies and were confirmed for the insert release using SpeI and BstEII. In order to develop gene constructs for apoplasmic targeting VT78 (vacuolar targeting determinant) was released by restriction with BglII restriction enzyme and self-ligated. Recombinant clones were confirmed by performing PCR using promoter specific forward primer and gene specific reverse primer. The differences in size were visualized between the positive control containing VT (1131bp and 1176bp for INH1 and INH2 respectively) and self-ligated without VT constructs (1059bp and 1098bp INH1 and INH2 respectively). Similarly, PCR confirmation was also done using promoter specific forward primer and VT reverse primer. Restriction digestion of VT with BglII in the positive plasmids was also done for confirmation. In this way, we have successfully developed eight gene constructs (Fig. 45 and 46) and have further checked for reading frame and presence of VT by Sanger's sequencing.

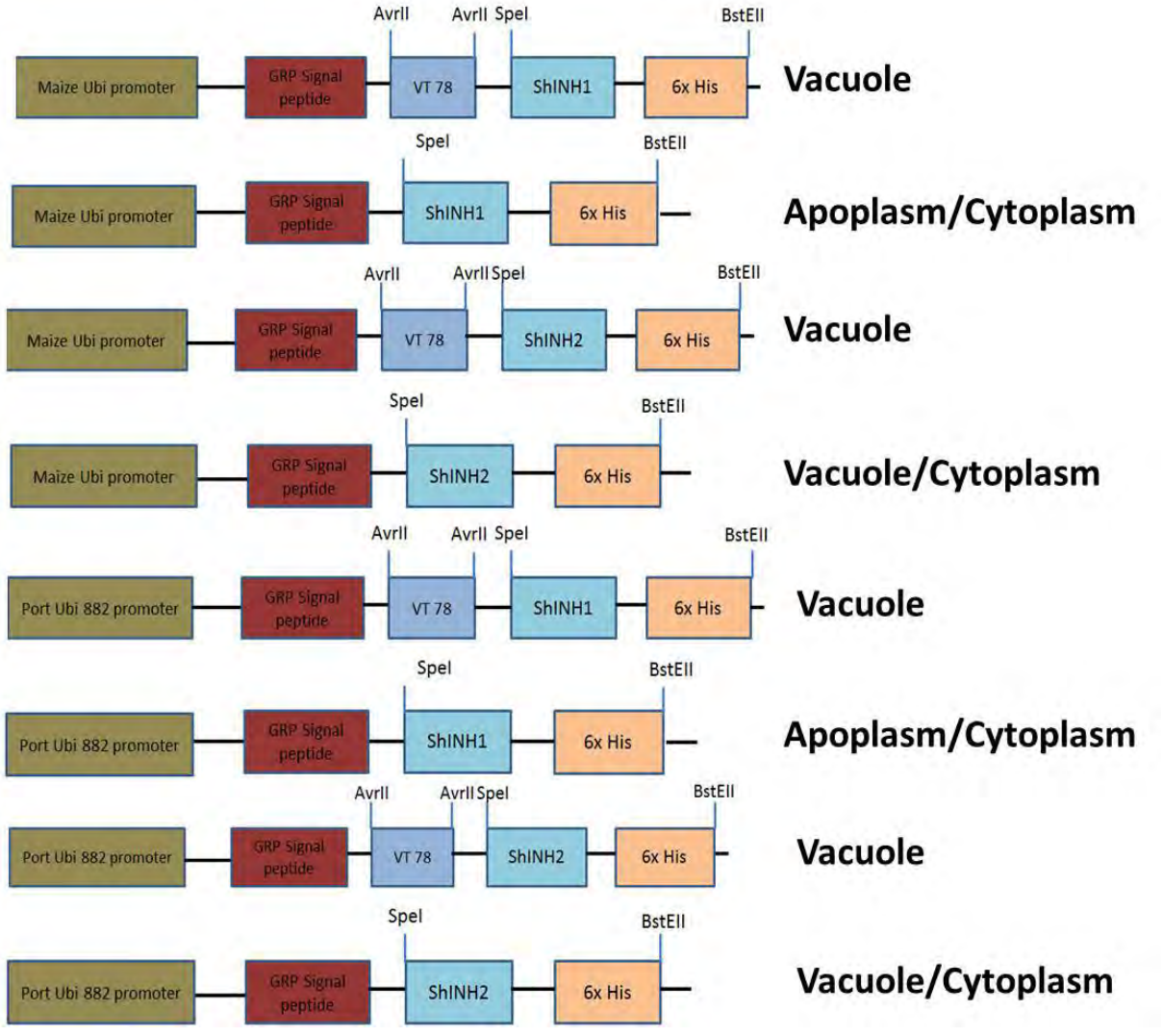


Fig. 45. Invertase inhibitor gene constructs developed for subcellular targeting and functional testing in sugarcane

Development of invertase inhibitor overexpression transgenic events: The recombinant plasmids were mobilized into competent *Agrobacterium tumefaciens* LBA4404 cells by Freeze thaw method. Colony PCR was performed to confirm recombinant *Agrobacterium* clones.

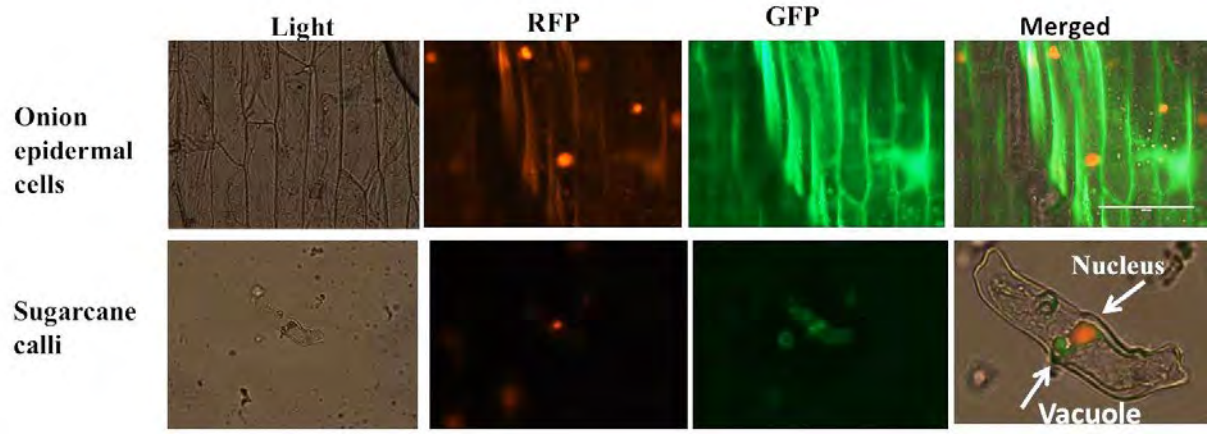


Fig. 46. Sub-cellular localization of ShINH2 using C terminal GFP fusion (ShINH1-GFP)

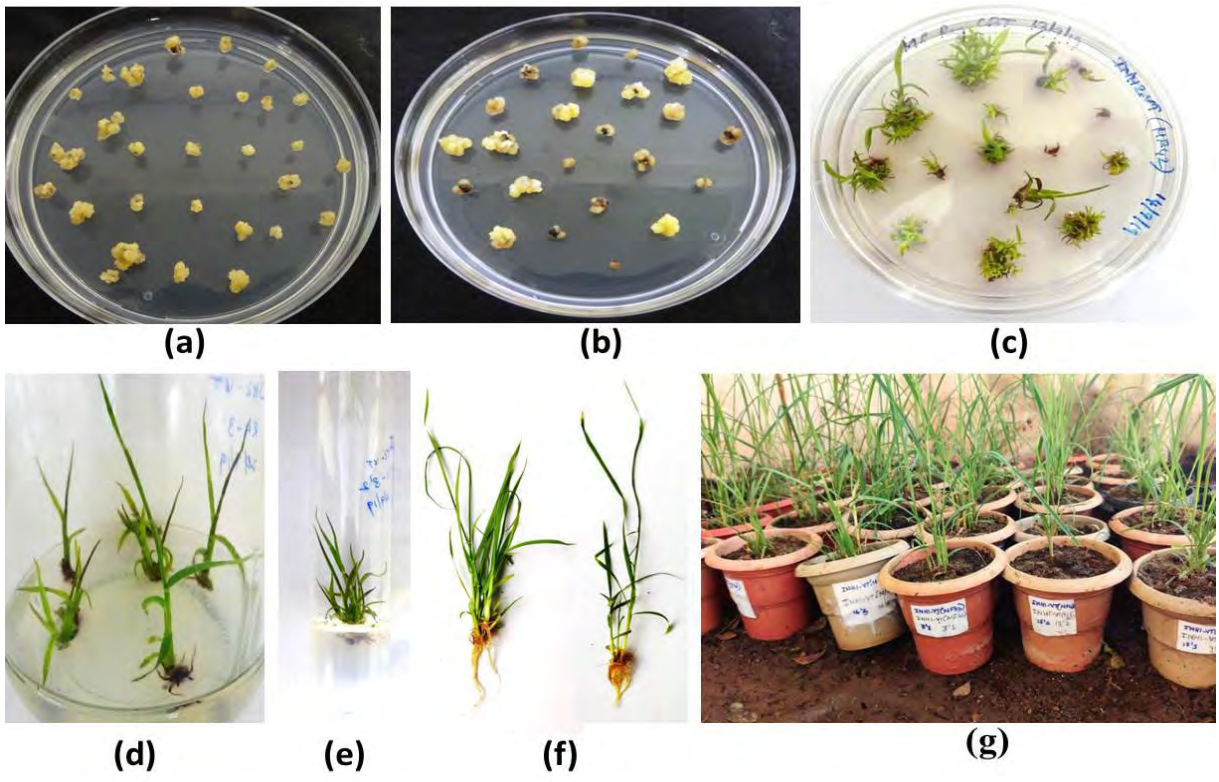


Fig. 47. a) and b) Invertase inhibitor genes bombarded calli under hygromycin selection; c) & d) Callus regeneration in shooting media; e) Regeneration in rooting media f) Putative transgenic plants after regeneration of roots f) Putative transgenic events hardening in pots.

The constructs were used to transform sugarcane leaf tissues by two methods namely *Agrobacterium* mediated transformation and particle bombardment. From these experiments, we have generated 260 and 280 ShINH1 and ShINH2 calli transformed by particle bombardment and 45 and 56 of ShINH1 and 54 and 60 of ShINH2 leaf whorls transformed by *Agrobacterium* infection. This selection process was continued till 6/7 selection and the putative recombinant calli was transferred to regeneration medium for the development of shoots Calli that survived were then transferred to sugarcane regeneration media with NAA and Kinetin. 58 and 62 events of ShINH1 and ShINH2 were kept for regeneration at 16 dark and 8 hour light photoperiod for 2 months. After the appearance of healthy shoots from a callus, it was transferred to White's (rooting) medium to form roots. Transgenic events regenerated in the test tubes were transferred to pots for further growth (Fig. 47). PCR screening of putative transgenic events are being carried out and positive plants will be tested for physiological and biochemical parameters.

(G.S. Suresha)

5.3 DIVISION OF CROP PROTECTION

5.3.1 PLANT PATHOLOGY

Host resistance, interactomics, pathogen variability, diagnosis and disease management in sugarcane

Screening of sugarcane progenies and germplasm for disease resistance, disease survey and surveillance and impact of climate changes on sugarcane pathogens

Screening for red rot resistance: About 2805 clones from different trials of Crop Improvement Division, SBI Research Centres of Kannur and Agali comprising clonal trials, PZVT, elite hybrids, waterlogging tolerant clones, allied genera, true seed derivatives etc. were screened for red rot resistance under controlled conditions against CF06 (Cf671) pathotype. Disease development was ideal during the season and identified ~1504 clones as resistant to red rot.

Field tolerance to red rot: Detailed field experiments were conducted to assess red rot

disease development from *C. falcatum* inoculum applied in the soil involving 13 varieties varying in red rot resistance and 12 fungal isolates with different virulence spectrum. Most of the isolates caused reduction in sprouting of buds, where the isolate Cf671 caused maximum loss in pre-germination of buds. Among the varieties CoV 92102, CoV 09356 and Co 06030 recorded maximum losses in bud sprouting. For disease development after germination, the isolate Cf86032-SKPM caused disease in maximum of 10 varieties followed by eight by CfV09356-ENGR and seven by Cf99006-MPM, Cf671-Tuhuli and CfC24-MDPU. The reference pathotypes CF06 and CF12 caused disease in five and four varieties, respectively at 30 DAP. At 60 DAP, fresh disease development declined marginally in the varieties and at 120 DAP most of the varieties remained free from the disease except in cases of Cf86032-SKPM, Cf06002-KUT, Cf0323-Petta and Cf671. Only two cvs Co 09004 and CoV 92102 remained free from disease development against *C. falcatum* isolates whereas the susceptible cvs CoC 671 and Co 94012 along with Co 06030 picked up red rot against all the pathogenic isolates. The variety Co 0238 was the least affected variety with only one incidence against Cf0323-Petta and Co 0212 picked up disease from the isolates Cf09356-ENGR, Cf671-Tuhuli and Cf86032-SKPM. Unusually the field tolerant variety Co 86032 picked up red rot from eight isolates during the season. In other varieties, 4 to 9 isolates caused infection. However, the disease development has totally declined by 120 DAP and subsequently the disease development was found in isolated clumps here and there. When compared to previous season, the disease development was very poor under field conditions probably due to climatic factors and that need to be investigated in detail.

(*R. Viswanathan, P. Malathi, A. Ramesh Sundar, R. Selvakumar, V. Jayakumar and K. Nithya*)

Yellow leaf disease (YLD)

Epidemiology: YLD severity on various germplasm and parental lines maintained at Coimbatore and Agali Centre was assessed. In DUS reference lines, out of 189 entries 88 entries were found apparently YLD free and 13 entries *viz*., Co 86010, Co 91002, CoA 8201, CoA 89082, CoA 93082, CoA 01082, 81V48, 97V97, CoV 92101, CoV 92102, CoV 94101, CoV 94102 and CoV 09356 were highly susceptible with severity grade of more than 3. In 'Co' canes and 'Co' allied entries, 149 and 201 entries were apparently YLD free, and the highly susceptible entries with grades more than 3 were Co 875, Co 8213, Co 8364, Co 85246, Co 86029, Co 11001, CoBln 9101, CoBln 9605, CoLk 97009 and LG 95053. Most of the species clone entries *viz*., *S. barberi*, *S. sinense*, and *S. robustum*, were apparently free of YLD, however, 13.3% entries in *S. officinarum* clones had exhibited susceptible reaction to the disease with severity grade in the range of 2-3. At NHG, YLD incidences were recorded in 19.0% of the parent clones, of that 6.0% were highly susceptible with severity grades of more than 3, 7.9% entries were susceptible and the remaining 5.2% entries were moderately resistant to YLD.

Impact of YLD on cane growth and yield: A field trial was conducted with healthy and disease-affected planting materials of three popular cvs Co 86032, Co 0238 and Co 11015 and assessed impact of YLD on cane growth and yield under field conditions. Overall, in all the three varieties virus-infected materials exhibited a poor crop stand and lacked uniform crop stand as that of virus-free plants (Fig. 48). The disease

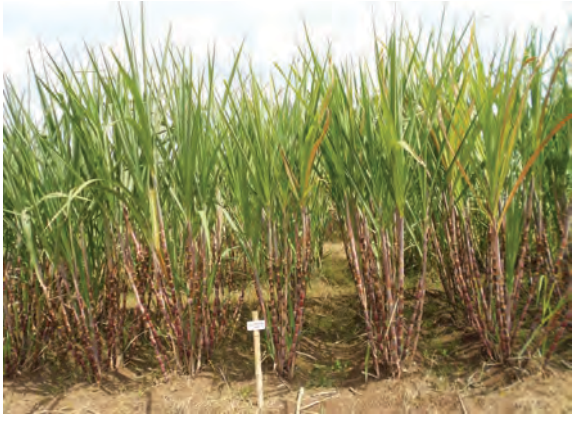


Fig. 48. Crop from YLD-free seed cane exhibits vigorous, disease-free crop (left) as compared to the diseased (right) crop from YLD-affected seed by seventh month in the field (Co 86032)

affected plots recorded significantly reduced flowering especially in the cv Co 86032 (Fig. 49). Further, it was also observed that in the disease affected plants, either flowering was delayed

Fig. 49a. YLD-free Co 86032 exhibits profuse flowering by November end;

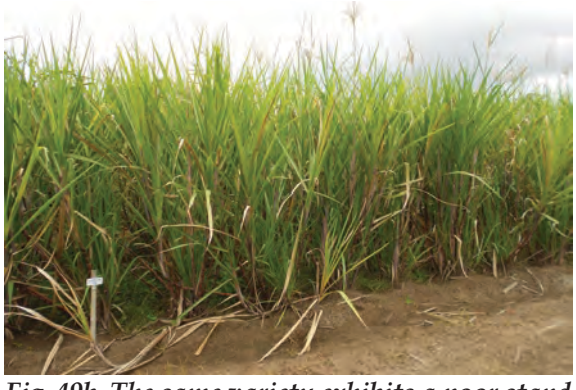


Fig. 49b. The same variety exhibits a poor stand due to YLD with reduced or delayed flowering

or the arrows along with short blade dried without complete emergence. Among the three varieties, the virus-free plants of cv Co 11015 picked up the disease and recorded severe YLD as in the case of virus-infected plots. Virus-free plots recorded PDI of 48.0% as compared to 63.0% in virus-infected plots. However, in other two varieties healthy plots exhibited less than 3.0% disease as compared to 15.6% (Co 0238) and 52.1% (Co 86032) in the diseased plots. In the plots YLD severity grades were recorded in the plot and upto severity grade 4 was recorded till December. In case of Co 86032, only 0.11 % canes in the healthy plots were observed with grade 1 symptom and no further severe grades were observed. Whereas in the diseased plots 3.5, 4.2, 7.01 and 3.7 % plants exhibited YLD grades 1-4, respectively. In the cv Co 0238 the severity grades 1-2 were observed in limited number of plants. However, in case of Co 11015, 12.5% plants of healthy and 16.8% plants of the diseased plots expressed YLD grade 3 and the respective figures for the grade 4 were 32.5 and 35.06.

Dynamics in aphid population: As in the previous seasons, **s**ugarcane aphid, *Melanaphis sacchari* population dynamics were monitored under field conditions on a set of varieties. Many varieties exhibited aphid colonization from April onwards and the population increased till June, later it declined. During September to December, no aphid colonization was found in most of the varieties. Further, number of plants with aphid colonization was low in the varieties as compared to the previous seasons. It was found that frequent rains during the season have affected colonization of aphids.

(*R. Viswanathan and K. Nithya*)

Characterization of red rot pathotypes

Thirty-five *C. falcatum* isolates from tropical region were tested on 32 sugarcane varieties showed broad pathogenic variation. Unlike last year, it was found that comparatively more isolates behaved as less virulent during this season. The Tamil Nadu isolates CfC24-Mandagapattu, Cf86032-Srikandapuram and), Cf95020 isolate from Gujarat and Cf86032 from Odisha behaved as more virulent whereas the isolates CfV09356 Ellanganur, CfC 24 -Radhapuram, Cf92061-NKM, Cf95020 Koogalur, CfV92102 Muttakudi, CfC 24 Thandavarayanpattu, Cf94012-Guruvareddiyur, Cf94012-Cholachiramani, Cf671-G and Cf94012-G that exhibited high virulence during the last season showed a reduced virulence. Only the three isolates CfC24-Mandagapattu, Cf95020-G and Cf86032-Srikandapuram maintained higher virulence. CfV09356-Paripalli isolate from Odisha exhibited total avirulence whereas another isolate from the same state Cf86032-Nayagarh exhibited a gained virulence during the season. Overall 16 isolates including the reference pathotype CF12 exhibited poor virulence as compared to nine during 2018-19 and 11 in 2017-

Fig. 50. Differential interaction of the cv Co 6304 to different C. falcatum isolates.

Fig. 51. Differential interaction of the cv Co 7805 to different C. falcatum isolates

18 seasons. The known susceptible varieties Co 419, Co 658, Co 997 and Co 6304 (Fig. 50) exhibited MR/MS reactions against different isolates; similarly, MS varieties like Co 7805, Co 86002 and Co 86032 behaved more towards resistance (Fig. 51).

(*R. Viswanathan and R. Selvakumar*)

Identification of anti-fungal genes and identifying sugarcane phytoalexins as marker for red rot resistance

In the host-pathogen interaction, further studies were continued to assess relative expression of the identified miRNA targets. Defense related six candidate miRNAs *viz*., osa-miR162a, osa-miR396e-5p, osa-MIR319a.3p, osa-MIR5538, sof-MIR167b and osa-MIR1862c were selected along with their 18 respective gene transcript targets, three for each miRNA and then temporal expression studies were carried out by qRT-PCR. The differential expression analyses revealed early induction of the target gene transcripts in the incompatible interaction as compared with the compatible interaction. Whereas the miRNAs expression was higher in the compatible interaction than incompatible interaction and the correlation between miRNA and their targets was evidently established. In another experiment, expression of candidate defense related genes during the host-pathogen interaction was carried out. Temporal expression of nine candidate gene transcripts, earlier identified to be involved in sugarcane defense mechanism against red rot pathogen was analyzed by qRT-PCR from 6 to 600 h in compatible and incompatible interactions and these assays revealed differential expression of the transcripts *viz*., cyclic nucleotide-gated ion channel protein, Actin-related protein 2/3 complex subunit 3, 26S protease regulatory subunit 7B, serine/ threonine protein kinase, mitogen-activated protein kinase, glycerol-3-phosphate transporter, laccase and caffeic acid O-methyltransferase. The resistant variety exhibited a higher expression of candidate gene transcripts as compared to the susceptible variety and the differential expression clearly established association of the above candidate defense gene transcripts in red rot resistant mechanism.

(*R. Viswanathan, P. Malathi and A. Ramesh Sundar*)

Developing chitosan based nano-delivery systems for disease management and enhancing nutrient use efficiency in sugarcane. (a) Inducer nano-particles as smart delivery system for harnessing red rot resistance in sugarcane

Testing chitosan coated systemic acquired resistance inducer nanoparticles against fungal diseases of sugarcane: The chitosan (CS) coated benzothiadiazole (BTH) and salicylic acid (SA) nanoparticles (NPs) were tested in sugarcane in pot and field experiments for their efficacy in inducing resistance against red rot, smut and wilt diseases. Four treatments were taken for glass house experiments, *i.e.*, T_1- setts treated with CS-BTH NPs + challenge inoculation of pathogen, T_2- setts treated with CS-SA NPs + challenge inoculation of pathogen, T_3- pathogen inoculated control and T_4- healthy control. In the experiment conducted against smut (cv Co 96007), 33.3% of T_3 and 10% of T_4 seedlings showed smut whip (on clump basis), while no disease incidence was noticed in CS- BTH (T_1) and CS- SA NPs (T_2) treated seedlings. Field experiments were carried out using CS-BTH and CS- SA NPs formulated with three types of adjuvants *viz*., polyvinylpyrrolidone-0.5% (PVP), Sil- spread®- 0.02% (commercial product) and potassium silicate (Psi)- 0.01%. The formulated NPs were sprayed on leaves, challenge inoculated with pathogen and disease incidence was recorded. In red rot experiment, the cv CoC 671 was sprayed with NP formulations and *C. falcatum* isolate Cf671 was challenge inoculated by plug and nodal cotton swab method and disease incidence

Fig. 52. Efficacy of CS- SAR inducer NPs against red rot

Table 9. **Evaluation of CS coated SAR inducer NPs treated sugarcane for red rot**

Treatment	Details	Plug method		Nodal cotton swab method
		Score	Reaction	Reaction
CS- BTH NPs formulation				
T_1	CS-BTH NPs + PVP one spray	7.3	S	MS
T_2	CS-BTH NPs + PVP two sprays	6.3	S	MS
T_3	CS-BTH NPs + Sil one spray	7.7	S	S
T_4	CS-BTH NPs + Sil two sprays	6.3	S	S
T_5	CS-BTH NPs + Psi one spray	5.7	MS	MS
T_6	CS-BTH NPs + Psi two sprays	3.7	MR	MR
CS- SA NPs formulation				
T_7	CS-SA NPs + PVP one spray	6.3	S	MS
T_8	CS-SA NPs + PVP two sprays	4.0	MR	MR
T_9	CS-SA NPs + Sil one spray	5.0	MS	S
T_{10}	CS-SA NPs + Sil two sprays	4.7	MS	MS
T_{11}	CS-SA NPs + Psi one spray	6.3	S	S
T_{12}	CS-SA NPs + Psi two sprays	4.3	MS	MS
Control				
T_{13}	Control	8.8	HS	HS

was scored 60 days after inoculation. In general, all formulations of CS-BTH and CS-SA NPs reduced the intensity of red rot when compared to control (Table 9). In plug method, when disease incidence was scored in a 0-9 scale the pathogen inoculated control canes (T_{13}) exhibited score of 8.8 (highly susceptible reaction), while in T_8 and T_6 the scores were reduced to 4.0 and 3.7 (moderately resistant reaction), respectively (Fig 52). In a similar set of treatments, scoring of disease resistance in cane by cotton swab method also showed similar trend of red rot development. These results clearly indicated that the formulated SAR inducer NPs especially, CS- BTH NPs combined with Psi and CS- SA NPs combined with PVP are efficient in inducing the resistance in the host against red rot pathogen.

(V. Jayakumar, A. Ramesh Sundar and R. Viswanathan)

Characterization of rust resistance in sugarcane and dynamics of rust pathogens under changing climate in India

Integration of spore trap with foldscope for air borne detection of rust spores in field: The rust on sugarcane leaves can be detected by rubbing the fingers over the symptoms to observe dusty brown / orange coloured dust. In our earlier study, the sticky traps made of vaseline coated glass slides mounted on thermo-coal structures helped in trapping the rust spores present in air were observed under microscope in laboratory. The Foldscope®, a paperfold handheld microscope available at low price in India helped in observing the coloured uredospores of rust fungi in the field without an aid of a microscope (Fig. 53). The observation of spores indicated the presence of uredospores in wind as a predisposing factor for secondary infection in sugarcane. This tool will help in monitoring the rust movement in the field and making decision for management of sugarcane rust based on rust severity under favourable weather condition for rust infection

Epidemiology of sugarcane rust: The rust severity was less in 2019 compared to the previous year 2018 at SBI, Coimbatore. But the rust appeared in many popular varieties, 'Co' canes, ISH clones and popular parental clones at low severity. The temperature prevailed at SBI, Coimbatore was similar to year 2018, the maximum temperature was in range of 25-38°C, reached 38°C during second fortnight of April and minimum temperature was between 15 and 29°C. The relative humidity was in range of 70-98% high during the forenoon and the lowest humidity was in the range of 26-91% obtained in the afternoon throughout the crop season (Fig. 54). The difference was observed in rainfall and number of rainy days compared to 2018. In 2018, the rainfall was less but there was rain at uniform interval whereas in 2019, there was heavy rainfall and continuous rain for seven days in two spells. The highest maximum rainfall of 152 mm was recorded on 9 August and the entire week was rainy. The second continuous rain spell was observed during 3rd week of October (175.2 mm). The rainfall was found to play a crucial role in curtailing establishment of rust in the field. The continuous rain, dislodges the rust spores from the pustules and the spores are washed way thus minimizing the source of inoculum for secondary infection.

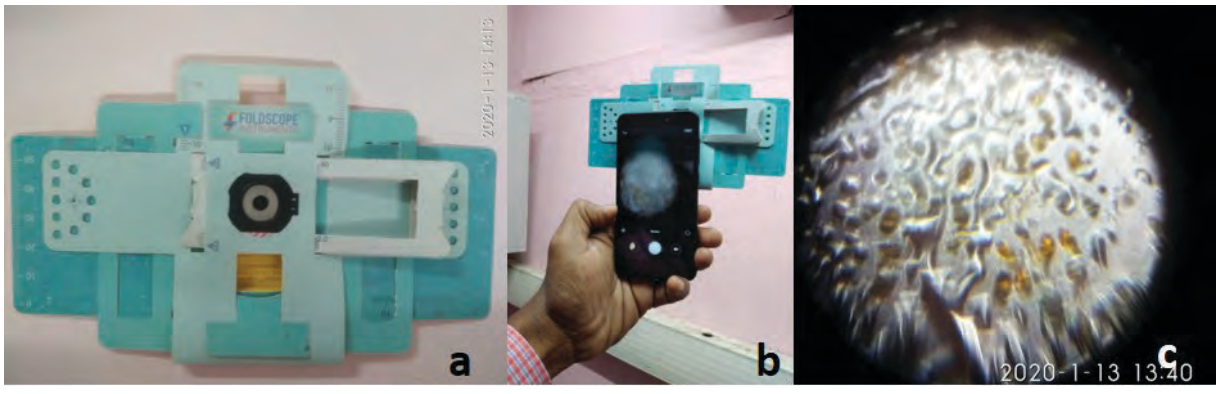


Fig. 53. Observation of uredospores using mobile phone integrated with foldscope

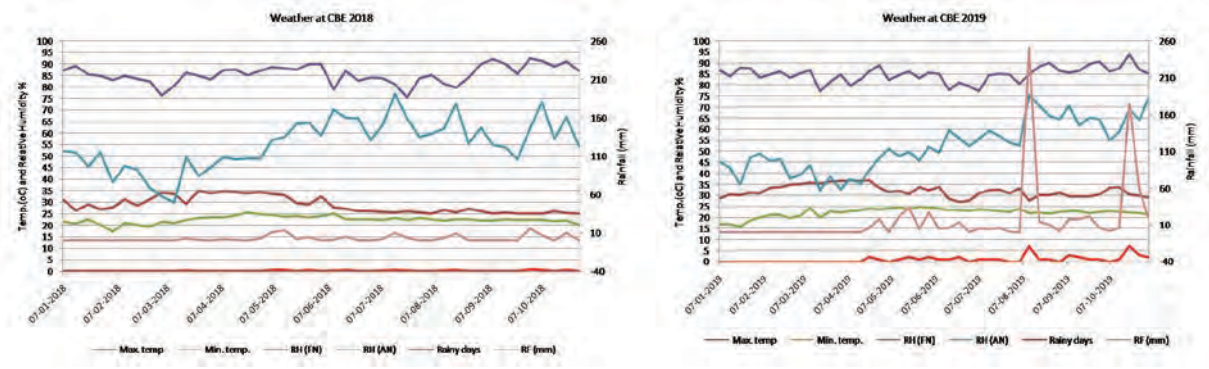


Fig. 54. Weather conditions prevailed during the season at Coimbatore

Adult plant rust resistance status in sugarcane clones: In Pre-Zonal varietal trial, 38 entries were free from any disease and rust was observed in traces on 20 entries and only on few entries 2018-12, 2018-45, 2018-105 and 2018-165 the rust was severe in the range of 5-10%. In 'Co' cane plots, out of 2006 total clones, only 136 clones expressed rust symptoms from traces to mild form. Of the 1440 'Co' clones, only few clones *viz*., Co 0218, Co 0223, Co 0310, Co 0409, Co 10032, Co 14001, Co 14033, Co 62423 and Co 7116 were showing severe rust in the range of 10-20%. In pre-zonal varietal multiplication trials, of the 115 entries, rust was observed in traces in many clones but the severe rust was observed on 2019-4, 2019-34 and 2019-83. In arrowing plot, more than 50 clones expressed rust in trace to mild form and remaining clones were free from rust infection.

(*R. Selvakumar and T. Lakshmi Pathy*)

Molecular characterization of phytoplasma associated with sugarcane

Sugarcane grassy shoot incidence was observed at zonal varietal trial *viz*., CoN 14073, CoM 14081, Co 14002, CoC 671 and CoSnk 05103 from AVT I plant and Co 13006, CoSnk 13106, CoSnk 13101, CoSnk 05103, Co 13020, Co 13009, CoN 13073, Co 13002, Co 13018, Co 13004, CoN 13072, Co 86032 and CoC 671 from the AVT II plant and also from the same varieties from AVT I plant ratoon. Similarly, symptomatic samples were collected from the pathology field from CoC

Fig. 55. Typical SCGS symptoms in the cv CoC 671

671 and CoV 94101 (Fig. 55). Total DNA was extracted using the CTAB buffer and the quality was checked in nanodrop spectrophotometer 2000/2000C in that all the samples were

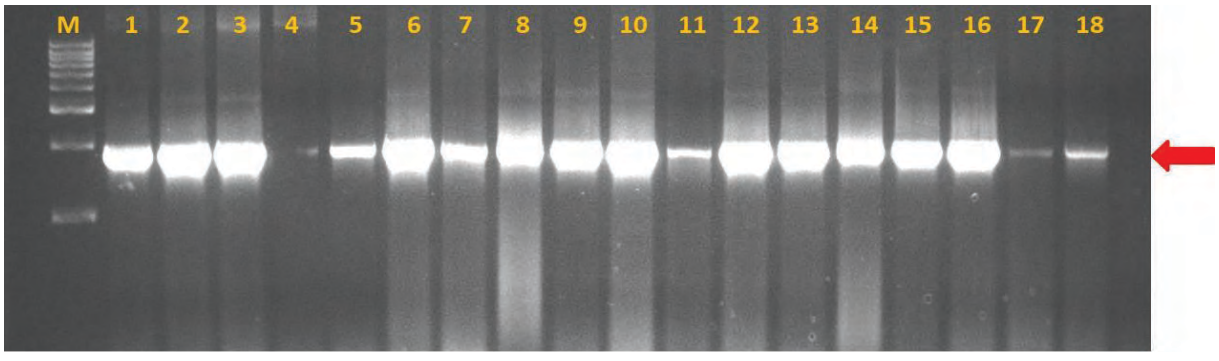


Fig. 56. SCGS phytoplasma amplifications using universal primers

between 1.7 and 1.9 showing good quality. SCGS phytoplasma was confirmed using the universal P1/P7 and R16F2n/R2 primers as well as by the custom designed GSD FP1/RP1 primers in that most of the all the samples were showing the expected amplification length of 1.2kb in size (Fig. 56). Besides, a greater number of aphids and leaf hopper *Pyrilla perpusilla* presence were observed on the symptomatic plants during June and December. qPCR primers were designed from the conserved 16s-23s ribosomal RNA regions with the amplification length of 170bp. SCGS phytoplsma isolate was cloned into pGEMT easy vector and was further serial diluted at different concentrations for preparing the standard curve in real time PCR assay.

(K. Nithya and R. Viswanathan)

Mechanized means of sett treatment to deliver different agro-inputs for the management of biotic and abiotic stress in sugarcane

Standardization of vacuum level and microbial load for effective delivery of microbes: The Sett Treatment

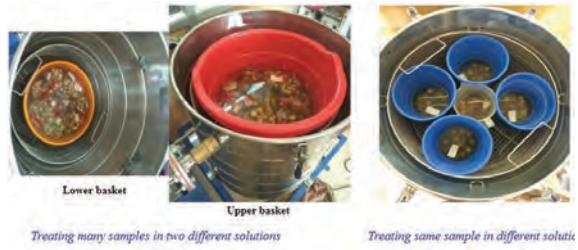


Fig. 57. Provision in Sett Treatment Device for the treatment of various samples and inputs

Device (STD) has advantage of treating many samples with various inputs at a time by keeping in different baskets. Hence various concentrations *viz.*, 0.1%, 0.25%, 0.5%, and 1.0%, were tested at various vacuum levels *viz.*, 100, 150 and 200 mm/Hg. Provision of treating setts in various baskets is shown in Fig. 57. Results clearly indicated that, the germination was affected by 200 mm/Hg vacuum level, while vigour of the settlings was not affected at all the levels of vacuum. However, to have maximum effect, 150 mm/Hg has been selected. With respect to concentration of the formulations, irrespective of formulations, 0.5% and 1% of

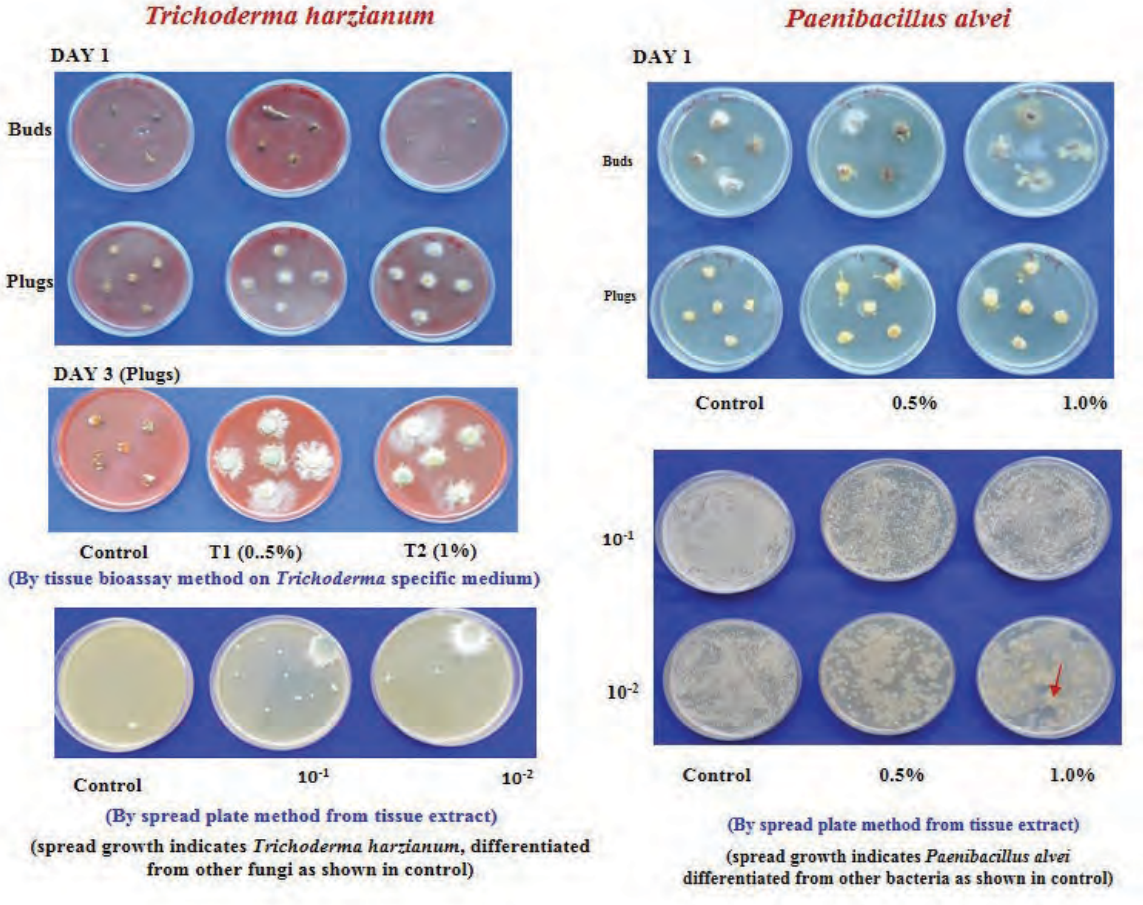


Fig. 58. Confirmation on infiltration of antagonistic microbes in sugarcane tissue by mechanized sett treatment

Pseudomonas alvei and *Trichoderma harzianum* were selected for moderately susceptible and highly susceptible varieties respectively as they have significantly improved plant growth without affecting the germination. Among the two formulations of *T. harzianum,* compared to suspended spores, composite of blended mycelium along with spores had significant effect on germination and plant growth.

Confirmation on infiltration of antagonistic microbes inside sugarcane tissue: After treating the setts in STD, infiltration of bioformulation inside the setts was confirmed by tissue bioassay by taking buds from outside and tissue from inside the setts and by enumeration of *P. alvei* and *T. harzianum* colonies in the tissue extract followed by plating on specific medium. Tissue bioassay results of *T. harzianum* treated setts revealed that, the infiltration in buds is low as there was not much growth, while all the plugs taken from inside the setts invariably showed *T. harzianum* growth**.** Recovery of *T. harzianum* in *Trichoderma* specific medium was further confirmed by potato dextrose agar medium. Hence it is clear that the microbes are getting inside sugarcane setts during treatment. Further the presence of *T. harzianum* was confirmed by extracting the tissue in sterile water and plating by spread plate, which showed the *Trichoderma* colony in both the dilutions**.** Presence of small white colonies in plates having both control and treated tissue extract could be due to use of unsterilized water for sett treatment in the STD. Like *T. harzianum, P. alvei* also entered effectively inside the tissue as shown in the picture. Unlike fungal antagonist, bacterial antagonist entered the sugarcane buds and shown more growth in treated buds, while there was fungal growth in the control buds. It is very clear that the bacterial growth appeared early at the beginning and growth of *P. alvei* could be differentiated by observing difference in colony colour. Besides, plating tissue extract in King's B medium has differentiated the bacterial population between control and treated plates (Fig. 58).

Sett treatment device for treating other vegetatively propagated crops: The corms of banana and setts of tapioca were treated with a mixture of agro-inputs involving fungicide, an insecticide and nutrients for protecting the planting material from pest and diseases and to improve plant growth (Fig. 59). Here the vacuum level was maintained at 200 mm Hg for 20 min including slow pick up of 5 min followed by slow release of 5 min as standardized for sugarcane setts with the newly fabricated device. For both the

(Urea + $FeSO_4$ + $ZnSO_4$ - 0.1% + Propiconazole -100 ppm + Fipronil = 50ppm)
Banana - One month old

Fig. 59. Validation of mechanized sett treatment with diffrent agro-inputs for vegetatively propagated crops other than sugarcane - Banana

crops, the treatment effect in improving plant growth was clearly evident as it has been proved in sugarcane and hence this technology could be utilized for treating any other vegetative propagated crops by mechanized means.

(P. Malathi, R. Viswanathan, A. Ramesh Sundar, T. Ramasubramanian, A. Vennila, M.L. Chhabra and B. Parameswari)

Epidemiology and management of *Fusarium* diseases in sugarcane

Epidemiology of wilt: In the crop season, the climate was favourable for sugarcane and the crop was more or less free from *Fusarium* infections. Pre-wilting symptoms were observed on few entries in NHG, but they did not turn to wilt in later stages. However, progress of wilt was monitored in 16 varieties after initial pre-wilting symptoms under field conditions in VPT farm. Pre wilting symptoms appeared as chorosis of the lamina either partial or complete and progressed to complete paleness of leaf lamia and discolouration of the lamina as yellow or orange by 4-5 months after planting. With increased disease severity, the affected leaves showed drying of lamina from the tip and progressed downwards leading to drying of entire lamina (Fig. 60). Due to wilt, leaves in the canopy do not open freely and showed a bunchy crown. Pale green leaves were observed by 132 DAP in the cvs Co 86002, Co 94012, Co 09004, CoC 671, CoS 8436, CoSi 6, and PZVT 2018-144. The cvs Co 419, Co 658, Co 94008, Co 0403, CoV 09356, PI 1110 and Khakai exhibited foliage discolouration without pale

Fig. 61. Progress of wilt in sugarcane varieties PI 1110 and CoSi 6

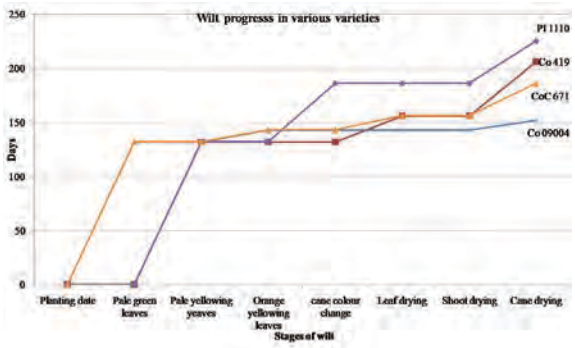


Fig. 62. Stage shift in wilt symptoms in different sugarcane varieties under field conditions

green symptoms (Fig. 61). The cvs Co 0212 and CoC 24 expressed pale green colour by 156 DAP and within 10 days the colour turned to yellow. In most of the cases, turning of yellow from pale green happened within 10 days. However, in the clone PZVT 2018-144, it took 20 days and the colour turned to orange in next 15 days and remained as such without any further progress of wilt symptoms. Few affected cvs such as Co

Fig. 60. Progress of wilt symptoms in sugarcane from pre-wilting to drying. a. Initial pale green foliage; b. Pale yellowing of canopy; c. Orange discolouration of old leaves and progressive thick yellowing of younger leaves; d. Drying of lamina in all the leaves in the canopy from tip and margin; e. Complete drying of the canopy; f. Rind discolouration due to internal wilt; g. Drying of entire foliage along with the stalks

0212, CoC 24, CoS 8436, CoV 09356 and PI 1110 showed discoloration of rind by 20-30 days after appearance of orange discoloration of leaves. In many varieties, final wilt phenotype was exhibited as leaf drying followed by shoot drying and complete death of canes. The cv Co 09004 completely dried by 152 DAP followed by CoC 671 in 186 days, Co 94008 in 193 days, Co 419 in 206 days and PI 1110 in 225 days (Fig. 62). However, there was no complete drying of canes in the cvs Co 658, Co 86002, Co 94012, Co 0212, Co 0403, CoC 24, CoS 8436, CoSi 6, CoV 09356 and Khakai and this may be due to prevailing weather conditions and initial inoculum level and further investigations will be continued.

Pathogenicity of Fusarium *isolates:* Impact of sett borne infections of *F. sacchari* on sett germination and disease development was studied in 12 varieties. Sett germination was drastically reduced in cvs such as 69A591, CoT 8201, CoJ 83, CoPant 97222 and Co 87023. Sett borne infection progressively reduced crop stand in the plots planted with diseased canes in some varieties in different growth stages of the crop and significantly reduced crop stand in the field (Fig. 63 a-c). Soil application of *F. sacchari* infected crop debris and sorghum grain inocula significantly sett germination in nine of the 10 varieties. Among these two inocula, the sorghum grain inoculum of PZVT 2018-84 caused more damages to bud germination. During the season the inocula caused less wilt infections in the crop and impact to the crop stand was less compared to the previous season. Ten *F. sacchari* isolates FsEB09004, Fs86002, FsMs 901, Fs 86010, FsPb10181, FsOr03152, Fs419, FsISH 100, FsSi2000-02 and FsPZVT2018-84 were artificially inoculated on eight varieties by plug method of inoculation and being assessed for their variation in pathogenicity.

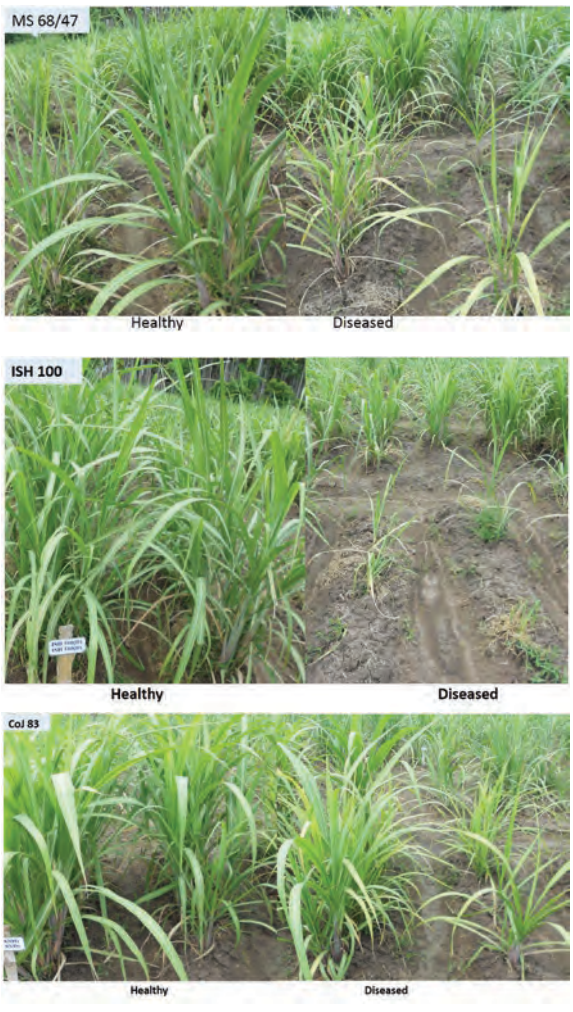


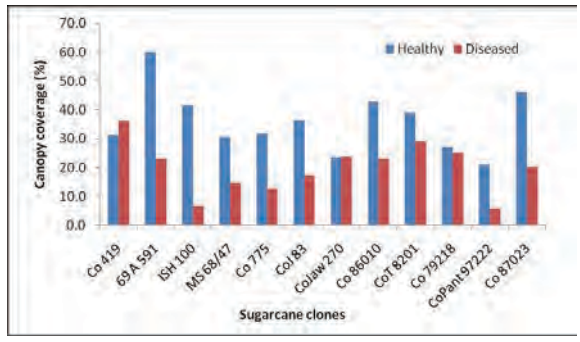
Fig. 63. Diseased plot exhibiting a poor crop stand in the field; a. MS 68/47, b. ISH 100 and c. CoJ 83

Fusarium *infection on crop growth and physiological parameters*: A detailed pot culture study was conducted with healthy and wilted canes of the cvs Co 419, Co 86010, Co 87045, CoA 93081 and NB 94-545 (Fig. 64a). Sett germination, pre wilting symptoms, root morphology and physiological parameters were recorded at various intervals. About 90-100% germination was observed in healthy setts whereas 40-100 % was observed in the diseased setts. The cv NB 94-545 recorded the lowest germination of 40% in the diseased setts. Pre-wilting symptoms were observed in diseased setts as well as in few healthy setts indicating the hidden source of *Fusarium* in some of the apparently healthy setts.

Morpho-physiological data were recorded in monthly intervals to study the impact of wilt on physiological processes which determines the biomass and finally yield. The root of individual clones was collected carefully, washed and the root data *viz.,* root length (cumulative length of individual roots), surface area, diameter and root volume parameters were recorded using root scanner. The data revealed that there was a significant decline in all the studied parameters in wilt affected clones compared to healthy clones (Fig. 64 b) (Table. 10).

Fig. 64a. Pot culture experiment to assess impact of **Fusarium sacchari** *infection on sugarcane growth and physiological parameters.*

Fig. 64b. Comparison of root growth in wilt affected healthy plants of the cv Co 419.



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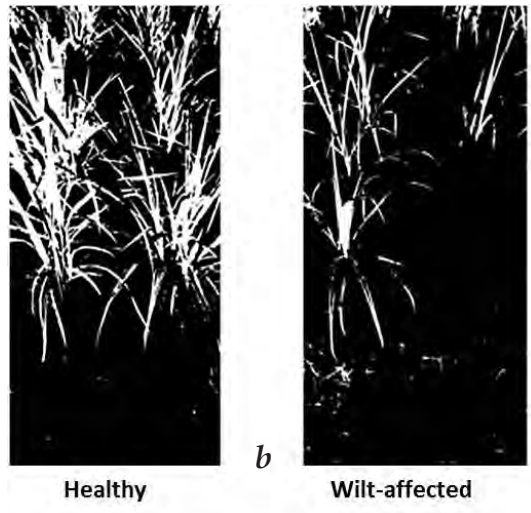


Fig. 65 Impact of **F. sacchari** *infection on sugarcane growth; a. Effect of wilt on fractional canopy coverage in sugarcane varieties, b. Fractional canopy coverage of sugarcane cv CoPant 97222 affected with wilt*

Morpho-physiological observations on wilted and healthy sugarcane: Under field conditions, wilt affected sugarcane clones were observed with poor crop growth and active vegetative cover data was recorded in the sugarcane clones of healthy and wilted using simple *canopeo* app. The application is a powerful tool in estimating the fractional canopy coverage and the results are given in percentage. Significant decline of 45% in FCC% was observed in wilt affected clones compared to the healthy at formative phase. The ISH 100 had shown 84% decline in

Table 10. Morphological parameters of root in healthy and wilt affected plants in different sugarcane varieties

Clones	Length (cm)	Surface Area (cm^2)	Avg Diam (mm)	Root Volume (cm^3)	Root Fresh wt (Kg)
Co 419 (D)	14917	2853	0.610	43	0.280
Co 419 (H)	51724	8272	0.526	108	0.930
Co 86010 (D)	14787	2523	0.542	35	0.250
Co 86010 (H)	36550	5129	0.458	59	0.630
Co 87023 (D)	25234	4076	0.517	53	0.696
Co 87023 (H)	40702	5883	0.483	70	0.690
NB 94-545 (D)	38361	4807	0.408	49	0.570
NB 94-545 (H)	68333	8839	0.441	97	1.800

D-Diseased; H-Healthy

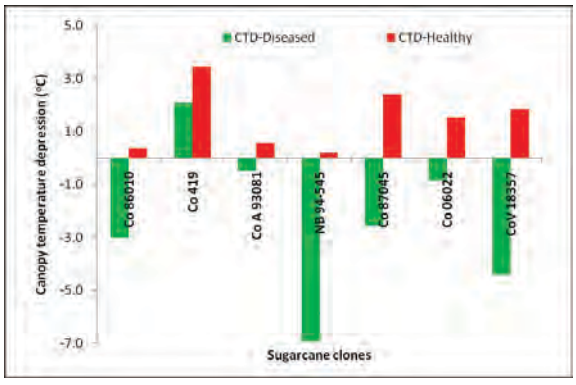


Fig. 66a. Effect of wilt on canopy temperature depression in different sugarcane varieties

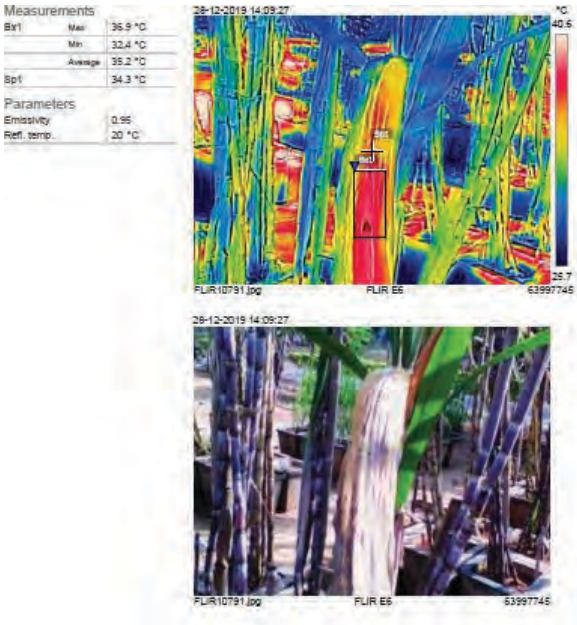


Fig. 66b. The cv CoV 18357 showing warmer canopy with higher CT due to wilt

FCC%, while the Co 419 and CoJaw 270 were found otherwise no decline which could be plausibly poor infection of *F. sacchari* (Fig.65a, b). Also, the canopy temperature depression (CTD= Ta-Tc) was recorded in both healthy and wilted clones using IR camera (FLIR). The healthy plants had shown better CTD, while the wilted ones were recorded with warmer (-ve CTD) canopy revealing that *F. sacchari* infection caused significant decline in physiological processes (Fig. 66a, b).

SBIRC, Kannur: Chlorosis due to pokkah boeng was observed in nine *S. officinarum* genotypes *viz.*, Koeng, Rastali, 96 NG 24A, 28 NG 80, 28 NG 263, 57 NG 184, IK 76 2, IK 76 19 and IK 76 94, and one foreign hybrid Q 66 during June, 2019. Maximum incidence of the disease was noticed in IK 76- 2 and all the plants were found infected in this particular clone whereas, only one or two plants showed chlorosis in other clones. In July, only two clones 28 NG 80 and IK 76-2 showed pokkah boeng symptoms and remaining clones recovered completely and were found completely free from disease. Later all the infected plants recovered completely. As in the previous season, rainfall was comparatively high during June-August months hence, only chlorosis phase was noticed during this season. It was found that there was a possible influence of rainfall on occurrence of this disease in sugarcane.

(R. Viswanathan, R. Selvakumar, P. Malathi, A. Ramesh Sundar, M.L. Chhabra, B. Parameswari, R. Gopi and R. Arun Kumar)

ICAR-CRP on Development and application of diagnostics to viruses infecting sugarcane

On-site lateral flow immunoassay detection kits for sugarcane viruses: Nanoparticle enabled lateral flow immunoassay (LFA) kit was developed and standardized for on-site detection for viruses *Sugarcane mosaic virus* (SCMV) and *Sugarcane streak mosaic virus* (SCSMV) causing mosaic disease in sugarcane. Total crude protein was extracted from the mosaic diseased samples using potassium phosphate buffer (pH 7.0). The primary antibody of SCSMV and SCMV with the concentration of 3 mg/mL was used for imprinting the nitrocellulose membrane with the pore size of 10 µm with 4mm thickness because of its slow absorption which increases the detection specificity. Similarly, secondary antibody IgG (1 mg/mL) @ 1: 100 and 1:200 dilution was used for imprinting in both test line (T) and control line (C) on the NC membrane at the medium speed, and dried at 37°C for 4 hrs. The 1st and 2nd antibodies loaded in the LFA printer (Advanced Microdevices, India) was found sufficient to imprint 3 membranes. One time imprinting of 1st antibody and two times imprinting of 2nd antibody was optimized to get the positive results. The plant crude sample loading was standardized as 80-100 µL on the LFA cassette and the visible results can be seen after 10-15 min. The mosaic samples showing

Fig. 67. Developed LFIA kit of SCMV and SCSMV associated with mosaic in sugarcane

moderate to severe symptoms were tested with the total crude extracts in that results were quickly visible after 10min in case of severe symptoms whereas, the moderate infections results were visible after 30 min only with very light colour intensity in test line positive. After standardization and validation from the field samples, LFA kit was assembled with sample extraction buffer (100mL), sterile micro-pestles small size (10 nos), 1.5mL centrifuge tubes (10 nos), sample dropper, tissue paper, pair of gloves and LFA cassette's (10 nos.) with instructions of how to use the kit with detailed SOPs along with its storage conditions at 4°C to -20°C (Fig. 67).

Comparison of LFA with other assays: Besides, the sensitivity of nanogold labelled antibody detection was quantitatively analyzed in comparisons with qRT-PCR and ELISA. Total protein and RNA were extracted from the mosaic samples, SCSMV antigen and cDNA were serially diluted and used for all the three experiments. It was observed that the detection limit of viral pathogen in qRT-PCR was up to 10^{-9} dilutions whereas, ELISA could detect 10^{-5} to 10^{-4} dilutions and the nanogold labelled antibody in LFA could detect the pathogen at 10^{-7} to 10^{-6} dilutions (Fig. 68). These results clearly evidenced that the developed LFA is comparable to ELISA for its sensitivity, even slightly better to detect the virus at 100ng concentration in the samples. However, qRT-PCR is found be more sensitive due to multi-fold amplification of the target gene.

New report of sugarcane viruses on its closely related host species: Presence of sugarcane mosaic disease causing viruses SCMV (*Potyvirus*, *Potyviridae*) and SCSMV (*Poacevirus*, *Potyriridae*) was suspected in the closely related species such as sorghum and maize based on the characteristic mosaic symptoms. Presence of SCMV in sorghum leaf samples (Fig. 69) and SCSMV in maize leaf samples was confirmed by RT-PCR assay using the respective viral coat protein primers followed by sequencing.

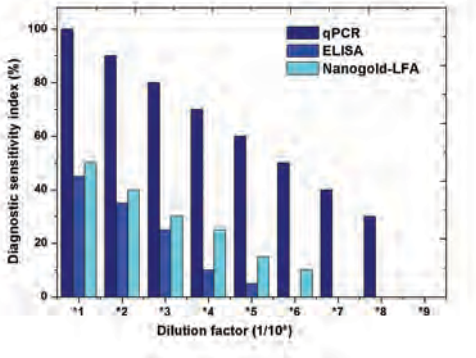


Fig. 68. Sensitivity analysis of nanogold labelled antibody of SCSMV

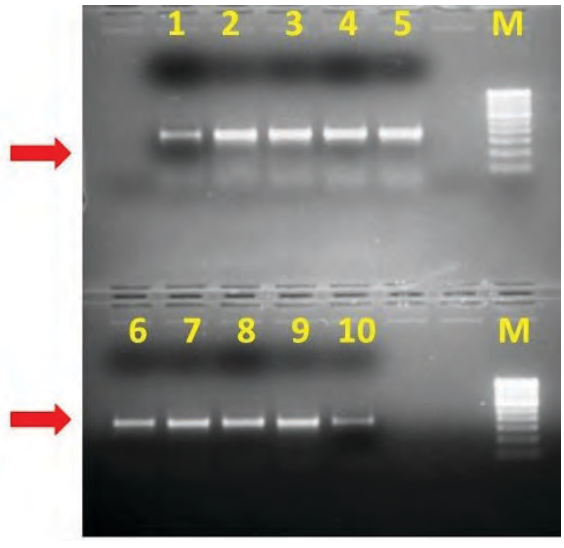


Fig. 69. Confirming presence of SCMV in sorghum by RT-PCR

Similarly, an attempt was made to diagnose the presence of *Maize dwarf mosaic virus* (MDMV) (*Potyvirus*, *Potyriridae*) in sugarcane using the coat protein primers designed from a set of MDMV isolate sequences available in the GenBank database. The primers had shown the expected amplification of 386 bp in the cv Co 94008 and the same was sequenced and the results revealed the SCMV with 99% similarity.

(R. Viswanathan, B. Parameswari, D. Neelamathi and K. Nithya)

Dissecting the molecular interface between the biotrophic pathogen *Sporisorium scitamineum* and its host - sugarcane

Quantitative and qualitative analyses of transcriptome of S. scitamineum *during in vitro stages and interaction with sugarcane for whole transcriptome sequencing/RNA-Seq* **:** For whole transcriptome analysis, RNA samples were extracted from *in vitro* (haploid sporidia and dikaryotic mycelium) and *in planta* (2 dpi – primary hyphae formation, 5 dpi – intercellular colonization and 60 dpi – sporogenesis at the meristem) developmental stages of *S. scitamineum* isolates, Ss97009 (a high virulent isolate) and SsV89101 (a low virulent isolate). Good quality samples with RNA Integrity Number (RIN) value greater than or equal to 6 were proceeded for library preparation for whole transcriptome sequencing at Agrigenome Pvt. Ltd.

GFP tagging of S. scitamineum *haploid sporidia using* Agrobacterium *mediated transformation***:** To better understand the plant colonization of *S. scitamineum*, Ss97009 MAT-1 haploid sporidia was tagged with green fluorescent protein using *A. tumefaciens* strain SK1044 that harbors the T-DNA binary vector pBHt2-gfp. Fungal transformation was done by co-cultivation method and *GFP* tagging was confirmed by visualization of green fluorescence under fluorescence microscopy as well as by PCR using ZsGreen1 specific primers resulting in a specific amplicon of 447 bp.

Scanning electron microscopy (SEM) analysis of S. scitamineum *developmental stages in vitro and in planta***:** Distinct developmental stages *in vitro* and *in planta* of the *S. scitamineum* isolates Ss97009 and SsV89101 were compared using scanning electron microscope (SEM) (FEI Quanta 250, USA). Comprehensively, there was no visible differences among the *in vitro* developmental stages of Ss97009 and SsV89101. In the case of *in planta* colonization stages, extensive colonization of external surface with germinating teliospores

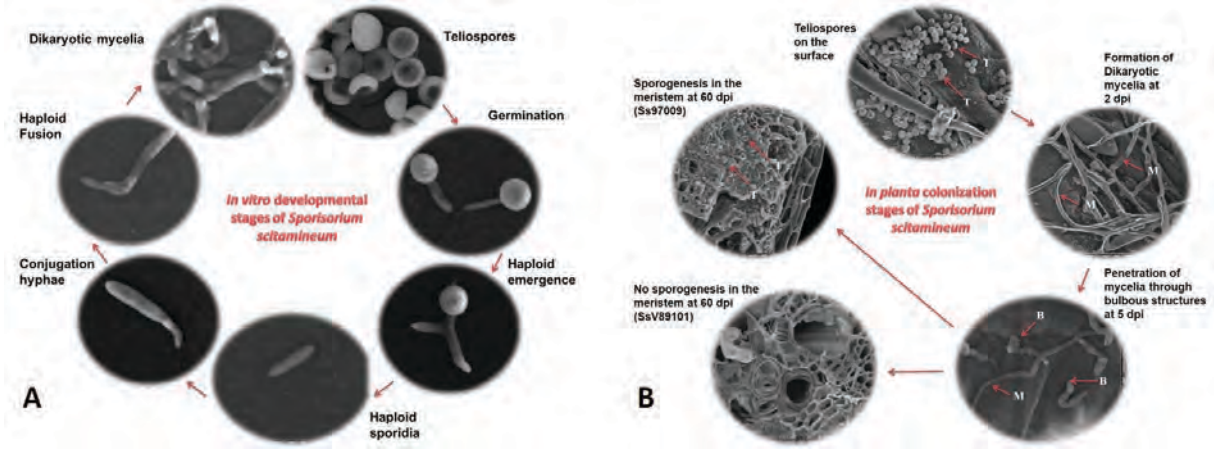


Fig. 70 An illustrative life cycle image of* Sporisorium scitamineum *depicting the different developmental stages. A) In vitro stages; distinct developmental stages viz., teliospores, germination of teliospores to give rise to promycelia, emergence of haploids, formation of conjugation hyphae upon interaction with the compatible mating type, fusion of compatible mating types and formation of dikaryotic mycelia were represented. B) In planta stages; Germination of teliospores (T) inoculated on the buds to form dikaryotic mycelia (M) and penetration of mycelia through bulbous structures (B) was observed at 2 dpi and 5 dpi, respectively. At 60 dpi, sporogenesis in meristem was resulted in the case of a high virulent isolate (Ss97009) in contrast to a low virulent isolate (SsV89101).

and mycelia at 2 dpi and, bulbous structures attempting penetration on the internal surface and intracellular colonization at 5 dpi were observed with Ss97009 and SsV89101. At 60 dpi, sporogenesis in meristem with fragmented hyphae and teliospores were observed with Ss97009 whereas comparatively less colonization was observed with SsV89101 reaffirming its less virulence compared to Ss97009. An illustrative image displaying the different developmental stages of *S. scitamineum in vitro* and *in planta* was given in Fig. 70.

Molecular marker based profiling of distinct mating types of S. scitamineum *isolates to assess genetic variability*: Molecular marker based profiling of distinct mating types of *S. scitamineum* isolates was done to assess genetic variability using five *S. scitamineum* isolates; Ss96007, Ss97009, SsV89101, SsSi6 and Ss6806. Culturing and isolation of distinct mating types of the isolates was done by random plating method and discrimination of mating types were confirmed by PCR using primers targeting *bE* mating type gene (bE1F1 and bE1/2R1 and bE2F2 and bE1/2R1). Inter-simple sequence repeats (ISSR) markers were used to assess the genetic variability among the five isolates with the primers, ISSR9, P5, P6, P10 and P25 and there was no considerable variation was found between the five isolates.

Development of an efficient method for protoplast isolation from S. scitamineum : In an attempt to establish an efficient protoplast based transformation protocol, isolation of protoplasts was optimized using Ss97009 MAT-1 haploid sporidia. Optimal amount of protoplasts were obtained with an enzyme combination, lysing enzymes (20 mg/ml) and β-glucanase (5 mg/ml) in SCS buffer (20 mM Trisodium citrate, 1 M sorbitol pH – 5.8) when incubated at 30°C for 1 h at 80 rpm. The quality of the protoplats was confirmed using the fluorescent stains,

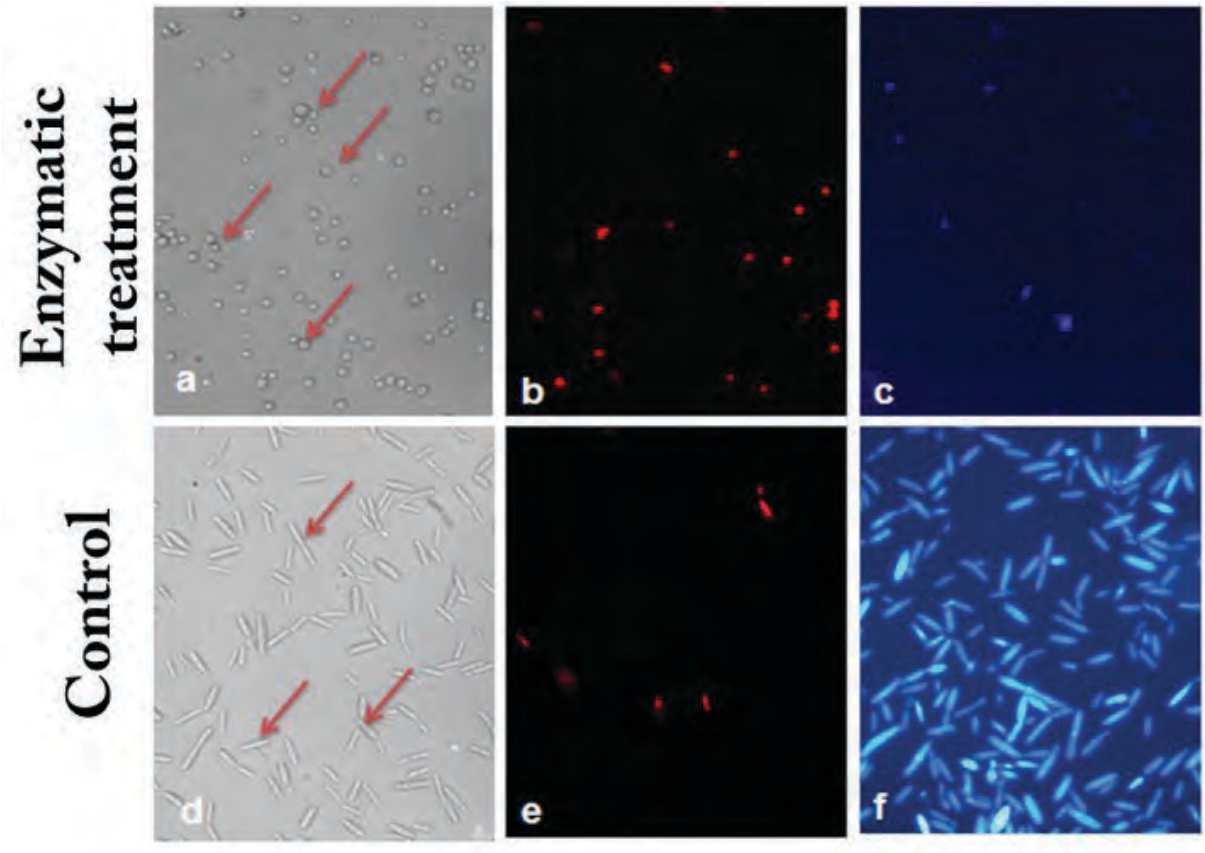


Fig. 71. Protoplast isolation from Ss97009 MAT-1 haploid sporidia. Protoplasts isolated from Ss97009 MAT-1 (a) observed under bright field, (b) stained with Propidium iodide, and (c) stained with Calcofluor white; and Ss97009 MAT-1 haploid sporidia (control - without enzyme treatment) (d) under bright field, (e) stained with Propidium iodide and (f) stained with Calcofluor white. Arrows indicate the changes in structures (from haploid to protoplast)

Calcofluor white (indicate the presence of cell wall) and Propidium iodide (indicate the presence of nucleus). Majority of the protoplasts did not take up the stains, confirming their quality and intactness (Fig. 71).

(A. Ramesh Sundar, R. Viswanathan, P. Malathi and P.T. Prathima)

Deciphering *in planta* secretome of *Sporisorium scitamineum* x sugarcane interaction

The project is envisaged to decipher the *in planta* secretome of sugarcane x *Sporisorium scitamineum* interaction. Since, there is no standard protocol for apoplast wash fluid extraction from sugarcane meristem, this project aims in developing a standard protocol for apoplast protein extraction from smut whip emerging meristematic tissue (cv. Co 97009). Three different buffers *viz.*, sodium phosphate, potassium phosphate, calcium chloride + sodium acetate was used to evaluate the extraction efficiency of apoplastic wash fluids employing two different methods of extraction viz., syringe infiltration and vacuum infiltration (Fig. 72). Results of quantitative assessment of extracted proteins by Bradford assay indicated that both syringe and vacuum infiltration methods yielded relative equal amount of protein quantity. Among the buffers evaluated, sodium phosphate buffer yielded maximum quantity of proteins, when compared to others. On the other hand, the results of qualitative assessment of extracted apoplastic wash fluids using the cytoplasmic marker - Glucose-6-phosphate dehydrogenase (G6PDH) biochemical assay indicated that all the extracts have relatively <20% of cytoplasmic protein contamination, except the extracts collected using sodium phosphate buffer which recorded around 20-50% of contamination (Fig. 73A). Similarly, the qualitative analysis of another cytoplasmic marker – malate dehydrogenase

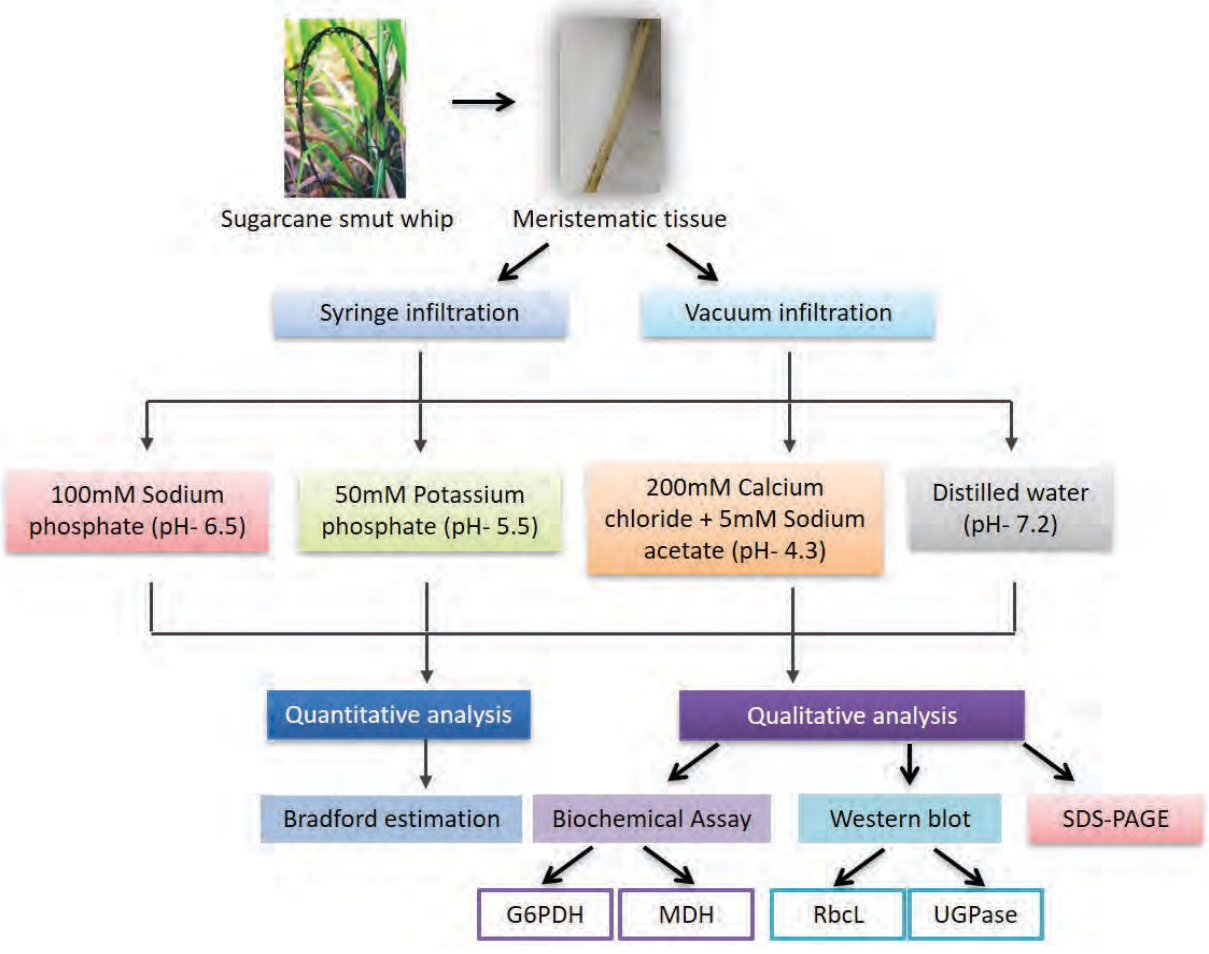


Fig. 72. Strategy for optimizing apoplastic (in planta secreted) protein extraction

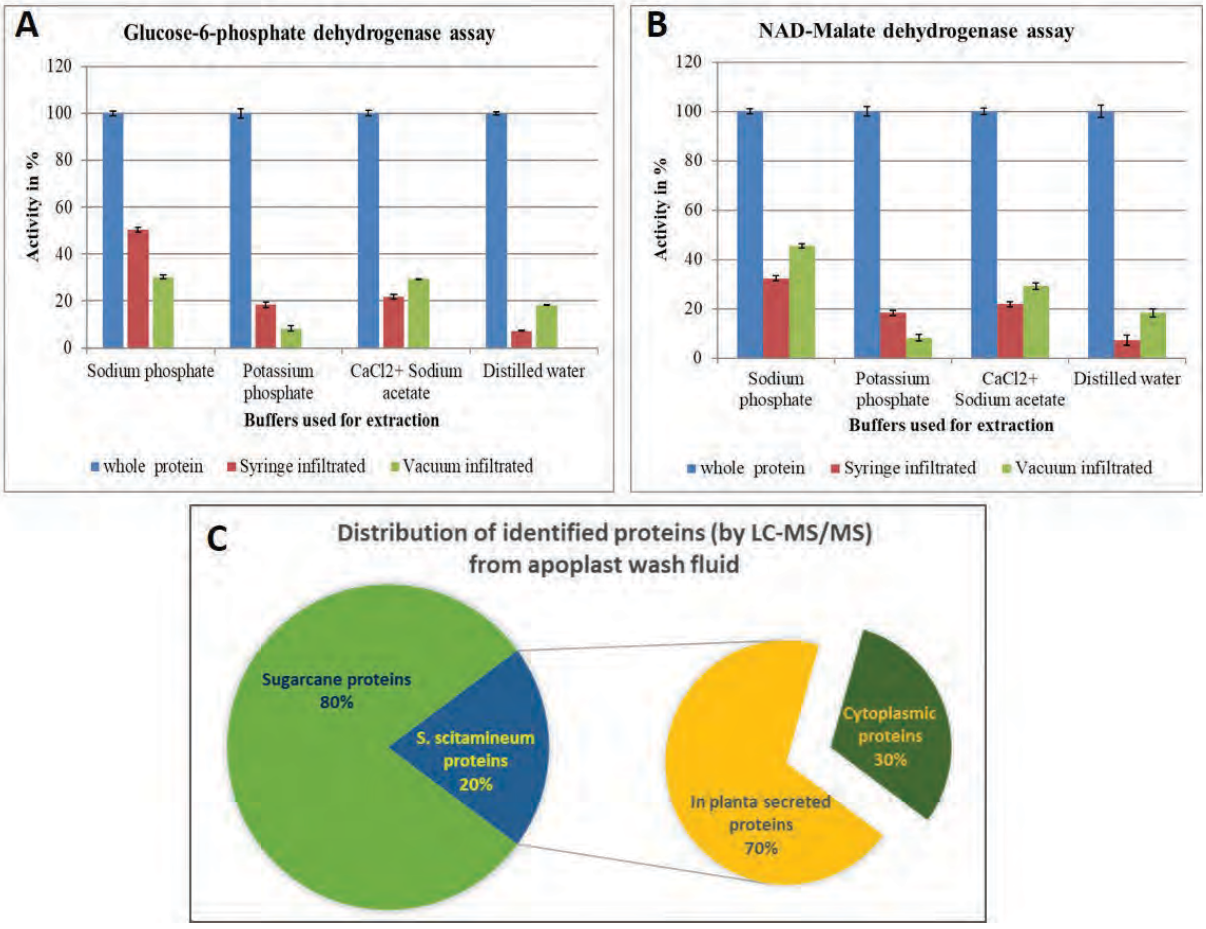


Fig. 73. Normalized results of the qualitative analyses for the activity of G6PDH and MDH biochemical assay (A and B). Distribution of proteins identified by LC-MS/MS from the pooled apoplast extracts (C)

(MDH) assay also indicated 10-30% cytoplasmic contamination, except the sodium phosphate buffer extract by vacuum method, which was way higher than the rest of the extracts (Fig. 73B). Hence, the prelusive works on the extraction methodology of apoplastic wash fluid suggested that the syringe method of extraction with appropriate buffer may serve as an ideal method of extraction. However, before selecting an appropriate buffer, the quality of extraction is being further evaluated by a more stringent method - western blot by using cytoplasmic marker-specific antibodies like Rubisco large subunit and UDP-glucose pyrophosphorylase. Meanwhile, for preliminary assessment and identification, apoplastic proteins extracted from the above buffers using syringe method were pooled and subjected to quantitative proteome analysis using iTRAQ labeling coupled with LC-MS/MS method. Analysis of the output data using the tool Proteome discoverer (Thermo Scientific) against the *S. scitamineum* protein database and an in-house generated *Saccharum* specific amino acid database resulted in identification of 1643 peptides that accounted for 64 proteins. Out of 64 proteins, 13 proteins were identified as *S. scitamineum* proteins and 51 proteins were from sugarcane. Out of 13 *S. scitamineum* proteins, nine proteins (around 70%) were identified as secreted proteins using SignalP and TargetP tools (Fig. 73C). However, due the absence of full-length proteins and complexity in *Saccharum* specific amino acid database, the percentage of secreted proteins from the host could not be identified.

Once, an appropriate buffer has been selected through western blot analysis, quantitative comparative proteome analysis using iTRAQ would be performed between compatible (involving virulent pathotype and susceptible host) and incompatible interaction (involving virulent pathotype and resistant host). In line

with the second objective for transcriptional profiling of identified *in planta* secreted proteins during compatible and incompatible interactions, appropriate time intervals for sampling were identified for different developmental stages *in planta* which includes 2 dpi (infection peg and primary hyphae formation), 5 dpi (intercellular colonization) and 60 DPI (sporogenesis and teliospore formation at meristem) through critical histopathological analysis using light and electron microscopy. Accordingly, samples were collected at different time points viz., 2 dpi, 5 dpi and 60 dpi samples from both compatible and incompatible interactions in triplicates. RNA extraction from the collected samples is being processed.

(A. Ramesh Sundar, R. Viswanathan and G.S. Suresha)

Deciphering interacting partners of PAMPs/ Effectors of *Colletotrichum falcatum* that trigger innate immunity in sugarcane

In planta *localization of tagged EPL1 and PDIP1 of* C. falcatum *by transient expression on tobacco and sugarcane by agroinfiltration*: In order to determine the sub-cellular localization of putatively identified pathogen-associated molecular patterns (PAMPs)/Effectors of *Colletotrichum falcatum viz.*, EPL1 and PDIP1 in tobacco and sugarcane, a versatile expression vector pSiM24, with strong constitutive M24 promoter and GFP reporter (Sahoo *et al*, 2014) was identified as a suitable vector for agroinfiltration. The pSiM24-GFP vector was modified by cloning 69 bp synthetic sequence comprising of unique restriction sites, a thrombin cleavage site and a flexible linker. Subsequently, the candidate genes *Cf*EPL1 and *Cf*PDIP1 together with their native signal peptide coding regions was PCR amplified from *C. falcatum* cDNA. The insert and vector were double digested using HindIII and NcoI, ligated to the modified vector, pSiM24_syn_GFP followed by transformation into *E. coli* strain *DH5*α. The putative recombinant colonies were confirmed by vector PCR, restriction digestion and sequencing. Further, pSiM24-EPL1-GFP & pSiM24-PDIP1-GFP constructs were mobilized into electrocompetent *Agrobacterium tumefaciens* LBA4404 cells and the putative colonies were confirmed by vector PCR. Subsequently, agroinfiltration was carried out in *Nicotiana tabacum* leaves using these *Agrobacterium* transformants (Fig. 74), for studying the transient expression of tagged *Cf*EPL1 and *Cf*PDIP1. Results indicated that both the proteins were secreted into the intercellular spaces. However, the sub-cellular localization of the candidate effectors is being critically analyzed for precision.

Verification of copy numbers of EPL1 and PDIP1 in C. falcatum *by qPCR*: For verification of copy numbers of EPL1 and PDIP1 genes in *C. falcatum*, qPCR was performed for *Cf*EPL1 gene and *Cf*PDIP1 gene cloned in pET28a vector, by serial dilution of plasmids from $1/10^2$ to $1/10^6$ and $1/10^1$ to $1/10^4$ respectively. A standard graph was generated by plotting Ct values in X axis and plasmid DNA concentration in Y axis. Further, the copy number of *Cf*EPL1 and *Cf*PDIP1 in *C. falcatum* was assessed by qPCR and the results indicated the presence of single copy for both genes and the same was cross validated with whole genome of data of *C. falcatum*.

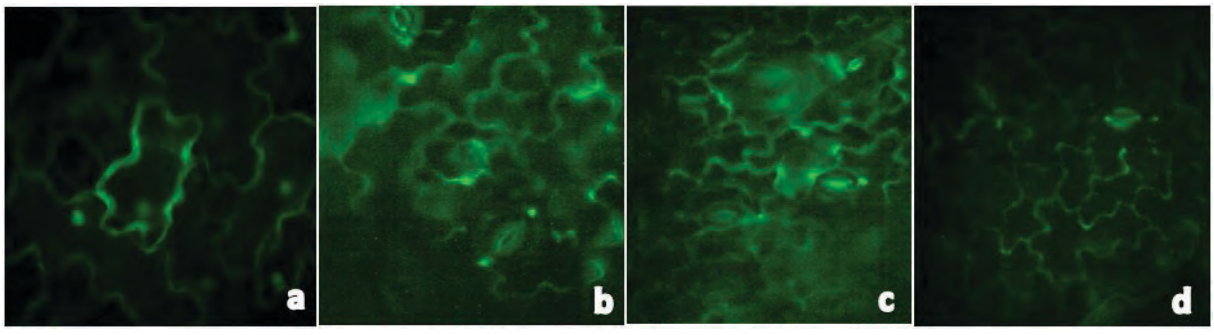


Fig. 74. Transient expression of green fluorescent protein in agroinfiltrated leaves of* N. tabacum *leaves at 68hpi: (a) pCAMBIA1302_GFP (Positive control) (b) the construct, pSiM24-SYN-GFP (c) pSiM24-EPL1-GFP (d) pSiM24-PDIP1-GFP were found to be confined to extracellular spaces.

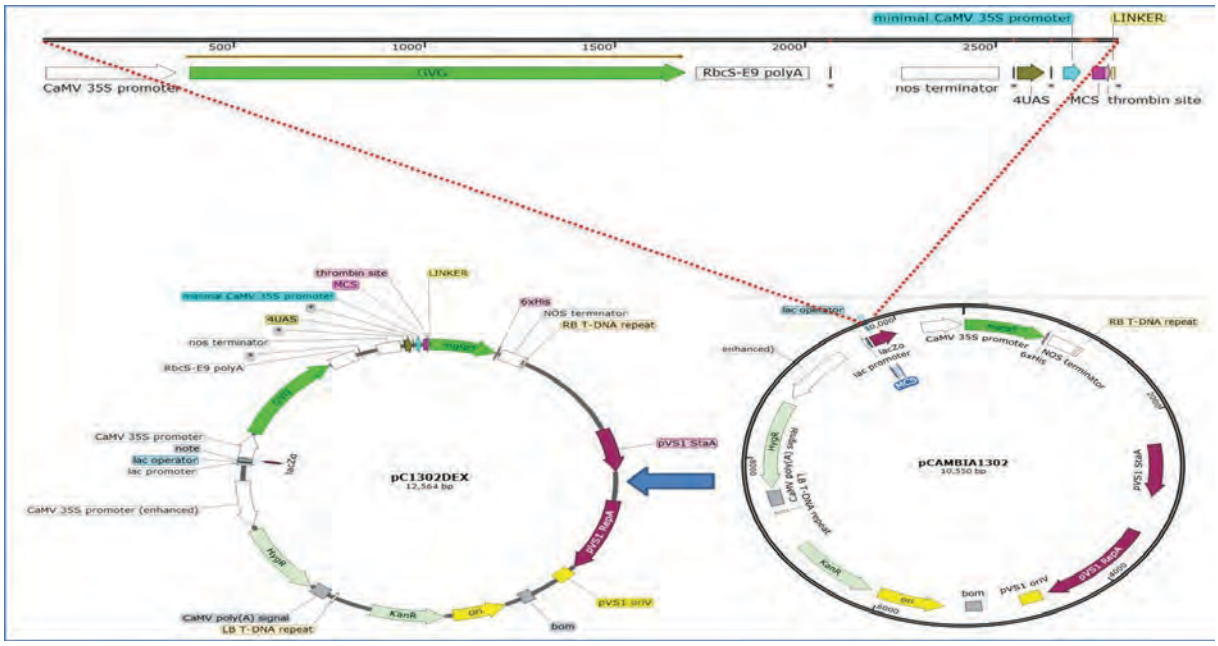


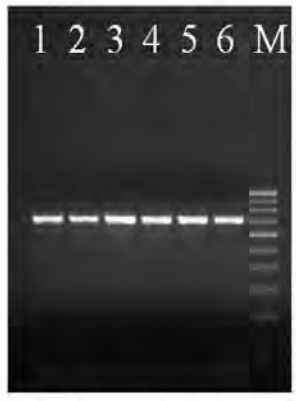
Fig. 75. Strategy of cloning customized DEX cassette into pCAMBIA 1302: Customized DEX inducible cassette together with their interacting elements was cloned into pCAMBIA 1302 vector between KpnI and NcoI, resulting in pC1302DEX

Ectopic expression of CfEPL1 and CfPDIP1 on tobacco and sugarcane: To monitor the pathogen-responsive transcriptional and biochemical changes during ectopic expression of effector genes, it has to be tightly regulated by an inducible promoter (preferably chemically inducible). The unavailability of such commercialized DEX (Dexamethasone) inducible vectors, prompted us to design a DEX inducible cassette. For which, DEX inducible cassette and its interacting elements were extracted from the reference vector pINDEX3 (Gen Bank ID: AF294982; Ouwerkerk *et* al 2001) and modified by customizing the MCS region, inclusion of a flexible linker and a thrombin cleavage site. The synthesized construct was cloned into pCAMBIA1302, which was named as pC1302-DEX (Fig. 75). Further, the vector was transformed into *E. coli* strain *DH5a* and electrocompetent *A. tumefaciens* LBA4404 cells. The putative colonies were confirmed by vector PCR and restriction digestion. Presently, *Cf*Epl1 and *Cf*PDIP1 is being cloned into this inducible vector for ectopic expression studies, to decipher PTI/ETI (PAMP/Effector triggered immunity) mechanisms in sugarcane.

(A. Ramesh Sundar, R. Viswanathan, P. Malathi, C. Appunu, and Dr. Rajeev Sukumaran, NIIST, Trivandrum)

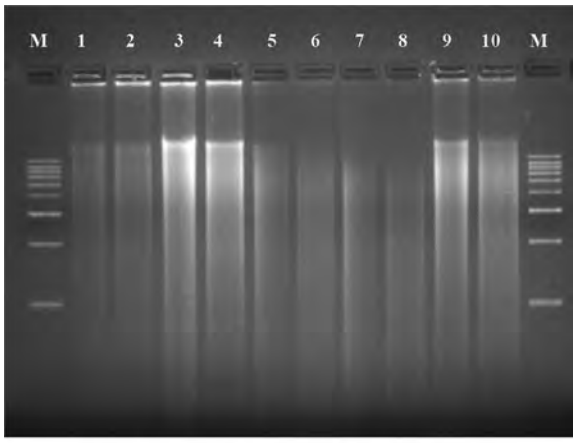
Development of sugarcane bacilliform virus (SCBV) based VIGS vector for functional genomics in sugarcane

About 135 leaf fleck affected samples of different sugarcane varieties/ genotypes were collected from Plant Pathology field, Agali Centre, *Saccharum* species collections, quarantine and from other surveyed areas in India. Total genomic DNA was extracted by following Cetyl trimethyl ammonium bromide method, treated with RNase I and purified. Different sets of primers *viz.*, SCBV F1R1, SCBV F5R5 and SCBV



Lane M-100bp marker; 1-6: SCBV isolates

Fig. 76. Gel picture shows positive amplification of SCBV target gene in PCR assay



Lane M-1kb ladder; 1-10: RCA products

Fig. 77. Gel image of RCA amplified whole genome of SCBV-BO91 isolate

F8R8 were designed from ORF 1 and 3 regions or RT/RNase H region to detect the viruses from the suspected plants. Among the primers, SCBV F8R8 was found more efficient to amplify the target region from the viral genome with the expected size of 726bp and wide sample coverage (80%) of total samples (Fig. 76) followed by SCBV F5R5 with the expected amplification of 1273bp. The cv BO 91 was selected for the rolling circle amplification (RCA) based whole genome sequencing of the virus because of its ubiquitous infection to SCBV. RCA is a simple and efficient isothermal enzymatic process that utilizes unique Phi29 DNA polymerases to generate long single stranded DNA. SCBV-BO 91 was amplified by RCA using IllustraTempliPhi DNA Amplification kit (GE healthcare) with PUC19 as a positive control. In order to confirm the SCBV genome (7.5-8kb), restriction digestion was carried out using unique single cutting enzymes such as, Eco47III, Cla I, Swa I, BstBI, Eam 11051, NcoI, PshAI, SnaBI, BamHI, KpnI, HpaI, StuI, NheI, EcoRV, Xbal and Spe I which were selected based on available whole genome sequences in Genbank database and the result was visualized on 1.2% agarose gel along with undigested RCA products (Fig. 77). The protocol standardization was initiated based on the obtained results with different modifications like, random primed RCA (RP-RCA), SCBV primer spiked RCA (SP-RCA), random primed SCBV primer spiked RCA (RP-SP-RCA) etc. to get the expected product. Besides, all the positive samples of both the primers ~10 numbers were sequenced to analyze the genetic variability of the isolates collected from different cultivars, species and places. The results showed that all the isolates had 80.93 to 99.68 similarity to the whole genome sequences of SCBV-BRU, India; SCBV-BO 91, India; SCBV-YG 40, China and SCBV-IM, Australia isolates.

(R. Viswanathan, B. Parameswari, C. Appunu and K. Nithya)

Virus indexing service

About 2427 tissue culture raised plants from different tissue culture production units *viz.*, M/s EID Parry, Pugalur, M/s RSCL, Theni and ICAR-SBI tissue culture lab were indexed for SCYLV, SCMV, SCSMV and grassy shoot phytoplasmas by following SOPs. Test reports were prepared and sent to the respective labs. A revenue of Rs 6,12,800/- was generated under virus indexing charges from the private tissue culture labs.

(R. Viswanathan)

Sugarcane quarantine

The following clones BO 128, CoP 9301, CoP 18436, CoP 18437 (Pusa), CoV 18357, CoV 18358 (Vuyyuru) and LG 11440, LG 14482, LG 14482 (Lucknow) were handed over to NHG after quarantine. Similarly, the following clones CoLk 11206 (Lucknow), CoN 13073 (Navsari), CoS 12232 (Shahjahanpur), CoSnk 14102, CoSnk 15101, CoSnk 15102, CoSnk 15103, CoSnk 15104 (Sankeshwar), CoV 13356, CoV 14356, CoV 16356, CoV 18357, CoV 18358 (Vuyyuru) and CoVc 16061, CoVc 18061(Mandya) were handed over to NAG after quarantine.

The following clones CoS 14231, S. 301/87 (Shahjahanpur), CoPant 12221, CoPant 12226 (Pantnagar), CoPb 18211, CoPb 18212, CoPb 18213, CoPb 18214 (Kapurthala) and VSI 08121, CoVSI 08123, VSI 12121 (VSI, Pune) were received for NHG and are in quarantine. The following clones G 2005047 (Melalathur), CoC 13339 (Cuddalore), 2005 T 50, 2011 T 70, 2012 T 58 (Perumalapalle), CoH 13263, CoH 14261, CoH 06266 (Uchani) and CoN 13072 (Navsari) were received for NAG and are in quarantine.

(R. Viswanathan)

5.3.2. ENTOMOLOGY

Studies on sugarcane pests and their management

Host plant factors influencing genotypic reaction to shoot borer *Chilo infuscatellus*

Assessment of internode borer incidence on the progenies of red-fleshed Saccharum robustum: During 2019-20 cropping season, 20 progenies of red-fleshed *S. robustum* clones were screened under field conditions for their relative degree of resistance against *Chilo sacchariphagus indicus* and the percent incidence ranged from 0.00 to 85 %. In the 20 entries, two genotypes namely GUK14-836 (14.81%) and GUK14-129 (15.15%) were graded as least susceptible (LS); three genotypes *viz*., GUK14-48, GUK 14-675 and GUK 14-829 as moderately susceptible (MS) and 15 genotypes as highly susceptible based on the percent incidence of INB at 8th month after transplanting.

Survivability of sugarcane shoot borer on Erianthus arundinaceus**:** *E. arundinaceus* genotypes such as IK 76 78, IJ 76 400, IK 76 84, IK 76 88, IJ 76 370, ERI 2798, Fiji 55 and IJ 76 364 were identified as resistant (R) to shoot borer in field screening. To confirm the resistance, the identified *Erianthus* (R) genotypes were further screened under laboratory screening techniques. Survival characteristics of shoot borer were studied on these resistant *E. arundinaceus* genotypes along with a cultivated variety Co 86032 (Fig. 78). There was a significant difference observed in the larval and pupal survivability of sugarcane shoot borer which ranged from 44 to 82% and 28 to 56% on selected *E. arundinaceus* genotypes. The lowest larval and pupal survival was recorded in the genotypes IJ 76 370, IK 76 78 and IJ 76 364 resulting with 44 and 32%, 56 and 36% and 60 and 28%, respectively. However, it was highest in the genotypes IJ 76 400 (82 and 48 %) and Co 86032 (69 and 48%).

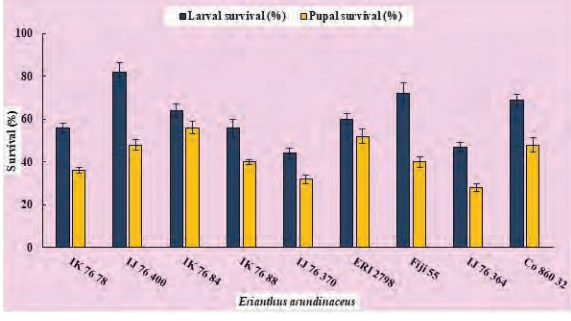


Fig. 78. Survivability of sugarcane shoot borer on Erianthus arundinaceus

(M. Punithavalli and K.P. Salin)

Screening of indigenous isolates of *Bacillus thuringiensis* isolated from sugarcane ecosystem for various crystal toxin genes

The full-length sequence of *cry1D* and *cry1E* gene isolated from Bt isolate SBI-KK27 after cloning was deciphered and it was found to be 3501 and 3531 bp, respectively. To express these genes in the shuttle vector pSTK for functional validation of Cry1 and Cry1E proteins, Material transfer agreement (MTA) was signed with Dr. Jie Zhang, from State Key Laboratory for Biology of Plant Diseases and Insect Pests, Institute of Plant Protection, Chinese Academy of Agricultural Sciences. In addition, MTA was also signed for cry 8 Ea, *cry8Ga, cry8Ha* and a *cry8* like gene for testing their efficacy on white grub, *Holotrichia serrata*. Analysis of the whole genome sequences of SBI-Bt41 revealed the presence of a novel *cry8* gene as per the guidelines of the International Committee on Bt toxin nomenclature. The whole genome sequence analysis of SBI-Bt721 revealed the presence of full length *cry3* gene which was found to have more than 99% similarity to the *cry3Ca* gene reported earlier. The same isolate was also found to contain partial sequences of vegetative insecticidal gene. Similarly, the whole genome sequence of another Bt isolate SBI-M6 was found to harbor a new holotype *cry 66* gene whose function is yet unknown.

(B. Singaravelu, J. Srikanth, C. Sankaranarayanan, P. Mahesh, C. Appunu and G.S. Suresh)

Development of DNA barcodes and species-specific markers for insects in sugarcane ecosystem

Species-specific markers were developed for economically important insect species of sugarcane. DNA barcodes earlier developed by us for *Chilo infuscatellus* (KM453722), *Scirpophaga excerptalis* (KJ013411), *Sesamia inferens* (KJ013410), *Proutista moesta* (KX519327), *Pyrilla perpusilla* (KJ013412), *Melanaphis sacchari* (KM453721), *Tetraneura javensis* (KM453723), *Neomaskellia bergii* (KF986270), *Aleurolobus*

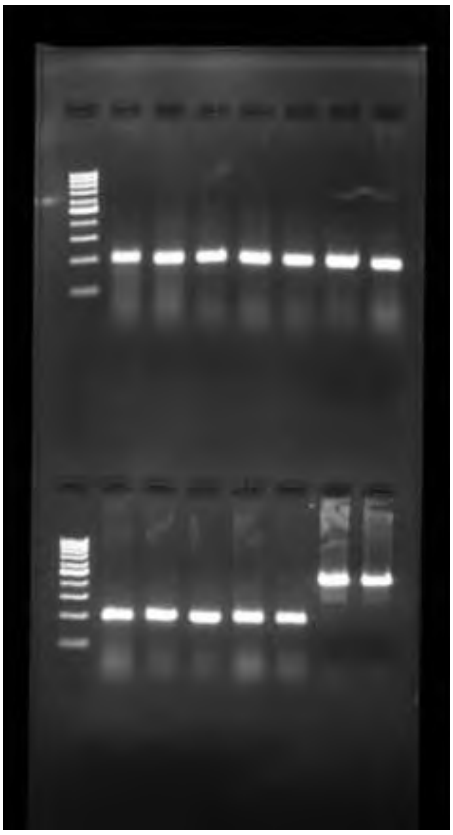


Fig. 79. Top lanes: 1–100 bp ladder, 2 to 8–specific marker from adults of ESB (204 bp); Bottom lanes: 1-100 bp ladder, 2 to 3–specific marker from pupae of ESB (204 bp), 4 to 5–specific marker from larvae of ESB (204 bp), 6–specific marker from eggs of ESB (204 bp), 7 to 8–specific marker from adults of Sturmiopsis inferens (466 bp)

barodensis (KF986269), *Sturmiopsis inferens* (KX519323), *Epiricania melanoleuca* (KX519320) and *Dipha aphidivora* (KX519319) were used to design primers for amplifying specific regions from the *COI* gene fragments of insect species. The target fragments were of 204 (*C. infuscatellus*) (Fig. 79) to 599 bp (*S. inferens*) (Fig. 80) in size. The primers used to amplify the target fragments of *C. infuscatellus*, *S. excerptalis*, *S. inferens*, *P. moesta*, *P. perpusilla*, *M. sacchari*, *T. javensis*, *N. bergii*, *A. barodensis*, *Sturmiopsis inferens*, *E. melanoleuca* and *D. aphidivora* were CACCTGGTATAGCTTTTCCACG; ATGAAATACCCGCTAAGTGAAGGG (204 bp), CGAACTAGGTACTCCTGGATCAC; GTGAGAGAAGAAGAAGAAGGGCAG (479 bp), GAGCTGGTATAGTAGGAAC; TCCTGCGGGGTCAAAGAAT (599 bp),

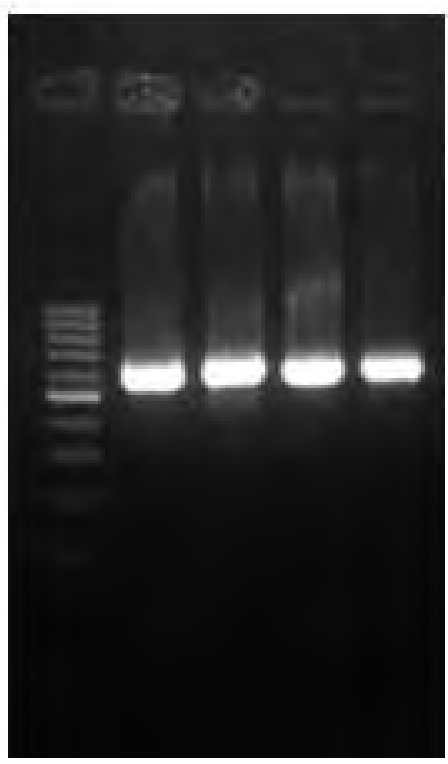


Fig. 80. Lanes: 1–100 bp ladder, 2 to 5–specific marker from larvae of Sesamia inferens (599 bp)

TGATCGGGACTATTAGGGTCGAT; CTATTGTTATAAACTTGGGTCG (463 bp), TATTCAACCAGGTAACCTTATTA; GAAGAGATAAAAGAAGAAGAATAGC (476 bp), CCTGGATCATTAATTGGAGATG; TGAGAGAAGAAGGAGAAGAG (465 bp), GGATTGTGATCAGGTATAATTGG; GTCCAGATATATCATTTCCACGA (494 bp), GAATTAGGAAGAGTTGGTC; CCTCCACAAGGATCATAAA (557 bp), CCAGGAAGATTAATTAATAACGACC; GGCTAATACTGGTAATGATAG (471 bp), GATCCAGAATAATTGGAACATCTC; CGATCAAAAGTAATTCCAGTAG (466 bp), GCAGGTTTATTAGGATC; CTCCAGCAGGGTCAAAGA (598 bp) and AACCCCGGTTCTTTAATTGG; AAAGAGCTGTAATTCCTAC (454 bp), respectively. Since the fragments of varying size amplified by the primers designed in the present study serve as species-specific markers, cloning and sequencing of the PCR products are not required.

(T. Ramasubramanian, K. Ramaraju (TNAU) and S.K. Pandey)

Studies on the prospects of *Telenomus* sp. as a candidate biocontrol agent of internode borer

Seasonal pattern of Telenomus *sp. in internode borer:* Seasonal dynamics of internode borer (INB) egg parasitoids were monitored by collecting borer egg masses from sugarcane crop system during January-December 2019. *Telenomus dignus* was recovered from most egg masses collected with overall parasitism of 82.6% on egg mass basis. Within the egg masses, parasitism rates were 100.0% in almost all observations whereas adult emergence from individual egg masses ranged 45.5-100.0%.

Laboratory parasitization studies: In laboratory multiplication studies, *Telenomus* adults were exposed to variable number of freshly laid lab-reared egg masses of INB to give different host egg: parasitoid ratios in glass tubes and glass chimneys. When exposed in glass tubes, parasitism was 100% within egg masses but with variable adult emergence (23.9-87.5). Tests in glass chimneys intended to standardize a mass multiplication method also produced 100% egg parasitization within egg masses with moderate to high adult emergence (44.2-90.9%).

Improvised mass multiplication method: An improvised method was attempted to further scale-up the mass multiplication of *Telenomus* sp. as an improvement over the chimney method. Egg masses on leaf bits were exposed to the parasitoid at 10:1 ratio in a plastic box (14 cm ht x 12 cm dia.) that was enclosed in a polyvinyl cylindrical cage (30 cm height) with cloth top such that the cage would fit in to the plastic box. This set up produced 50.8-100.0% parasitization in different batches. While the chimney method could hold about 100 eggs, the polyvinyl cage accommodated up to 400 eggs on leaf bits with no mould development.

Storage studies with INB eggs: Exposure of INB eggs to -20°C for short durations resulted in mortality of eggs in earlier studies. As an alternative, egg masses were stored at a relatively higher temperature of 10°C for a longer duration of up to 10 days. At 2-10 d storage, hatching of eggs (0.0-11.0%) was affected considerably with the decline dependent on storage duration. Also, the percentage of developed yet unhatched eggs and under-developed eggs increased with duration of storage. When the egg masses stored at this temperature for different durations, namely 2, 4, 6, 8 and 10 days were exposed to the parasitoid, varying levels of parasitization were obtained. Percent parasitization, comprising both emerged and failed-to-emerge parasitoids, generally decreased with storage duration.

Field release: *Telenomus* sp. was evaluated in preliminary augmentative field trials against internode borer. In one trial, the parasitoid was released at a dosage equivalent of 3000/ha in a span of two months. Pre-treatment and post-treatment observations taken at monthly intervals indicated that the increase in INB incidence and intensity was relatively lower in release plot than in control plot 30 d after release. There was a general decline in the borer activity in both plots in the next 30 days (Table 11).

Table 11. Augmentative evaluation of *Telenomus* sp. against INB (Trial-1)

Treatment	Pre-treatment INB		Post-treatment INB			
	Incidence	Intensity	Incidence		Intensity	
			30 d	60 d	30 d	60 d
Release plot	3.1	4.1	9.1	9.0	5.1	4.7
Control plot	2.8	2.7	11.5	9.6	7.5	4.0

Table 12. Augmentative evaluation of *Telenomus* sp. against INB (Trial-II)

Treatment	Pre-treatment INB		Post-treatment INB (30 d)	
	Incidence	Intensity	Incidence	Intensity
Release plot	12.33	5.7	16.5	5.34
Control plot	5.4	3.11	11.68	4.06

In the second augmentative field trial, the parasitoid was released at a dosage equivalent of about 2500/ha in a staggered manner over a 45-day period. Pre- and post-release observations once again indicated that borer incidence and intensity increased at a much lower rate in release plot than in control plot a month after release (Table 12).

Pennisetum purpureum *as possible food source for* Telenomus**:** Our earlier observations indicated attraction of various groups of insects to selected genotypes of *P. purpureum* and enhanced longevity of *Telenomus* adults exposed to leaf sheaths of the genotypes. In continued field observations, a large number of ants, bees, wasps, flies and coccinellids were observed foraging on the top internodes of select *P. perpureum* genotypes. Systematic observations of the number of visitors on the top five visible dewlaps of 15 plants between 9.00 and 10.00 am recorded at monthly intervals indicated that all groups were active during August – October 2019 with higher predominance of ants. The visitors' numbers dwindled during November-December 2019. Freshly emerged adults of *Telenomus* sp. maintained on leaf sheaths of the genotypes survived for a maximum of 7 d whereas unexposed adults survived for only 1-2 d.

*Field trapping of Telenomus with INB eggs***:** INB egg masses were evaluated in the field to trap *Telenomus* eggs. to use them as sentinel eggs in field efficacy studies of *Telenomus* sp. through augmentative releases. About 10 laboratory obtained egg masses on leaf bits were kept in grown-up crop of sugarcane, collected 24 h later and maintained in the laboratory for parasitoid emergence. In three such field tests, parasitoid emerged from one egg mass with low adult emergence. When egg masses were placed in release and control plots in two augmentative trials, parasitoid was recovered from 30-50% egg masses with variable adult emergence. Two factors, namely desiccation and predation of egg masses appeared to undermine the results of the trial and, hence, need to be addressed.

(J. Srikanth, P. Mahesh, K.P. Salin and L. Saravanan)

Bio intensive management of white grub in sugarcane

To assess the efficacy of various microbials in the laboratory against target hosts: The cultures of *Beauveria brongniartii, B. bassiana* and *M. anisopliae* were mass cultured on liquid SD/PD/YPSS/ oats media and maintained on solid medium. The cultures of entomopathogenic nematodes *Heterorhabditis indica* and *Steinernema glaseri* were obtained and mass cultured on *G. mellonella*. Cultures are maintained in the laboratory and routinely sub cultured and passed through insect hosts as and when deemed necessary in order to retain virulence.

Assessment of the impact of soil temperature on viability and virulence of entomopathogenic fungi: Two batches of fungal suspensions ($2.35x10^7$ spores/pot) with one of the batches maintained inside the incubator at constant temperature of 15°C and another batch, at ambient temperature. The treatments with three replications were the individual and combinations of three fungus *B. bassiana*, *B. brongniartii* and *M. anisopliae* and two nematodes *Heterorhabditis indica* and *Steinernema glaseri.* To assess the viability and pathogenicity of inoculated fungus, ten batches of soil samples were retrieved from pots at every ten days interval after treatment and it was continued up to 100 days. Bioassays with *G. mellonella* indicated high degradation of *Beauveria* species compared to *M. anisopliae* with the latter retaining up to 60% efficacy till 100 days after inoculation at ambient temperature while at 15°C significant differences between viability of *Beauveria* spp. and *M. anisopliae* were not observed.

Efficacy of various microbials: Laboratory experiments conducted as a confirmation study to assess the individual and combined efficacy of three fungal pathogens (*B. brongniartii*, *M. anisopliae* and *B. bassiana*) and six insecticides (chlorantraliniprole, imidacloprid, chlorpyriphos, phorate, carbofuran, fipronil) against IV instar *Galleria* larvae in two different methods (DM: Direct dipping method; FW: Filter paper walk) with the data recorded on mortality and spore yield/larvae are under process for further analysis. In general combination treatments resulted in higher mortalities than when EPF were used alone

with certain exceptions. For example *B.bassiana* alone caused 68.99% mortality (DM) while a combination of *B. bassiana* with chlorphyriphos resulted in 42.22% but chlorpyriphos alone caused 100% showing the contradiction. The combinations were definitely more effective than *B. brongniartii* alone in FW but less effective in DM in a few instances. Vast differences in mortalities due to the method of exposure was found in case of *M. anisopliae* but combinations resulted in appreciable mortalities. For example, in FM, mortalities due to *M. anisopliae* alone and chlorantraliniprole were 48.89 and 44.45 % respectively while a combination of *M. anisopliae* and chlorantraniliprole was 100%.

Pot culture experiments (three sets) were continued with various combinations of *B. brongniartii, B. bassiana, M. anispliae, H. indica*, *S. glaseri* and the six selected insecticides imposed at field recommended dose. First instar grubs of *H. serrata* were inoculated 5/pot with three replications including a control and recovered for observations on mortality after a month through upturning the pots. Effect of residual effect was observed by re-inoculation of grubs and recovered one month later. While all the EPF showed high mortality rates of inoculated white grub, the residual impact varied when tested at 30, 60, 90, 120, 150 and 180 days. Combination of all three EPF and *H. indica* showed only 15% mortality due to EPF at 30 days but at 90days it was 59.2%. Insecticides with *S. glaseri* showed 0-55% mortality at 90 days after application while the best treatment involving *H. indica* was with imidacloprid with 48% residual effect at 90 days.

Average mortalities of three sets ranged from 31.84 (*M. anisopliae* + fipronil) to 77.41 (*M. anisopliae* + chlorantraniliprole) for combinations involving *M. anisopliae* while in case of *B. brongniartii* they ranged from 43.69 (*B. brongniartii* + *H. indica* to 100 % (carbofuran) and in the case of *B. bassiana*, mortalities were of the range of 29.62 (*B. bassiana* + Fipronil) -94.07 % (*B. bassiana* + chlorpyriphos).

EPN either alone or in combination with insecticides showed differential mortalities, *i.e.*, 18.76 (*H. indica* + Fipronil) to 75.55 (*H. indica* + imidacloprid) in case of *H. indica* while the range was 42.58 (*S. glaseri*) to 98.14% (*S. glaseri* + chlorantraniliprole). When insecticides were tried alone, mortalities of 53.33 (phorate and fipronil) to 100% (carbofuran) were observed. Combination of all agents resulted in an average mortality of 61.09%.

Persistence of the microbials: In order to assess the persistence EPF, EPN, insecticides and their combined efficacy over the period of six months, six batches of soil samples were collected from respective treatment pots at every thirty days interval and maintained. The bioassay study and observations on mortality showed incompatibility of EPF with both insecticides and EPN. While the combinations of EPN with insecticides suffered the worst, *M. anisopliae* with other EPF fared the best, retaining efficacy even at 180 days. In case of treatments with *B. bassiana*, the mortality was 100% up to 60 days of treatment while at 90 days, the percent mortality ranged between 90% (*B. bassiana*) and 100% (in combination treatments) but at 120 days, the lowest mortality of 75.56% was observed in the treatment with *B. bassiana* + *S. glaseri.* However, by 150 and 180 days the persistence levels were higher showing increasing but differential buildup of the biocontrol agents with mortality ranges of 70-98.7% wherein, the lowest was in insecticide combination (*B. bassiana* + chlorpyriphos) and the highest was in *B. bassiana* and *M. anisopliae* combination (180 days). With regard to *B. brongniartii*, in the combinations with EPN, the persistence at 180 days was low at 75% with *H. indica* but high (91.11%) with *S. glaseri*. More than 90% mortality was observed in case of *M. anisopliae* even at 120 days, though combinations with EPN and cholorantraniliprole resulted in <80% mortality during the same period. At 90 days, insecticides showed lower level of persistence with 56.7% (fipronil) to 80% (chlorpyriphos) mortalities.

Impact of temperature on survivability and growth of EPF: Different strains of EPF were assessed for their performance under different temperatures, nutritional regimes with the purpose of economizing efficient production of virulent EPF for field use. Different agricultural byproducts and grains were evaluated with marked differences in the production. Various standard media used for culturing EPF were found to influence their production with a

distinct influence of temperature and strains on the growth.

A single isolate of *B. brongniartii*, nine selected isolates of *B. bassiana*, eight isolates of *M. anisopliae* were tested for their competence to grow under four different temperatures and in four different media through eight periodical observations on their colony growth. At 20 days of inoculation, *B. brongniartii* showed lowest radial growth of 4.42 mm at 15°C and 7.58 mm at 35°C while 25°C (22mm) as well as 30°C (21.75mm) were best for culturing. The differences were significant. Irrespective of the temperature, SDA was the best medium (15.07mm) for *B. brongniartii* while OATs medium was the worst (13.27mm) showing high level of influence of nutrition on temperature tolerance. For example, at lower temperatures of 15 and 20°C there were differences in growth while at 25°C and 35°C nutritional impact was nullified. Growth was incremental on all days of observation (3, 5, 7, 9,12,15,17 and 20 days) and significantly different. For *B. bassiana* too, similar pattern of 25°C and 30°C being ideal for growth and 15°C and 35°C being stressful was observed irrespective of the medium on wihich the isolates were cultured. Based on 20th day growth it could be seen at the ideal temperature of 30°C, lowest growth was observed in Bb 23 (25.0 mm) and Moaner Bb (24.67 mm) and in most others, the growth was better and on par with each other. However, at deleterious temperature of 35 °C, the growth declined to less than 10 mm with Bb 58 showing the most drastic reduction (29.5mm reduced to 4.5mm). In oats based medium and YPSS too, similar pattern was observed. However, Bb 61 which showed statistically significant highest growth on other medium showed lower growth (7 mm) than CBE Bb (10.5 mm) and INB (11.6 mm) at 35°C but at the ideal temperature of 30°C Bb 61 showed significantly higher (35.17 mm) growth than INB Bb (31.83 mm) showing the latter heat tolerance.

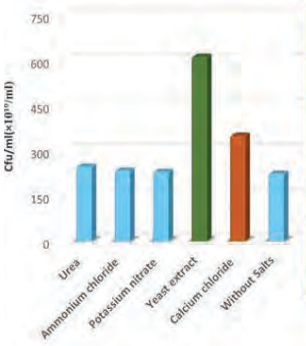
The overall growth (average of all observations at different periods of growth) pattern of *M. anisopliae* strains indicated that all strains were equally robust irrespective of medium and temperature. But the interaction of temperature and medium showed that PDA (15.77mm) and SDA (15.48mm) were significantly better than OATS and YPSS (14.5 and 14.33 mm respectively). Unlike *Beauveria* spp., *M. anisopliae* showed high tolerance to higher temperature, *i.e.*, the average growth of all strains was significantly better as the temperature increased from 15 (7.83 mm) to 35 °C (20.24 mm). Observation on 20th day of inoculation showed that among the different temperatures 35 °C was the best (30.44) and significantly different from all other lower temperatures which in turn were significantly different from each other. However, no differences among the isolates based on temperature was observed at 20th day growth (20.83 and 23.22 mm across the four media). But within a temperature point of 35 °C significant differences were observed with MCC1189 (35.58mm) and Ma local (34.42 mm) out performing other isolates. Similarly Ma local which had an average (of all periodical observations) growth of 14.45 mm across the media and temperature regimes, turned out to be the best at 35 °C (34.42 mm) on 20th day observation but at 15 °C it was the worst (27.37 mm) and statistically lower than several other isolates having (34.11-37.12 mm) higher radial growth at 20 days which signifies identifying the workable temperature regimes of isolates inoculated for target pest management. Sporulation and germination of the isolates followed similar pattern with odd differences in certain instances.

Field evaluation : Field mail at Thavady area under, M/s. Bannari Amman Sugars indicated Significantly higher and best reduction of white grub pupulation in plots heated with *M. amisophate* which was on par with Lesenta.

(N. Geetha, K.P. Salin and M. Punithavalli)

Standardization of mass production of scarabaeid specific *Bacillus thuringiensis* using agro-industrial by products for white grub management

Production of Bt-62 isolate in sugarcane juice with different nitrogen supplements: Sugarcane juice fortified with five nitrogen supplements, namely, urea, ammonium chloride, potassium nitrate, calcium chloride and yeast extract at 1% was evaluated as media for enhanced production of Bt-62 strain. Among the fortified media, maximum spore production (612 x 10^{10} CFU/ml) was obtained in sugarcane juice containing



S.n	Salt supplements	Spore production@
1	Urea (NH_2 CO NH_2)	247.10
2	Ammonium chloride (NH_4Cl_2)	234.00
3	Potassium nitrate (KNO_3)	230
4	Yeast extract	612
5	Calcium chloride ($CaCl_2$)	350
6	Without Salts	223.78

@ Colony forming units (x 10^{10} /ml)

Fig. 81. Media supplements for enhanced growth and sporulation of Bt-62 isolate

yeast extract. This was followed by calcium chloride (350 x 10^{10} CFU/ml). The remaining media containing urea (247 x 10^{10} CFU/ml), ammonium chloride (234 x 10^{10} CFU/ml) and potassium nitrate (230 x 10^{10} CFU/ml) produced moderate and more or less similar spore count (Fig. 81). The spore count in sugarcane juice without supplements (223 x 10^{10} CFU/ml) was generally lower than the media containing different supplements.

Mass production of Bt-62 strain in seed fermenter: Bt 62 was multiplied on the standard T3 media and molasses 3% in seed fermenter at M/s Bannari Amman Sugar Mills Ltd, Sathyamangalam. About 20 l of media was inoculated with 2 l of mother culture in the seed fermenter and the growth of Bt was monitored at 4 and 7 days after inoculation. T3 media produced higher bacterial population than molasses 3%. In T3 medium, the population was higher (8.0 x 10^8 CFU/ml) on 4th day after inoculation than 7th day (2.5 x 10^8 CFU/ml). Similarly, in molasses 3%, higher spore count of 4.7 ×10^8 CFU/ml was observed on 4th day than 7th day of observation (2.3 ×10^7 CFU/ml) (Table 13.)

Field evaluation: Bt-62 culture multiplied on the standard T3 media and molasses 3% in seed fermenter was evaluated in white grub endemic Thalavady area under M/s Bannari Amman Sugars (Fig. 82). Three trial plots of 200 sq m

Fig. 82. Field evaluation of Bt-62 strains of B. thuringiensis against white grub

each with 7-month-old sugarcane crop were demarcated in a highly grub-infested grower's farm. In each plot, soil was excavated for about 1 m length in the root zone at randomly selected spots and grub number counted to represent pre-treatment assessment of white grub. Bt-62 multiplied on T3 (5.0 x 10^{12} CFUs) and molasses (4.6 x 10^{12} CFUs) was applied in one plot each and an untreated plot was maintained as control. The 20 l fermenter product with pre-determined dosage was diluted with 20 l of water and dispensed uniformly in the furrows of the standing crop with a rose can. Post-treatment white grub incidence was assessed 15 days after imposing the treatments following the procedure described above. Data indicated a decrease in grub number in both treatments as well as control. In addition, diseased grubs and soil samples collected from treated plots indicated the presence of Bt-62.

(P. Mahesh, B. Singaravelu, J. Srikanth and K. Hari)

Temperature driven phenology modelling to assess the impact of climate change on population dynamics of internode borer, *Chilo sacchariphagus indicus* in sugarcane

Stock culture of internode borer, *Chilo sacchariphagus indicus* was established in the laboratory, from the larvae and pupae collected in sugarcane fields located in Coimbatore District, Tamil Nadu and were maintained on sugarcane shoot bits (variety Co 86032) and in semi synthetic diet for conducting experiments.

Table 13. Population growth of Bt-62 strain in seed fermenter

Media	CFU/ml on different days after inoculation	
	4	7
T3	8.0x 10^8	2.5x 10^8
Molasses	4.7x 10^8	2.3x 10^7

An experiment was carried out at 25 ± 0.5 °C constant temperature in BOD incubator. The eggs were collected from captive adults in the insect stock culture maintained in the laboratory and transferred to incubator until they hatched. The newly hatched larvae were carefully placed individually on tender sugarcane sheath kept in transparent jars initially. Later, they were provided with fresh split shoots regularly until the larvae reached pupal stage. Survival, duration of larvae and pupae were determined. The daily observation was continued even after pupation until adult emergence. Newly emerged adults were sexed and were paired. Pairs were individually confined to transparent plastic jars having sugarcane leaf bits immersed in water at bottom end to maintain turgidity, which served as substrate for egg laying. Adult moths were fed with 50.0% honey solution fortified with multivitamins using absorbent cotton. The observations on fecundity, duration of oviposition for fecund females and longevity of adults were recorded daily until the death of both the adults. At this temperature, a female laid about 244.5 eggs. Larval stage lasted for about 40.88 days and pupal stage for about 18.0 days. Male moths lived for about 5.5 days, while female lived for about 6.0 days. The experiments for other temperature regimes are on progress.

(L. Saravanan and T. Ramasubramanian)

Isolation of novel Bt isolates from biodiversity hot spots and functional validation of indigenous crystal toxin genes against sugarcane insect pests

Soil samples were collected for Bt isolation from western Ghats of Karnataka which is one of the biodiversity hot spots of India. Two samples were collected from location: one representing the surface soil and the other constituting the subsurface. The GPS Coordinates of each location from where soil was collected was also recorded. In total 396 soil samples were collected from various places *viz.*, Mudubidri, Karkala, Bajegoli and Kudremukh National Park, Kundadiri Hills, Srimane falls, Kalasa, Horamadu, Balehole, Balehonnur, Khandya, Kannathi, Vastare, Dhramsthala, Shiradi Ghats forest, Sakleshpur, Kodlipet and Shanivarasanthe. Isolation of *Bacillus thuringiensis* is in progress.

(B. Singaravelu, C. Appunu, G.S. Suresha, C. Sankaranarayanan, K.P. Devakumar and P. Mahesh)

Screening for novel genes in the transcriptomes of cane Crambids for RNAi-mediated control

Total RNA was extracted separately from each instar of early shoot borer *Chilo infuscatellus* using TRI reagent. Larvae of a particular instar were homogenized with liquid nitrogen in DEPC-treated pestle and mortar. 1 mL of TRI reagent was added and the homogenate was transferred to a 2 mL micro centrifuge tube. The homogenate was kept at room temperature for about 5 min and then centrifuged at 12000 rpm for 10 min at 4°C. The supernatant was collected and transferred to another Eppendorf tube. To this 250 µL of chloroform was added, shaken vigorously for less than a min and incubated in ice for about 3 min. This was followed by centrifugation at 13000 rpm for 10 min at 4°C. The top aqueous layer was pipetted out carefully, added with ice-cold isopropanol (250 µL), mixed well by inversion and incubated in ice for 10 min. The content was centrifuged at 13000 rpm for 15 min at 4°C. The supernatant was drained off and the pellet was retained. The total RNA pellet was washed with 100 µL of 70% ethanol and centrifuged at 13000 rpm for 5 min at 4°C. The pellet was air-dried and dissolved in 20-50 µL of DEPC-treated water depending upon the size of the pellet and stored at -20 °C. The quality of the RNA was checked in 0.8% agarose gel and then quantified in NanoDrop spectrophotometer ND 1000. The purity of the isolated RNA was also assessed by recording the absorbance ratio of $OD_{260/280}$ with the expected values from 1.8 to 2.0 using the NanoDrop spectrophotometer ND 1000. The protocol described above was observed to be suitable for isolating total RNA from all the instars of the early shoot borer. The extracted total RNA will be used for further downstream processes *viz.*, transcriptome sequencing and analysis. The same protocol was also found suitable for extracting total RNA from different instars of sugarcane internode borer.

(T. Ramasubramanian and S. Mohankumar (TNAU)

5.3.3 NEMATOLOGY

Studies on insecticidal molecules of symbiotic bacteria associated with entomopathogenic nematodes

Insecticidal molecules from Photorhabdus / Xenorhabdus**:** Insecticidal fraction studies of symbiotic bacteria *Photorhabdus luminescence laumondii* (SBIPLLHB) and *Xenorhabdus stockiae* (SBIXSTND52) was done using GCMS column. Around 77 and 40 compounds respectively have been identified from diethyl ether extract of both bacterial cultures.

Maintenance of symbiotic bacterial cultures: Totally 45 symbiotic bacteria belong to *Photorhabdus* spp. (26 Nos.) and *Xenorhabdus* spp. (19 Nos.) are being regularly sub cultured on NBTA media and stored in glycerine.

(C. Sankaranarayanan, K.P. Salin, K. Hari and B. Singaravelu)

Isolation and evaluation of entomopathogenic nematodes (EPN) from white grub endemic areas of subtropical sugarcane ecosystem

Identification of EPN from sugarcane ecosystem: Molecular identification of eleven EPN isolates was done by analysis of genomic DNA sequences with internal transcribed spacer (ITS) specific primers. ITS sequences of 11 EPN (*Heterorhabditis* and *Steinernema* spp.) isolated from sugarcane ecosystem have been submitted to NCBI Database with following accession numbers from MK995657-MK995661; MK995677-MK995681; MK511973

Delivery methods for EPN against white grub: A field experiment was conducted to evaluate the efficacy of five EPN species (three subtropical isolates and two tropical isolates) with three different application methods of novel EPN formulation against white grub *Holotrichia serrata* at Banagahalli village Thalavadi area. The trial was conducted in 1 acre area planted with sugarcane cv. Co 86032. Totally 16 treatments including control was maintained with two replications. The EPN was applied at the rate of $1x10^9$ per acre. White grub population was recorded initial and after 15 days by randomly in six places per treatment by counting dead and alive in one m^2 area. In general, a reduction in white grub population was observed irrespective of the EPN species and application methods compared to untreated control. Among the nematodes, *Heterorhabditis bacteriophora* (SBIH6) and *Steinernema glaseri* (SBILN1) recorded maximum reduction (78.79%) of white grubs with EPN applicator than other nematodes and other EPN application methods.

Bio efficacy of EPN against 3rd instar white grub: Bio efficacy of five EPN (3 subtropical and 2 tropical isolates) against 3rd instar white grub of *H. serrata* under potted condition revealed the mortality of white grubs by EPN. The mortality of grubs ranged between 50 to 90%. *H. indica* (SBIP11) recorded the maximum.

Mass production EPN by monoxenic liquid culturing: Mass production of two EPN isolates was attempted in monoxenic liquid culturing and successful nematode mass production was observed in the liquid media.

Formulation of subtropical EPN: Ten EPN (Five *Heterorhabditis* spp and five *Steinernema* spp) were mass produced in *Galleria* larvae and formulated in novel talc based formulation to study the shelf life of EPN.

Maintenance of EPN cultures: Seventy-six EPN isolates belong to tropical (47) and subtropical (29) isolates were maintained by regular culturing in *Galleria mellonella* larvae and are being maintained in the culture collection.

(C. Sankaranarayanan, S.K. Pandey and B. Singaravelu)

5.4 ECONOMICS AND STATISTICS SECTION

An economic analysis on sugar recovery in different states in India

A decade wise sugar recovery improvement was estimated to find out the sugar recovery improvement over period of time. The sugar recovery improvement comparatively better in the major cane growing states in the tropical India up to first decade of the 21st century. However, in the current decade, the sugar recovery improvement is sticky or fluctuating in the tropical states due to drought, fluctuations in the rainfall pattern and labour scarcity. On the other hand, sub-tropical India has overweighed

the reduction of the sugar recovery in the hitherto medium and high sugar recovery states of the country. The better sugar recovery in the sub-tropical is helping for overall sugar recovery improvement of the country despite fluctuating sugar recovery pattern.

(P. Murali, D. Puthira Prathap and V. Venkatasubramanian)

Socio-economic impact of ICAR-SBI varieties and production technologies in different agro-climatic zones of India

The very first hybrid Co 205 which was released during 1918 proved success in North India, which was followed by many varieties had contributed for yield and sugar recovery improvement. Though lot of varieties and technologies were developed by various research and developmental institutions in the country, varieties and technologies developed by ICAR- SBI and its centers had greater impact on sugarcane and sugar system in the county as well as other countries.

Since development of first hybrid by the institute, the cane area is continuously increased over the period of time. At present, Co 0238 and Co 86032 exclusively developed by the institute are being cultivated in about 68.1 % of the total cane area in the country. Co 0238 and Co 86032 are being cultivated about 52.7 and 15.2% of the total cane area in the country. Overall, the share of Co varieties in the country is about 77.2 %. Similarly, the sugar recovery improvement was majorly contributed by the 'Co' varieties in the country.

The yield improvement was mainly attributed to the tropical states due to favourble climate conditions. However, wonder variety Co 0238 which was released in 2009 for North Western Zone has metamorphized the yield and sugar recovery in the subtropical India. The yield was improved about 10/ha and average yield of India was lifted from 70 t//ha to 79 t/ha in the recent period.

(P. Murali, V. Venkatasubramanian, Ravinder Kumar and K. Elayaraja)

Economic impact and climate smartness of variety Co 0238 in sub-tropical India

The variety Co 0238 is widely cultivated in the sub-tropical India. To study the impact of the variety, survey was conducted in Punjab, Haryana and Uttar Pradesh (UP). In Punjab, Rana sugars and distillery unit, Butter Seviyan, Amritsar was visited. About 30 farmers were interviewed to collect data on cost of cultivation and economic impact of the variety Co 0238. The yield improvement of about 15-20 t/ha was recorded in the progressive farmers field. The farmers – industry and institute meet were organized for more insight on variety and technologies which was developed by the Institute.

In Haryana, Karnal cooperative sugar mill was visited and data were collected. Most of the farmers were told that variety Co 0238 is being cultivated since 2014. The average yield of about 8-10 t/ha was increased by cultivation of the variety Co 0238. In UP state, Uttam sugars, Barkatpur, Bijnor Dist. and DCM Sriram sugars, Daurala, Meerut Dist. were surveyed to collect the primary and secondary data. The secondary data has revealed that Co 0238 is cultivated about 95% of cane area in the sugar mills area. The sugar recovery has significantly improved in the range of 1.5-2.0 units. The farmers have earned additional profit of Rs.45,000–60,000/ ha by cultivation of the variety Co 0238 in the study area.

ICAR-SBI varieties and technologies are continuously improving the yield and sugar recovery of the sugarcane production in the country. Co 0238 is being cultivated about 77% of the total cane area in the sub-tropical India. The surplus sugar and jaggery production have immensely contributed towards supply of white sugar and jaggery for domestic and international markets.

(P. Murali, V. Venkatasubramanian, D. Puthira Prathap and Ravinder Kumar)

A feasibility study of recommended sugarcane technologies for promoting rural entrepreneurship

The project started with an aim of achieving excellence in ICAR-SBI HRD through

promoting entrepreneurship, requirement analysis for starting a commercial enterprise, building partnership/ Linkages/ Networking, and Institution building. Analysis of men and materials, manufacturing process, knowledge, skill and financial requirements etc and preparing a business plan/ project report on three selected enterprises (SMI, Settling Transplanter and Organic farm yard manure) have been undertaken. Two potential technologies of ICAR-SBI namely, Soil Moisture Indicator and Settling Transplanter and one promising allied enterprise like production of organic farm yard manure were selected based on their income generation potential and starting an enterprise. Analysis of entrepreneurial qualities and needs of potential rural youth for providing technological and methodology support related to starting an enterprise and developing a CD module for developing entrepreneurship were carried out for developing the skill development manual.

Identification of 25 agri-preneurial qualities and a test battery to measure the entrepreneurial qualities, development of attitude scale to measure entrepreneurship and a test for recognition of pre learning (knowledge test) and development of a Skill Capacity Development template for entrepreneurial promotion are the highlights of the project output. Developed leadership development programme module for effective management of enterprises.

(V. Venkatasubramanian, P. Murali, D. Puthira Prathap, T. Arumuganathan and K.Hari)

Sugarcane based Agri-Business Incubator

The project was initiated to provide the necessary support for validation and up-scaling of sugarcane-based technologies and other technologies to encourage their reach to the user as an attractive business proposition. ABI is facilitating innovator and researchers to tum their ideas into commercial venture. The centre is focusing on incubation and business development programme, including entrepreneurship, skill development, start-ups and grassroots innovators activities.

Purchashing the machineries for business incubator and capacity building: The SBI-ABI has initiated purchase of machineries with the available project funding. The double jacket jam kettle with boiler, dispenser foil sealing machine, clean air work bench and refrigerator were ordered for establishing sugarcane based value-added product, technology transfer and capacity building.

Brainstorming session: Technical support was provided for brainstorming on focused group discussion on sugarcane products. sugarcane juice powder, granulated jaggery, sugarcane-based jam, jelly and other products was presented. The experts provided the valuable inputs for upscaling the products for commercial ventures. Consequently, brainstorming session on post-harvest technology and value addition was organized with the participation of experts from various institutes who are working on food and value chain products. It was participated by industrialists, NGO's and successful farm entrepreneurs. The brainstorming has come out with ways and means to improve sugarcane-based entrepreneurship in the country.

(P. Murali, V. Venkatasubramanian, K. Hari, A.J. Prabakaran, G. Suresha and D. Puthira Prathap)

5.5 EXTENSION SECTION

Utilization of extension methods and media for effective transfer of sugarcane technologies

Sugarcane Research and Development workers' meetings

The 50th Sugarcane R and D Workshop of Tamil Nadu and Puducherry was organized at Chennai during 23-24 October 2019. The workshop was hosted by Cheyyar Co-op Sugar Mills Ltd., Anakkavoor. Shri M.C. Sampath, Hon'ble Minister for Industries, Govt. of Tamil Nadu was the Chief Guest and released the compendium (Fig. 83). Dr Bakshi Ram, Director, ICAR-SBI delivered the Theme address. About 300 delegates comprising scientists from ICAR-SBI and Tamil Nadu Agricultural University, Coimbatore, Cane Development personnel from various sugar factories, officers from the Department of Agriculture, Directorate of Sugar and other Cane Development organizations in

Tamil Nadu and Puducherry participated in the workshop. The main topics discussed were, Wide row planting with intercropping and Review of sugarcane mechanization initiatives including mechanical harvesting.

Fig. 83. Release of compendium during the R and D Workers meeting

National level programs organized

Nine National level training programs sponsored under National Food Security Mission by the Ministry of Agriculture and Farmers Welfare, Government of India were conducted (Fig. 84) as detailed below :

- I program: 25-26 June 2019 with 28 cane development officials from the states of Andhra Pradesh (4), Gujarat (2), Karnataka (2), Tamil Nadu (18) and Uttar Pradesh (2).
- II program: 2-3 July 2019 with 27 participants from the states of Gujarat (2), Karnataka (4), Tamil Nadu (19) and Uttar Pradesh (2).
- III program: 9-10 July 2019 with 25 participants from the states of Gujarat (3), Karnataka (3), Maharashtra (2), Tamil Nadu (15) and Uttar Pradesh (2).
- IV program: 16-17 July 2019 with 25 participants from the states of Andhra Pradesh (2), Karnataka (2), Tamil Nadu (19), and Uttar Pradesh (2).
- V program: 25-26 July 2019 with 25 participants from the states of Andhra Pradesh (2), Haryana (2), Karnataka (2), Tamil Nadu (17) and Uttar Pradesh (2).
- VI program: 1-2 August 2019 with 25 participants from the states of Haryana (2), Karnataka (2), Tamil Nadu (17), Uttar Pradesh (2) and Uttarakhand (2).
- VII program: 13-14 August 2019 with 25 participants from the states of Haryana (2), Karnataka (4), Tamil Nadu (17) and Uttar Pradesh (2).
- VIII program: 22-23 August 2019 with 25 participants from the states of Karnataka (4), Tamil Nadu (19) and Uttar Pradesh (2).
- IX program: 27-28 August 2019 with 31 participants from the states of Karnataka (2), Maharashtra (8), Punjab (2), Tamil Nadu (11) and Uttar Pradesh (8).

Knowledge evaluation studies were conducted pre and post training using a teacher-made knowledge test (Table 1). The average pre-evaluation score was 60.99 (range being 46.58 to 70.80) and average post-evaluation score was 87.73 (range 81.94 to 93.39) with an average knowledge gain of 26.74.

Table 14. Pre and post evaluation of knowledge level

Date	No. of participants	Pre-knowledge score (%)	Post-knowledge score (%)	Difference
25-26 June 2019	28	46.58	90.84	44.26
2-3 July 2019	27	61.04	88.31	27.27
9-10 July 2019	25	62.09	91.65	29.52
16-17 July 2019	25	49.97	81.94	31.97
25-26 July 2019	25	70.80	88.52	17.72
1-2 August 2019	25	60.17	93.39	33.22
13-14 August 2019	25	70.80	89.04	18.24
22-23 August 2019	25	66.96	82.43	15.47
27-28 August 2019	31	60.46	83.49	23.03
Average		60.99	87.73	26.74

2-3 July 2019

9-10 July 2019

16-17 July 2019

25-26 July 2019

1-2 August 2019

13-14 August 2019

22-23 August 2019

27-28 August 2019

Fig. 84. Participants of the national level training programs

Short term training programs

- Conducted a three-days training for 42 sugarcane farmers from Edappadi, Salem district sponsored by ATMA during 28-30 August 2019 (Fig. 85). The training focused on 'SSI planting and micro-irrigation in sugarcane'.

Fig. 85. Farmers visiting Institute museum (28 August 2019)

- Conducted a three-days training for 38 farmers from Thoothukudi district sponsored by ATMA during 25-27 September 2019 on 'Drip irrigation and SSI planting' (Fig. 86).

Fig. 86. A training session in progress

- Conducted three-days training for 35 farmers from Kamuthi, Ramanathapuram district, Tamil Nadu on 'SSI planting and drip fertigation in sugarcane' during 11-13 November 2019 (Fig. 87).

Fig. 87. Participants of the training program (11-13 November 2019)

One-day training programs

Conducted the following 34 one-day training programs (Fig. 88):

- For 20 cane officials from Kallakurichi Cooperative sugar mill unit II on 25 April 2019.
- For 31 sugarcane farmers from Marayoor, Idukki district on 24 June 2019.
- For 44 sugarcane farmers from Dharmapuri district on 5 July 2019.
- For 40 sugarcane farmers from Alanganallur, Madurai district on 12 July 2019.
- For 50 farmers from Kadayampatti, Salem district on 12 July 2019.
- For 62 farmers from Nallurpalayam, Tirupur district on 12 July 2019.
- For 37 cane officers from Kallakurichi cooperative sugar mills ltd., on 12 July 2019.
- For 47 farmers from Vellore cooperative sugar mills ltd., on 18 July 2019.
- For 48 farmers from ATMA, Sankagiri, Salem district on 26 July 2019.
- For 23 farmers from ATMA, Cuddalore district on 26 July 2019.
- For 25 farmers from ATMA, Modakurichi, Erode district on 29 July 2019.
- For 40 farmers from ATMA, Edapadi, Salem district on 28 August 2019.
- For 40 sugarcane farmers from Usilampatti, Madurai district sponsored by ATMA on 4 September 2019.
- For 45 cane development personnel from Cheyyar cooperative sugar mills Ltd. on 16 September 2019.
- For 35 sugarcane farmers sponsored by ATMA, Thanjavur district on 20 September 2019.
- For 33 sugarcane farmers sponsored by ATMA, Kanyakumari district on 15 October 2019.
- For 42 farmers from ATMA, Perambalur district, Tamil Nadu on 'SSI planting and drip fertigation in sugarcane' on 21 October 2019.

24 June 2019

5 July 2019

29 July 2019

15 November 2019

15 November 2019

20 November 2019

21 November 2019

22 November 2019

22 November 2019

25 November 2019

25 November 2019

27 November 2019

28 November 2019

28 November 2019

29 November 2019

Fig. 88. Participants of the one-day training programs

- For 33 farmers from ATMA, Kamuthi, Ramanathapuram district on 11 November 2019.
- For 44 farmers / input dealers from DASEI, Karnataka on 11 November 2019.
- For 50 farmers from Palur block, ATMA, Ariyalur district, Tamil Nadu on 'SSI planting and drip fertigation in sugarcane' on 15 November 2019.
- For 68 farmers from Anaimalai block, Pollachi, Tamil Nadu on 'SSI planting and drip fertigation in sugarcane' on 20 November 2019.
- For 35 farmers from Manur block, Tirunelveli district, Tamil Nadu on 'SSI planting and drip fertigation in sugarcane' on 21 November 2019.
- For 52 farmers from Krishnagiri block, Krishnagiri district, Tamil Nadu on 'SSI planting and drip fertigation in sugarcane' on 22 November 2019.
- For 30 cane staff from M.R.K. cooperative sugar mills ltd., on 22 November 2019
- For 50 farmers from Vellakovil block, Tirupur district on 'SSI planting and drip fertigation in sugarcane' on 27 November 2019.
- For 50 farmers from Bhavani block, Erode district on 'SSI planting and drip fertigation in sugarcane' on 26 November 2019.
- For 52 farmers from Uzhavar Mayam, Dindigul district on 28 November 2019.
- For 50 farmers from Ammapettai block, Erode district on 'SSI planting and drip fertigation in sugarcane' on 28 November 2019.
- For 42 farmers from Vasudevanallur, Tenkasi district on 'SSI planting and drip fertigation in sugarcane' on 29 November 2019.
- For 54 farmers from Bargur block, Krishnagiri district on 'SSI planting and drip fertigation in sugarcane' on 2 December 2019.
- For 12 farmers from Shimoga district, Karnataka on 'Drip irrigation in sugarcane' on 9 December 2019.
- For 04 farmers from Narasigapur, Madhya Pradesh on 19 December 2019.
- For 52 farmers from Alangulam block, Tankasi district on 19 December 2019.
- For 17 farmers from Kollegal, Karnataka on 19 December 2019.

Exposure visits

Conducted the following 14 one-day Exposure visits (Fig. 89):

- For 114 students from Vanavarayar Institute of Agriculture, Pollachi, Coimbatore on 04 April 2019.
- For 53 students from Kumaraguru Institute of Agriculture. Erode district on 27 June 2019.
- For 60 students from Ramakrishna Mission Vidyalaya, Coimbatore district on 29 June 2019.
- For 55 students from PSG Public School, Coimbatore on 5 July 2019.
- For 34 students from Yuvabharathi Public School, Coimbatore on 10 July 2019.
- For 32 students from Aravindhar Agricultural Institute of Technology on 12 July 2019.
- For 42 DAESI trainees from College of Horticulture, Mysore on 24 July 2019.

Fig. 89a. Students visiting museum (10 July 2019)

Fig. 89b. Students visiting tissue culture lab (16 November 2019)

- For 84 students from Samskara Academy, Coimbatore on 2 August 2019.
- For 39 input dealers from MYRADA KVK, Erode on 17 September 2019.
- For 08 trainees from KVK, Karamadai, Coimbatore on 3 September 2019.
- For 76 students from Delhi Public School, Coimbatore on 16 November 2019.
- For 30 Cane Officers / Cane Assistants from M.R.K. Cooperative Sugar Mills Ltd., Sethiathope on 22 November 2019.
- For 33 students of Agri-Clinic and Agri-Business Centre from Vanavarayar Institute of Agriculture, Pollachi on 5 December 2019.
- For 173 students from National Model Matriculation Higher Secondary School, Coimbatore on 20 December 2019.

Participation in Exhibition: Participated in the Agri-Intex 2019 conducted at CODISSIA Trade Fair complex during 12-15 July 2019 by putting up a stall depicting package of practices, live specimens of new sugarcane varieties and screening of video films on sugarcane (Fig. 90).

Fig. 90. A view of ICAR-SBI stall

Frontline demonstrations on sugarcane

Five frontline demonstration plots with the sugarcane variety Co 0212 and Co 86032 were planted in Kumarasamypuram, Ganeshapuram, Periyasadayampalayam, Vellode and Koorampalayam in Modakurichi block, Erode district in collaboration with MYRADA KVK and Sakthi Sugars, Modakurichi, Erode district (Fig. 91). There was considerable improvement in yield in all the demonstration plots over the farmers' practice. The average cane yield of Co 0212 was 127.5 t/ha compared to 108.75 in Co 86032. Highest yield was 132.40 in Co 0212 and 110.62 in Co 86032.

Fig. 91a. Young crop of Co 0212

Fig. 91b. Co 0212 in tillering stage

Fig. 91c. Control plot of Co 86032

Fig. 91d. Frontline demonstrations on the variety Co 0212

Survey based studies: Studies were conducted to study the adoption pattern and constraint analysis of sugarcane technologies in Villupuram district and Performance analysis of drip irrigation in sugarcane.

M.Sc. (Sugarcane Technology) in ODL mode: ICAR-Sugarcane Breeding Institute and Tamil Nadu Agricultural University are jointly offering the M.Sc. (Sugarcane technology) course in Open and Distance Learning mode from the academic year 2007-08. Personal contact classes were offered at Coimbatore for eleven IV semester students during 29 April to 3 May 2019.

- Printed three issues of ICAR-SBI News April 2019, July 2019 and October 2019.
- Three Training Manuals, nine pamphlets, one book.

Technology Park: Technology Park 2019 was maintained with 17 sugarcane varieties (Co 86032, Co 06027, Co 06030, Co 99004, Co 2001-13, Co 92005, Co 06022, Co 99006, Co 2001-15, Co 0118, Co 0212, Co 0232, Co 0233, Co 0237, Co 0238, Co 05011, Co 11015) and tissue culture plants in 100 rows.

Interaction with Krishi Vigyan Kendras: Participated in the Scientific Advisory Committee meeting of MYRADA KVK and Shri Avinashilingam KVK and offered suggestions for implementation of programs.

Visitors program: Entertained 5358 visitors to the institute comprising students (4166), farmers (788) and cane development staff (404).

(T. Rajula Shanthy, D. Puthira Prathap and V. Venkatasubramaniam)

Farmer support programme for sustainable sugarcane production

This project was sponsored by Solidaridad through Prakruthi with the objective to train progressive cane growers representing eight sugar mills of Tamil Nadu on sustainable agricultural practices to improve their knowledge base and thereby cane productivity and profitability of cane farming. The trained cane growers were designated as Sugarcane Lead Farmers to serve as change agents to enable fellow farmers take up sustainable farming at village level.

Sixteen training programs with the participation of 755 cane growers and 58 cane development personnel from eight sugar mills of Tamil Nadu state were conducted. A schedule was developed to get feedback from the participants on the usefulness of the capacity building program and the extent to which the messages are being utilized by them and being shared to fellow farmers.

A book on 'Know your weeds in sugarcane' was printed with details of 61 major weeds infesting sugarcane crop and the management measures with photographs.

(T. Rajula Shanthy)

Cane Adviser- A mobile app on sugarcane

We had developed an android mobile app 'Cane Adviser' in trilingual (English, Tamil and Hindi) and is available in google playstore for free download. The app contains information on state-wise sugarcane varieties, crop production technologies, crop protection technologies. Total downloads are 8716 from 61 countries and the number of hits are 131110 with 49611 (37.84%) on crop production, 42166 (32.16%) on crop protection, 27182 (20.73%) on sugarcane varieties, 9227 (7.04%) on fertilizer schedule and 2924 (2.23%) on *Saccharum* species.

(T. Rajula Shanthy, S. Alarmelu, C. Jayabose and P. Malathi)

5.6. ICAR- SBI, REGIONAL CENTRE, KARNAL

Breeding elite clones suitable for North Western Zone

Co 13035, a midlate maturing sugarcane variety was identified by Varietal Identification Committee of AICRP(S) during the Annual Group Meeting at the University of Agricultural Sciences, Dharwad (Karnataka) during October 2019 (Fig. 92).

Performance of Co 13035 in North West Zone: The variety was evaluated in AICRP(S) trials at nine locations in North West Zone of India during 2016-19 (9 trials/locations in IVT and 26 trials/locations in AVT). The comparative performance of the variety with the standards is given in Table 15.

Table 15. Comparative performance of Co 13035 in AICRP trials for cane yield and juice quality with the standard varieties

Entry/Standard	CCS (t/ha)	Cane yield (t/ha)	Sucrose (%)	Pol in cane
Co 13035	11.17	87.86	18.30	14.17
Standards				
CoPant 97222	10.00	80.11	17.97	13.91
CoS 767	9.61	78.44	17.71	13.39
CoS 8436	8.86	70.20	18.19	13.94
Per cent improvement over standards				
CoPant 97222	11.70	9.67	1.84	1.96
CoS 767	16.23	12.01	3.33	5.88
CoS 8436	26.07	25.16	0.60	1.71

Fig. 92. Field view of Co 13035

Entries accepted for inclusion in Zonal Varietal Trial of AICRP: One entry Co 19016 under early whereas two entries Co 19017 and Co 19018 were accepted for inclusion in ZVT trials of AICRP (S).

Hybridization, progeny evaluation and selection

Seedling ground nursery: A total of 2789 seedling derived from 45 bi-parental crosses, 13 GC, and 4 PC were field transplanted during July, 2019. The seedlings were winter ratooned during peak winter season (last week of December 2019), to evaluate the winter tolerance potential.

NAGS deposition an Index Number: The propagules of sugarcane varieties *viz.*, Co 13034 and Co 13035 were supplied to ICAR-SBI, Coimbatore for conservation in NAGS and index numbers were assigned as SBI/2019/Co 13034/255 and SBI/2019/Co13035/256 respectively.

Seedling selection in ground nursery: A total of 124 better performing clones were selected from the ground nursery based on HR Brix, NMC, cane diameter, cane height and other desirable morphological traits after assigning selection number K17-001 to K17-124 and were field transplanted into augmented design under C1 evaluation stage along with four standards (Co 0238, CoJ 64, Co 05011 and CoS 767). The experimental average for HR Brix, cane height (till the TVD), NMC, and cane diameter and selection intensity was 17.6%, 232.4 cm, 7.3, 2.5 and 19.2 respectively. The performance of top high quality cross combinations for cane yield contributing traits and selection intensity is given in Fig. 93.

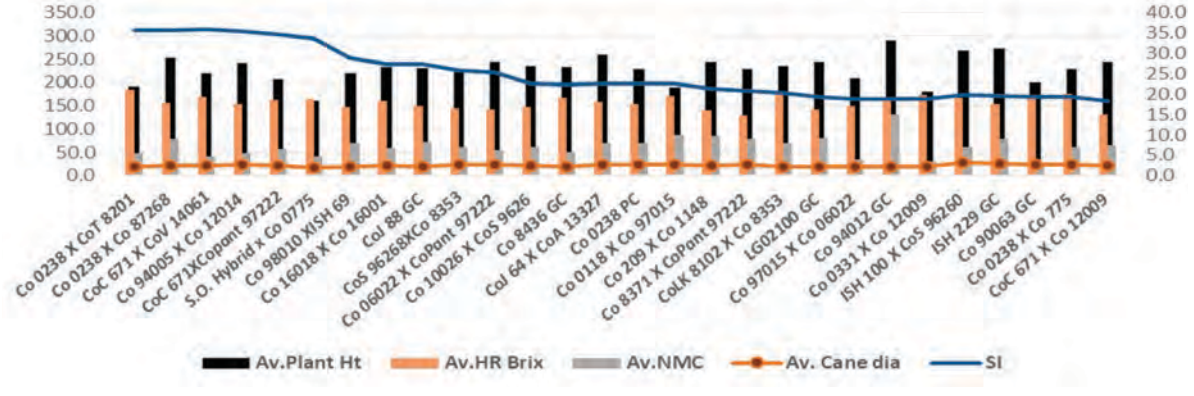


Fig. 93. Performance of major cross combinations for selection intensity, yield and quality traits

First clonal trial: The experiment consisting of 494 C1 selections of K16 series was evaluated for cane yield and quality traits during the month of October. The experiment average for HR brix, cane diameter and NMC was 16.9%, 2.5 cm and 0.99 lakh/ha, respectively. Among them, 19 clones exhibited >20 and HR brix whereas, 27 clones showed more than 1.5 lakh/ha NMC. Seven clones were top ranking clones for HR brix were; K16-313 (22.3%), K16-341 (22.0%), K16-301 (21.9%), K16-305 (21.8%), K16-204 (21.5%), K16-460 (21.1%) and K16-53 (21.0%) while, clones namely K16-209 (1.77 lakh/ha), K16-49 (1.76 lakh/ha), K16-183 (1.66 lakh/ha), K16-43 (1.66 lakh/ha), K16-288 (1.66 lakh/ha), K16-155 (1.66 lakh/ha) and K16-264(1. 6 lakh/ha) have recorded higher NMC in the experiment.

Red rot reaction: Among the 483 C1 trial clones evaluated, 24 showed resistant, 156 moderately resistant, 134 moderately susceptible, 95 susceptible and 74 highly susceptible reactions to red rot.

Preliminary trial: A total of 227 test clones of K15 series were planted in three sets (62+4, 62+4 and 103+4) in RBD layout along with four standards *viz.,* CoJ 64, Co 0238, CoS 767 and Co 05011. The trials were evaluated for NMC, SCW, estimated cane yield and juice quality traits at 8th month. For NMC, the performance of five clones *viz., K15*-004, K15-179, K15-260, K15-281 and K15-376 found superior over, best standard. Nearly half the (110) of the clones produced heavier single cane weight over the best standards. The estimated cane yield of 59 test clones was significantly higher over the best standard. The juice sucrose% of four entries *viz.,* K15-602 (20.29%), K15-088 (20.71), K15-638 (20.26%) and K15-614 (20.11%) was significantly higher whereas of 70 clones it was on par with best standards (trial 1; Co 0238 (19.78), trial 2; CoJ 64 (19.12), trial 3; Co 0238 (19.26). Combining expected cane yield, sucrose% in juice and red-rot reaction 35 of the genotypes found promising.

Red rot reaction: A total of 227 clones were evaluated for red rot resistance and 22 found to be resistant, 104 moderately resistant, 30 moderately susceptible, 52 susceptible and 19 highly susceptible.

(*Ravinder Kumar, M.R. Meena, N. Kulshreshtha and M.L. Chhabra*)

Pre-Zonal Varietal Trial

An experiment consisting of 54 elite clones along with four standards (Co 0238, CoJ 64, Co 05011 and CoS 767) were evaluated for tillering at 120 DAP. The experimental mean for the trial recorded was 1.27 lakh/ha and CoJ 64 (1.39 lakh/ha) was best among standard. Whereas, the eight clones recorded superior to it and fifty three were at par with best standard CoJ 64. For NMC ('000/ha) Co 05011 (103.7) was the best standard and three test clones K14-492 (124.38), K14-047 (123.46) and K14-516 (117.59) had superior performance over it. The SCW of entry K14-354 (1.48 kg) was heavier over best standard Co 0238 (1.28 kg). For juice sucrose content at 8th month, CoJ 64 (17.77%) was the best standard and four test entries *viz.,* K14-353 (19.71), K14-005 (18.95), K14-425 (18.92) and K14-422 (18.91) had significantly higher whereas six entries *viz.,* K14-175 (18.55), K14-462 (18.4), K14-219 (18.28), K14-192 (18.22), K14-063 (18.18) and K14-221 (17.78) had numerically higher performance over CoJ 64. For estimated cane yield Co 0238 (107.69 t/ha) was the best standard and six test entries viz., K14-047 (158.4), K14-542 (147.6), K14-492 (140.08), K14-231 (139.6), K14-516 (136.65) and K14-221 (130.5) produced significantly higher yield over it. Considering cane yield, juice quality and red rot reaction six genotypes viz., K14-063, K14-175, K14-192, K14-221, K14-353 and K14-462 found promising.

Red rot reaction: Fifty-four PZVT clones were inoculated with CF08 and CF09 pathotypes by plug method of inoculation. Seven clones were rated as resistant, 39 moderately resistant, four moderately suscepitible and four susceptible / highly susceptible with CF08 pathotype, while with CF09 pathotype, 10 clones exhibited resistant, 34 modetaetly resistant, four moderately susceptible and six susceptible/ highly susceptible to red rot. However, three clones *viz.* K14-025, K14-422 and K14-446 expressed susceptibility to both the pathotypes.

(*Ravinder Kumar, M.R. Meena, N. Kulshreshtha and B. Parameswari*)

Evaluation of elite clones at different factory locations in Bihar, UP and Haryana

Saraswati Sugar Mill, Yamunanagar: The trial was good but very high incidence of borers was

observed. Co 12029, Co 15023 and Co 15027 were the good performing entries. At Badtoli farm the performance of Co 15023 was excellent in terms of tiller population and height. At 8th month juice analysis for sucrose% in juice, Co 15023 (19.14%), Co 14034 (18.01%), Co 13035 (16.9) were the better test entries over Co 0238 (16.0) and Co 0118 (17.42%).

DSCL unit Ajbapur: The experiment was evaluated for jucie quality and cane yield traits at 8th month. For single cane weight Co 0118 (1.8 kg), Co 15023 (1.68 kg), Co 15027 (1.64 kg) and Co 15026 (1.58 kg) were the best entries. The sucrose% was better in entries Co 15023 (19.51%), Co 13035 (17.8%), Co 14034 (17.4%) and Co 0238 (16.45%).

Dalmia sugar mill unit Ramgarh: The trial was extraordinary in growth performance. Cane height was excellent for all the clones viz., Co 13034, Co 14034, Co 14035, Co 15023, Co 15024, Co 15025, Co 15026, Co 15027 and had on par performance with Co 0238. For single cane weight Co 15027 (1.76 kg), Co 15025 (1.66 kg), Co 14034 (1.45 kg) and Co 15023 (1.40 kg) had heavier cane wight over Co 0238 (1.36 kg). Co 15023 (18.40) and Co 15025 (16.18) were the best entries for sucrose % at 8th month of crop stage.

Balrampur Chini Mill unit Balrampur: In the ratoon trial at eight months after ratooning Co 15023 (20.19%), Co 13035 (18.25%) and Co 15024 (17.45%) were the better entries for sucrose% over Co 0238 (16.36%). In the plant crop also Co 15023 (19.2%) was the best entry for juice sucrose%.

(M.R. Meena, Ravinder Kumar, M.L. Chhabra and N. Kulshreshtha)

'Co' canes maintenance and evaluation

Co canes maintenance: Sixty-eight 'Co' canes were planted in ABD layout with four standards (Co 0118, Co 0238, Co 05011 and Co 12029) replicated in six blocks. At 8th month, the experiment was evaluated for juice quality parameters. Co 15023 (20.64), Co 14034 (20.59), Co 0237 (20.27), Co 12027 (20.21), Co 17016 (19.95), Co 89003 (19.92) and Co 0118 (19.7) were the best performing entries.

(Ravinder Kumar, M.R. Meena and N. Kulshreshtha)

Evaluation of sugarcane germplasm in sub-tropical conditions

Evaluation of inter-specific and inter-generic hybrid clones: The experiment consisting 30 entries was evaluated under drought stress and normal conditions for cane yield and juice quality traits and including physiological traits along with four standard Co 0238, CoJ 64, CoS 767 and Co 05011. Drought stress was imposed at formative phase of the crop by withholding irrigations and data on physiological and morphological traits along with quality parameters was recorded in normal and drought stress. The average plant height (till last exposed TVD) at 120 DAP in normal and drought stress recorded was 98 cm, 64 cm respectively. Among test entries, 14-111 (4%), Zepolita (6%), 14-84 (9%), Kavingire (16) had least reduction for cane height while, CL41-141 (59%), CL41-142 (58%), H-81 (56%), PRB (54%), B43-380 (51%) and Q62 (47%) exhibited highest reduction. Among the standards, Co 0238 had least reduction (9%) under drought stress. The experimental average for tillers population at 120 DAP and

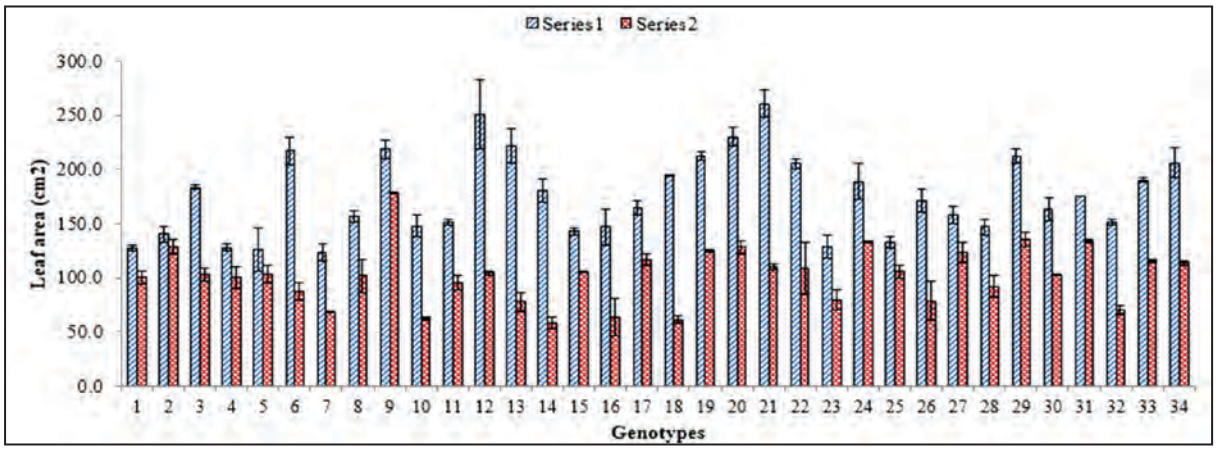


Fig. 94. Performance of the clones for leaf area under normal and drought stress

NMC at 240 DAP recorded was 1.03 lakh/ha and 0.76 lakh/ha, 0.94 lakh/ha and 0.70 lakh/ha, respectively under normal and drought conditions. The overall mean reduction under the drought for tillers population and NMC was 27% and 24.4%, respectively and Co 0238 was the best performer among the standards with least reduction of 6.7% for NMC under drought. The higher reduction for NMC recorded in clone 2012-124 (52.8%), H81 (42.6%), CL47-83 (41.3%), Q62 (40.4%), POJ 28-883 (40.3%), B43-380 (39.8) whereas, clone GUK00-1226 (2.6%), 14-50 (5.7%), Kavingire (9.3) and H49-104 (9.4) had minimum reduction under drought condition. In leaf area, the average reduction under drought stress was 40.31% as compared to normal. Clone PRB, B43-380, 91GUK-1242, POJ28-883, H49-104, PR1047and CL41-114 showed maximum reduction for leaf area whereas, clone Kavingire, 14-50, SP80-185, 51NG161 showed minimum reduction. In standards, Co 0238 had least reduction for leaf area compared to CoJ 64. The juice analysis from the experiment was carried out at 8th month crop stage and average cane height, cane diameter and pol% in juice under normal and drought stress was 198 cm and135 cm, 2.28 cm and 2.3cm, 15.66% and 16.43% respectively. The performance of the clones for leaf area under normal and drought stress is depicted in Fig. 94.

Red rot reaction: Twenty one ISH clones were evaluated with mixed inocula of CF08 and CF09 pathotypes by plug method. Two clones (H81 and 51 NG 163) found to be resistant, 11 moderately resistant, two moderately susceptible, five susceptible and one (RR1047) highly susceptible to red rot.

Insect pests: A total of 18 sugarcane germplasm /species clones (ISH and IGH) were evaluated against early shoot borer (ESB), top borer (TB). Early shoot borer incidence was <15.0 per cent. In case of top borer, 15.0 germplasm /species viz., 14-84 CBE, H49-104, H59-5765, Kavingere, 91GUK-1242, 51NG163,14-50 CBE, 2012-124 CBE, PR 1047,14-50 CBE, 69, GUK 10-572, B43-380, 14-111 CBE,14-111 showed least susceptible reaction and three germplasm /species (Zepuota, H81 and 2012-124) were moderatelu susceptible to top borer.

(N. Kulshreshtha, M. R. Meena, Ravinder Kumar, S.K. Pandey, M.L. Chhabra, Pooja and B. Parameswari)

Characterization and mining genetic variability in sugarcane germplasm against abiotic stress (Salinity/ alkalinity and low temperature) under sub tropical India (Karnal)

Nine 'Co' canes *viz.* Co 98014, Co 0118, Co 0238, Co 05011, Co 06034, Co 09022, Co 12029, Co 15023 and Co 15027 were planted in pots during first fortnight of April, 2019 to screen them under different level of chloride dominated

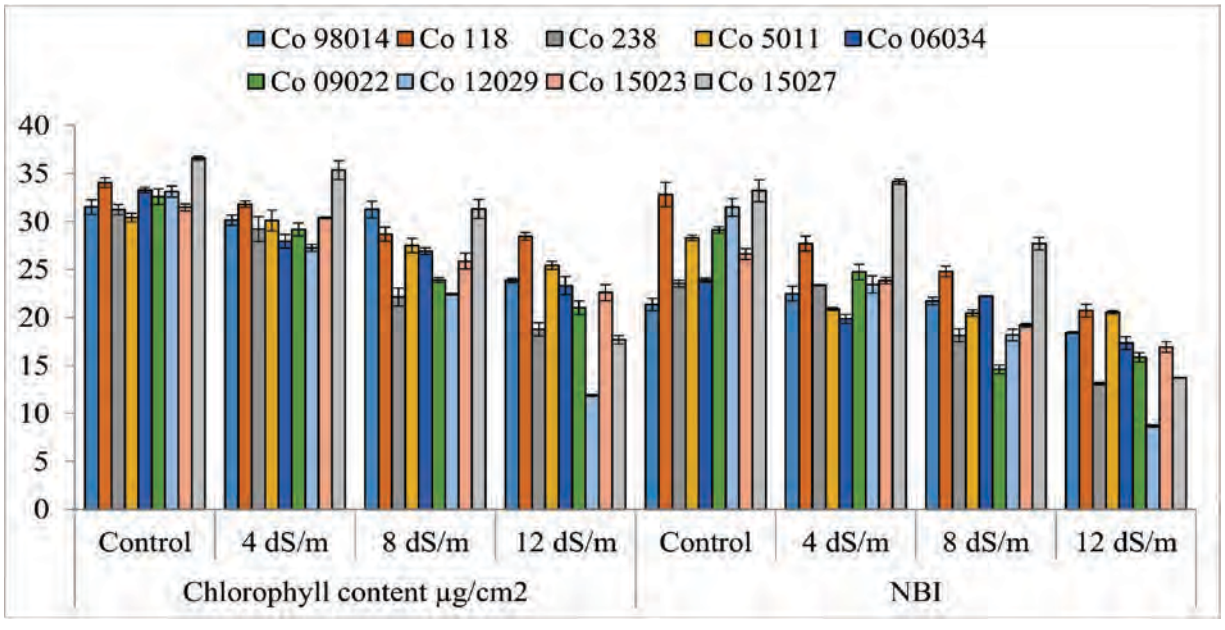


Fig. 95. Effect of diferent salinity treatments on chlorophyll content and nitrogen balance index

salinity levels *i.e.* 4 $dSm^{-1,}$ 8 $dSm^{-1,}$ and 12 dSm^{-1}. After 14 continuous saline irrigation, 'Co' canes Co 98014, Co 0118, Co 15023, Co 0238, Co 05011 and Co 06034 performed better under 4 dSm^{-1} and 8 dSm^{-1} saline treatment. Among nine 'Co' canes, minimum plant height reduction was recorded in Co 0238 (17.96 and 44.32%), Co 0118 (26.82 and 55.48%), Co 09022 (27 and 47%) Co 98014 (25 and 60%) and Co 15023 (28 and 60%) under 4 dSm^{-1} and 8 dSm^{-1} saline treatment with respect to their control at 150 DAP. These clones maintained better chlorophyll content (Fig. 95), nitrogen balance index (NBI) and chlorophyll fluorescence (Fv/Fm ratio) under 4 $dSm^{-1}$and 8 dSm^{-1} saline treatments.

(Ravinder Kumar, M.R. Meena, N. Kulshreshtha, A. Selvi and Pooja)

All India Coordinated Research Project (Sugarcane)

Subtropical zone - Breeding

IVT Early: Experiment consisting of nine test entries and three standards *viz.*, CoJ 64, Co 0238 and Co 05009 was evaluated for cane yield and juice quality traits. Co 0238 (17.61%) was the best standard for sucrose % at 8th month of crop stage. The entries Co 16029 (17.71%), followed by Co 15025 (17.39%) and CoPb 16211 (17.25%) were at par with the best check. The entries Co 15025 (1.42 Kg), followed by CoS 16231 (1.37 Kg) and CoPant 16221 (1.36 Kg) produced significantly heavier single cane weight (SCW) over Co 0238 (1.22 kg), the best standard. Test entries CoPb 16181 (1.33 kg), Co 16029 (1.30 Kg), CoLk 16201 (1.28 Kg), CoPant 16222 (1.17 Kg) and CoPb 16211 (1.11 Kg) had on par performance with Co 0238 for SCW.

AVT Early I Plant: CoJ 64 (17.52%) was the best standard for pol% at 8 months. Test entries Co 15023 (20.43%) and CoLk 15205 (18.15%) were significantly superior with respect to the best check.

AVT Early II Plant: Co 0238 (18.08%) was the best standard for pol% at 8th month. None of the test entry was superior to the best check for this trait. The entry CoPb 14181 (17.83%) and Co 14034 (17.41%) were at par with the best check. Other entries CoPb 14211 and CoLk 14201 were inferior.

AVT Early Ratoon: The experiment was evaluated for various cane yield and juice quality parameters at harvest (9th month of crop stage). Co 0238 was the best standard for SCW (1.32 kg), sucrose content (19.79%), CCS% (13.8), cane yield (108.25 t/ha) and CCS yield (14.94 t/ha). Test entry Co 14034 was on par with Co 0238 for SCW (1.37 kg), sucrose% (20.03%), CCS% (14.15), Cane yield (105.61 t/ha) and CCS yield (14.94 t/ha). CoLk 14201 with 109.52 t/ha was best entry for cane yield but its sucrose content was the least (15.56%) among the test entries.

(N. Kulshreshtha, Ravinder Kumar and M. R. Meena)

Identification of pathotypes / races of red rot pathogen

Twelve red rot isolates comprising seven reference pathotypes and five isolates collected from CoS 8436 (2), Co 89003 (1), CoJ 88 (1) and CoLk 94184 (1) were inoculated independently on a set of 20 sugarcane differentials (Co 975, Co 997, Co 1148, Co 7717, Co 62399, Co 89003, BO 91, Khakai, Co 86002, Co 419, Baragua, CoS 767, CoS 8436, CoJ 64, CoV 92102, CoSe 95422, CoS 86032, CoC 671, Co 7805 and SES 594) by plug method of inoculation. The overall disease reaction indicated that there was a clear pathogenic variation on the different host differentials. The pathogenic reaction on differential hosts shown that designated pathotype CF11 found to be most virulent followed by CF02, CF09, CF01, CF08, CF07 and CF03. Both the isolates from variety CoS 8436 (Cf8436 (Karnal) and Cf8436 (Bihar) caused disease in the differential CoS 8436 with intermediate/susceptible reactions, whereas, isolate Cf89003 collected from variety Co 89003 was too virulent and expressed intermediate to susceptible reactions on 12 host differentials, suggests the possible emergence of new pathotype in the subtropics. Further, isolate Cf 88 (UP) showed susceptibility to nine host differentials whereas, new isolate CfLk 94184 from variety CoLk 94184 (UP) also showed susceptibility to seven host differentials. The host differential SES 594 exhibited complete resistance to all the test isolates (Table 16).

(B. Parameswari)

Table 16. Pathogenic behaviour of *C. falcatum* pathotypes on host differentials

Isolate	Source	Reaction on host differentials																		
		Co 975	Co 997	Co 1148	Co 7717	Co 62399	Co 89003	BO 91	Khakai	Co 86002	Co 419	Baragua	CoS 767	CoS 8436	CoJ 64	CoV 92102	CoSe 95422	CoS 86032	CoC 671	Co 7805	SES 594
CF01	C0 1148	S	S	S	R	S	R	S	R	R	R	R	R	R	R	R	R	R	S	R	R
CF02	Co 7717	R	S	S	S	S	R	S	R	S	R	R	R	R	X	X	R	R	S	X	R
CF03	CoJ 64	R	R	R	R	X	R	R	R	R	R	R	R	R	S	R	R	R	X	R	R
CF07	CoJ 64	R	S	R	R	X	R	S	S	R	R	R	R	R	X	R	R	R	S	R	R
CF08	CoJ 64	R	S	R	S	X	R	R	X	S	R	R	R	R	S	R	R	R	S	X	R
CF09	CoS 767	R	S	S	R	X	R	R	R	S	R	R	S	R	S	R	R	R	S	R	R
CF11	CoJ 64	R	S	S	S	S	R	R	S	R	S	R	S	R	S	R	R	X	S	S	R
Cf8436 (Karnal)	CoS 8436	X	S	R	S	S	R	R	R	R	S	R	R	S	S	R	R	S	S	X	R
Cf8436(Bihar)	CoS 8436	R	X	R	R	S	R	R	R	X	S	R	R	S	R	R	R	R	S	R	R
Cf89003	Co 89003	X	S	R	S	S	S	S	S	X	X	R	R	R	R	X	R	R	S	S	R
Cf88 (UP)	CoJ 88	R	S	R	S	S	S	R	R	R	S	R	R	R	X	R	R	S	S	S	R
CfLk 94184	CoLk 94184	R	R	R	X	S	S	R	S	R	R	R	R	R	R	R	R	S	S	S	R

R-Resistant; X- Intermediate; S- Susceptible

Survey of sugarcane diseases naturally occurring in the area on important sugarcane varieties

Survey for sugarcane diseases was carried out in the reserved area of sugar mills of Haryana (11), Uttar Pardesh (10) and Uttarakhand (one).

Haryana: Pokkah boeng disease was prevailing in most of the cultivated varieties in the state. Maximum (20%) incidence of smut was noticed on variety CoH 160 at Shahabad and mild incidence on varieties Co 0238 and Co 89003 in Sonipat, Palwal, Meham, Jind, Kaithal, Gohana, Rohtak and Panipat area. Traces to severe (20.0%) incidence of wilt was recorded in varieties Co 89003 and CoH 160 in Panipat and Rohtak sugar mills area. Similarly, GSD was reported up to 5% in variety Co 89003 and trace to 2% in varieties *viz.*, CoJ 64, CoJ 85, CoS 8436 and Co 0238. Maxmum incidence of leaf fleck disease caused by SCBV was in variety CoH 160 (up to 10%) followed by Co 89003 (5%) and CoS 8436, CoJ 85, CoJ 88, Co 0238 (trace to 3%). Mild to 5% of brown rust incidence was also noticed in tissue culture plants of variety CoJ 85 at village Makhumajra (Karnal) and on variety CoH 160 at Meham.

Uttar Pradesh: Sugarcane fields of ten sugar mills *viz*. Unn, Maizapur, Mankapur, Balrampur, Kumbhi, Gularia, Faridpur, Bundhki, Afjalgarh and Meerganj of UP state were inspected and recorded traces to severe incidence of red rot in variety Co 0238. Under DSM Sugar, Meerganj incidence of red rot was recorded in varieties CoJ 88 (20-30%) and CoH 167(20.0%). By and large, incidence of Pokkah boeng was recorded in most of the cultivated varieties. Trace incidence of smut and GSD was also noticed in variety Co 0238 under Unn Sugar mill.

Uttarakhand: In the reserved area of Laksar Sugar Mill, trace incidence of smut, GSD, Pokkah boeng and top rot was noticed on variety Co 0238.

(M.L. Chhabra and B. Parameswari)

Evaluation of Zonal varieties for resistance to red rot

Forty entries of IVT along with eight standard varieties were evaluated for red rot resistance by plug and cotton swab methods of inoculation against CF08 and CF09 pathotypes. One IVT(E) entry CoPb 16211 exhibited highly susceptible reaction with CF08 and CF09 pathotypes by both plug and cotton swab methods whereas, entry CoLk 15201 (AVT (E)–I Plant) rated moderately susceptible to both the isolates by plug method. However, remaining entries were found resistant or moderately resistant with both the inocula and methods. Natural incidence of smut was also noticed in the test entries *viz.* CoLk 16201, CoLk 14201, CoPb 14181, CoH 14261, CoLk 14203, CoPb 14184, CoPb 14185 and CoS 14233 (Table 17).

Assessment of elite ISH clones for resistance to red rot: Twenty seven ISH clones were inoculated with CF08 and CF09 pathotypes of red rot by plug method of inoculation for red rot resistance. Twelve clones rated moderately resistant, six moderately susceptible and nine susceptible / highly susceptible to CF08, while ten clones showed moderately resistant, eight moderately susceptible and nine susceptible / highly susceptible reactions to CF09 pathotypes.

(M.L. Chhabra)

Yellow Leaf Disease (YLD)

Natural incidence of yellow leaf disease (YLD) was recorded in 48 entries planted in the zonal varietal trial based on the YLD severity (0-5) scale. Among the different IVT and AVT clones screened, 33 were apparently free from the yellow leaf disease symptoms and probably resistance to the YLD, however further observations are required. The disease severity in rest of the clones (CoS 14233, CoLk 15201, Co 05011 and Co 0238) exhibited moderately resistant (MR) and moderately susceptible reactions (CoPb 14181, CoPb 14211, CoPb 15213, CoS 15232, CoS 15233, CoH 14261, CoLk 14203, CoPb 14184, CoPb 14185, CoS 767). ZVT clone CoLk 14204 (AVT-ML-II) expressed severity scores of more than three and shown susceptible reaction to YLD Table 17).

Evaluation of zonal varieties for their reaction against major insect pests

AVT Ratoon: A total of eleven genotypes along with two check varieties were evaluated against major insect pests namely black bug

Table 17. Evaluation of zonal varieties for red rot and YLD resistance

Entry	Red rot rating				YLD	Other disease
	Plug Method		Cotton swab Method			
	CF08	CF09	CF08	CF09		
IVT (E)						
Co 15025	MR	R	R	R	R	
Co 16029	MR	MR	R	R	R	
CoLk 16201	MR	MR	R	R	R	Smut
CoLk 16202	MR	MR	R	R	R	
Co Pb 16211	HS	HS	S	S	R	
Co Pb 16181	MS	MR	R	R	R	
CoPant 16221	MR	MR	R	R	R	
CoPant 16222	MR	MR	R	R	R	
CoS 16231	MR	MR	R	R	R	
AVT (E)- I Plant						
Co 15023	R	R	R	R	R	
Co 15024	MR	MR	R	R	R	
Co 15027	MR	MR	R	R	R	
CoLk 15201	MS	MS	R	R	MR	
CoLk 15205	MR	MR	R	R	R	
CoPb 15212	MR	MS	R	R	R	
AVT (E)- II Plant						
Co 14034	MR	MR	R	R	R	
CoLk14201	MR	MR	R	R	R	Smut
CoPb 14181	MR	MR	R	R	MS	Smut
CoPb 14211	MR	MR	R	R	MS	
IVT (ML)						
Co 16030	R	R	R	R	R	
CoLk 16203	MR	MR	R	R	R	
CoLk 16204	MR	R	R	R	R	
CoLk 16212	MR	MR	R	R	R	
CoPant 16223	MR	MR	R	R	R	
CoS 16232	MR	R	R	R	R	
CoS 16233	MR	R	R	R	R	
AVT (ML) – I Plant						
Co 15026	R	R	R	R	R	
CoLk 15206	MR	MR	R	R	R	
CoLk 15207	MR	MR	R	R	R	
CoLk 15209	MR	MS	R	R	R	
CoPb 15213	MR	MR	R	R	MS	
CoS 15232	MR	MR	R	R	MS	
CoS 15233	MR	MR	R	R	MS	

Entry	Red rot rating				YLD	Other disease
	Plug Method		Cotton swab Method			
	CF08	CF09	CF08	CF09		
AVT (ML) II plant						
Co 14035	MR	MR	R	R	R	
CoH 14261	MR	MR	R	R	MS	Smut
CoLk 14203	MR	MR	R	R	MS	Smut
CoLk 14204	MR	MR	R	R	S	
CoPb 14184	MR	MR	R	R	MS	Smut
CoPb 14185	MR	MR	R	R	MS	Smut
CoS 14233	MR	MR	R	R	MR	Smut
Standards						
CoJ 64	S	S	S	S	R	
Co 0238	MR	R	R	R	MR	
Co 05009	MR	MR	R	R	R	
CoS 767	MS	MS	R	R	MS	
CoPant 97222	MS	MS	R	R	R	
CoS 8436	MR	MR	R	R	R	
CoPant 84211	MR	MR	R	R	R	
Co 05011	R	MR	R	R	MR	

(B. Parameswari)

(BB), early shoot borer (ESB), top borer (TB) root borer (RB) and stalk borer (SB). Early shoot borer and top borer incidence ranged from 0.0 to 3.8 and 0.0 to 3.9 per cent, respectively. Black bug population varied from 1.2 to 2.3 bugs/leaf. All the 11 genotypes *viz.* Co 14035, CoH 14261, CoS 14233, CoLk 14203, CoLk 14201, CoPb 14181, CoPb 14184, Co 14034, CoPb 14185, CoLk 14204 and CoPb 14211 showed least susceptible (LS) reaction to BB (<25.0 individual/20 leaves), ESB (<15.0%) and top borer (<10.0%). Root borer incidence ranged from 10.9 to 24.6 per cent. Four genotypes, Co 14035, Co 14261, CoS 14233 and CoLk 14201 were least susceptible (<15%) whereas seven genotypes, CoLk 14203, CoPb 14181, CoPb 14184, Co 14034, CoPb 14185, CoLk 14204 and CoPb 14211 were moderately susceptible (15.1 to 30%) to root borer. Stalk borer incidence ranged from 4.6-16.6 per cent and infestation index varied from 0.3 to 1.2. All the test genotypes were also least susceptible (infestation index < 2.0) to stalk borer.

AVT 1st plant: A total of thirteen genotypes along with two check varieties were evaluated against early shoot borer (ESB), top borer (TB). Early shoot borer and top borer, incidence ranged from 0.8 to 3.6 and 0.2 to 2.7 per cent, respectively. All the 13 genotypes (Co 15023, Co 15024, Co 15027, CoLk 15201, CoLk 15205, CoPb 15212, Co 15026, CoLk 15206, CoLk 15207, CoLk 15209, CoPb 15213, CoS 15232 and CoS 15233) showed least susceptible reaction to ESB and top borer.

AVT 2ndPlant: A total of eleven genotypes along with two check varieties were evaluated against early shoot borer (ESB), top borer (TB). Early shoot borer and top borer incidence ranged from 0.3 to 2.1 and 0.2 to 1.9, respectively. All the 11 genotypes (Co 14035, Co 14261, CoS 14233, CoLk 14203, CoLk 14201, CoPb 14181, CoPb 14184, Co 14034, CoPb 14185, CoLk 14204 and CoPb 14211) showed least susceptible reaction to early shoot borer and top borer.

Survey and surveillance of sugarcane insect pests

To identify the key insect pests' of sugarcane under North Western Zone, surveys were carried out under the reserved areas of 12 Co-operative sugar mills of Haryana namely: Shahabad, Karnal, Meham, Sonipat, Palwal, Jind, Kaithal, Asandh Gohana, Rohtak, Panipat and Yamunanagar and three sugar mills of Uttar Pradesh *viz.*, Dhampur, Sheohara, Ramnagar and Laxar sugar mills of Uttarakhand. Early shoot borer, top borer, root borer, stalk borer; pyrilla, black bug and termites were listed as key pests of sugarcane in Haryana. Gurdaspur borer, pink borer and blister mite were identified as minor pests of sugarcane in Haryana, UP and UK. Pyrilla, army worm, grass hopper, white fly, yellow mites, mealy bug and thrips were recorded as occasional pests of sugarcane in the zone. The incidence of whorl weevil, plant hopper and blister mites was 0.0 to 4.0, 0.0 to 2.0 and 0.0 to 2.0 weevils/ whorl; 0.0 to 41.0, 0.0 to 52.00 and 0.0 to 49.0 adults/ nymphs/ whorl and 0.0 to 75.0, 0.0 to 87.0 and 0.0 to 85.0% in Haryana, western Uttar Pradesh and Uttrakhand, respectively. Early shoot borer and pink borer incidences were 0.0 to 13.6, 0.0 to 17.0, and 0.0 to 22.0 per cent in Haryana, western UP and Uttrakhand, respectively. Top borer incidences were 0.0 to 30.0, 0.0 to 46.0 and 0.0 to 51.0 per cent in Haryana, western UP and Uttrakhand, respectively (where farmers have not applied control measures properly). Root borer incidences were 0.0 to 15.0, 0.0 to 22.0 and 0.0 to 27.0 per cent in Haryana, western UP and Uttrakhand, respectively. Stalk borer incidences were 0.0 to 35.0, 0.0 to 45.0 and 0.0 40.0 per cent in Haryana, western UP and Uttrakhand, respectively. Similarly, black bug incidence varied from traces to 9.0, 13.0 and 12.0, individuals/ tillers in Haryana, western UP and Uttrakhand, respectively. White grub incidence varied from 0 to 1, 1 to 2.0 grubs/m^2 and 1 to 2.0 grubs/m^2 mostly in sandy soils in Haryana, western Uttar Pradesh and Uttarakhand, respectively. White grub early shoot borer, top borer, root borer, stalk borer; pyrilla, black bug and termites were identified as key pests in western UP and Uttrakhand.

Monitoring of insect pests and bio agents in sugarcane agro ecosystem.

A non-replicated experiment with sugarcane variety Co 0238 was carried out and monitored the incidences of major insect pests and their bio agents of sugarcane at regular intervals. The cumulative incidence of pink borer right from shoot stage till harvest of the crop was 7.0 per cent. The incidence of early shoot borer and top borer was below ETL (<15.0 and <10%, respectively). Root borer and termite incidences were 16.5 and 16.2%, respectively. The mean population of black bug was 9.0/canes in ratoon and 3.9/canes in plant crop. Stalk borer incidence, intensity and infestation index were 30.4%, 8.5 % and 2.6, respectively. The Pyrilla population was 0.1 individual/20 leaf. Among bio agents, *Epiricania melanoleuca,* identified as an effective parasitoid of pyrilla nymphs and adult's with 35.0 per cent parasitisation. *Tetrasticus pyrillae,* an egg parasitoid of pyrilla, parasitized 1.3 per cent egg masses. *Isotima javensis* and *Stenobracon deesae* parasitisation of top borer larvae were 1.3 and 1.9 per cent respectively. *Cotesia flavipes* a larval cum pre pupal parasitoid of stalk borer parasitized 1.2% stalk borer larvae during the month of October.

(S.K. Pandey)

Genotypic behavior of sugarcane under moisture stress in subtropical India

Evaluation of plant crop of 'Co' clones under moisture stress conditions: An experiment was conducted to study the effect of drought stress in plant crop of ten 'Co' canes namely Co 98014, Co 0118, Co 0124, Co 0238, Co 05011, Co 07023, Co 11027, Co 12029, Co 15023 and Co 15027 during crop season of 2019-20. Drought stress was imposed during formative phase of the crop by withholding irrigation. Physiological, morphological and quality parameters were recorded in normal irrigated and drought stress treatments. Data were analyzed with factorial RBD. 'Co' canes, Co 98014, Co 15023, Co 07023, Co 0238, Co 05011 and Co 12029 performed better in drought stress and showed less reduction in photosynthetic rate, stomatal conductance, chlorophyll florescence, SPAD values as compared to normal irrigated clones. Under control conditions, maximum

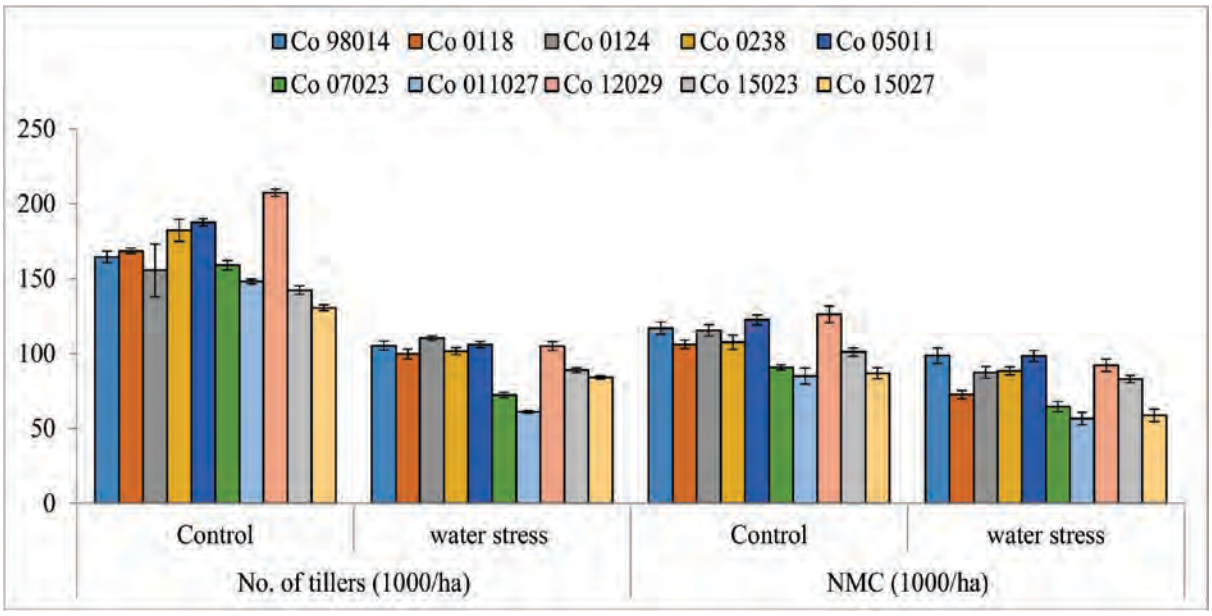


Fig. 96. Performance of clones for tillers and NMC under normal and drought stress

SPAD values for chlorophyll content were recorded in Co 15027 (46.30) followed by Co 0238 (46.10) whereas under drought, highest SPAD values were recorded in Co 0238 (40.24). Average reduction percent in SPAD values under drought was 25.5% as compared to normal irrigated condition. Average photosynthetic rate, stomatal conductance and transpiration rate was 28.40 µmol CO_2 m^{-2} s^{-1} , 6.58 mmol H_2O m^{-2} and 0.383 mmol H_2O m^{-2} s^{-1} respectively, in normal irrigated condition and reduced up to 9.75 µmol Co_2 m^{-2} s^{-1} , 0.101 mmol H_2O m^{-2} s^{-1} and 3.03 m mol H_2O m^{-2} s^{-1} respectively, under drought. Chlorophyll fluorescence reduced from 0.632 to 0.482 (Fv/Fm ratio) and minimum reduction was recorded in Co 98014, Co 15023, Co 07023, Co 0238 and Co 05011 while maximum reduction was recorded in Co 0124, Co 15027 and Co 11027. Among ten Co-canes, Co 98014, Co 0238, Co 05011, Co 0124, Co 12029 Co 15023 produced significantly higher number of tillers (000/ha) and NMC (000/ha) and showed less reduction under drought stress treatment as compared to their respective control (Fig. 96). Under juice quality parameters overall experimental average of pol% was 16.29% at 8th month and no significant difference was recorded in normal irrigated and drought stress treatments. Co 15023 (18.96), Co 0118 (17.49), Co 0238 (17.31) produced significantly higher sucrose over the experimental average.

(Pooja, N. Kulshreshtha and Ravinder Kumar)

Identification, characterization and verification of new sugarcane varieties for DUS testing

Maintenance of reference collection of sugarcane varieties: A total of 167 sub-tropical sugarcane reference varieties were field maintained under disease free condition in two row plots at ICAR-SBI-RC, Karnal. (Co-Nodal centre for testing of sub-tropical sugarcane varieties). The plot size per reference variety was 6 m length x 0.9 m row to row spacing x 2 rows per variety. Verification of DUS descriptors of reference varieties were taken as part of DUS characterization of the reference varieties. The following category DUS reference varieties being maintained at ICAR-SBIRC, Karnal are listed below: BO series-17 varieties; CoP series-7; CoB series-1; CoBln series 8; CoH series 12; CoJ series 5; CoPb series 4; CoLk series 9; CoPant series 9; CoS series 50; CoSe series 14; CoPk 1; UP series 6 varieties, 'Co' varieties 24.

Re-characterization of Reference Varieties: A total of 126 Reference varieties maintained at ICAR-SBIRC, Karnal were further verified /re-characterized whereas, 41 reference varieties received from IISR, Lucknow are being characterized for twenty seven DUS descriptor traits during 2019-20 and the database of all the verified DUS reference varieties will be submitted to the PPVFR Authority.

Cane yield and quality traits: The experiment consisting 167 entries was evaluated cane yield and quality traits in augmented block design. Observation on tillers population at 120 DAP and NMC population at 240 DAP were recorded. The average tillers and NMC recorded form the trial was 1.16 lakh/ha, 0.89 lakh/ha respectively. Top raking clones for tillers population were; CoS 08572 (2.13 lakh/ha), CoS 95222 (2.0 lakh/ha), CoPant 97222 (1.53 lakh/ha), CoS 767 (1.35 lakh/ha), CoPant 84211 (1.26 lakh/ha), CoS 97258 (1.24 lakh/ha), Co 0238 (1.16 lakh/ha) whereas, top ranking clones NMC population were; CoPant 97222 (1.37 lakh/ha), CoS 767 (1.35 lakh/ha), CoPant 84211 (1.26 lakh/ha), Co 0238 (1.16 lakh/ha). The juice analysis was performed at 8th month crop stage and the mean pol% in juice recorded was 16.99%. Top raking clones for pol% in juice were; Co 0118 (20.13%), Co 89003 (20.09%), Co 0237 (19.75%), Co 0238 (19.46%), CoJ 88 (19.42%) and CoJ 64 (18.52%). Fourteen clones have showed more than 18.5% pol% in juice at 8th month crop stage.

Farmer's varieties for DUS testing: The seed material of one farmer's variety Pursa was received from PPV&FR authority. Single bud setts were planted into pro-tray to check the germination and mean germination percentage recorded was 48%. Settlings of this variety were transplanted into field in 4 row plots (6m L x 0.9 m row spacing x 20 plants/row. The DUS descriptors are being verified during this year trial.

(M.R. Meena, Ravinder Kumar and N. Kulshreshtha)

ICAR Seed project–Seed production in agricultural crops and fisheries– sugarcane

Breeder seed production: The breeder seed crop was well maintained in nine acres of area in the centre. Variety Co 0238 planted through tissue culture generated material. A total of 1084.51 quintals of breeder seed was sold from on farm and 1098.15 quintals from seed farmers attached with centers Farmers Participatory Seed Production (FPSP) programme during autumn season to the various stakeholders of the country.

Transplanting autumn seed crop: A total of 32,000 settlings were raised at ICAR-SBI Regional Centre, Karnal and field transplanted in 4.5 acres using settling transplanter.

Production and sale of settlings to the stakeholders: A total of 20,630 settlings of varieties Co 0118, Co 0238 and Co 12029 were produced and sold to the various stakeholders.

Promotion of quality seed production technologies: For the promotion of quality seed production activities, setttling transplanting using tractor drawn two row settling planter was demonstrated to the farmers and sugar mill personnel. Training on Settling Transplanting Techniques were organized for Saraswati Sugar Mill, Yamunanagar, Haryana, Balrampur Sugar Mill Group UP, DCM Shiram Sugar unit Ajbapur, UP, Karnal Cooperative Sugar Mill, Karnal, Haryana. The licencing rights of Quatro Sugarcane Single Sett Cutter (QSSSC) machine was given to M/s Hanzra Engg Works, Karnal and 20 units were supplied by him to various sugar factories.

(Ravinder Kumar)

Healthy seed production and mechanization of sugarcane agriculture -A farmers participatory initiative

A total of 10,000 quintals of healthy seed of sugarcane varieties Co 0238 and Co 0118 was produced under participatory mode at farmers field and the visiting farmers and sugar mills of Haryana were advised for purchasing the healthy seed from these farmers field. A total of 3, 00,000 settlings were raised at farmers field for the planting of 40-42 acres of healthy seed. A total of 25000 settlings were raised at ICAR-SBI regional centre, Karnal and field transplanted in 4.25 acres. Variety Co 0238 was replaced with 100% tissue culture virus indexed material at the Centre. The farmers of the Haryana state were promoted to adopt wider spaced planting along with intercropping during autumn season.. A total of 282.76 quintals of high quality breeder seed of varieties Co 0118 (119.31 quintals), Co 0238 (20.75 quintals) and Co 12029 (142.7) quintals was supplied to the various sugarcane farmers and cooperative sugar mills of Haryana state.

(Ravinder Kumar, N. Kulshreshtha, M.R. Meena, M.L. Chhabra, S.K. Pandey, B. Parameswari and Pooja)

Sugarcane breeder seed production and demonstration of intercropping (NFSM)

Nearly 8500 quintals of Breeder seed was produced in 10 ha area. A total of 768.3 quintals of nucleus seed of varieties Co 98014, Co 0118, Co 0238, Co 0124, Co 05011, Co 0237, Co 06034, Co 09022 and Co 12029 were supplied to the farmers. The farmers were promoted for intercropping in sugarcane

(N. Kulshreshtha, Ravinder Kumar and M.R. Meena)

Physiological approaches for winter ratooning management in sugarcane under subtropical conditions (RKVY, Haryana)

Evaluation of effect of exogenous application of ethrel, calcium chloride and lime on winter ratooning in sugarcane: Two budded setts of three sugarcane varieties *i.e.* Co 0118, Co 0238 and Co 05011 were planted during spring season in 2018. Canes in each row were cut at ground level during second fortnight of December, 2018. Different doses of Ethrel (50, 100, 200, 400 ppm), calcium chloride (1000 and 2000 ppm) and lime (0.2%) were applied as foliar spray in sugarcane stubbles on same day. Data were recorded for winter sprouting and analyzed with factorial RBD. Among all the treatments, 100 ppm ethrel was found best treatment. Second year experiment is being repeated during 2019-2020 season. Different doses of ethrel (50, 100, 200, 400 ppm), calcium chloride (1000 and 2000 ppm) and lime (0.2%) were applied as foliar spray in sugarcane stubbles during second fortnight of December, 2019.

(Pooja, N. Kulshreshtha and Ravinder Kumar)

A whole genome based reduced representation approach for identification of resistance against *Sugarcane yellow leaf virus* in Indian sugarcane

To study the yellow leaf disease (YLD) resistance based on genome wide association approach, parental clones were screened at NHG during the last two years (2018 and 2019) using 0-5 YLD rating scale and categorized as R (0.0-1), MR (1.1-2), MS (2.1-3), S (3.1-4) and HS (4.1-5). Among the screened clones, 81% and 76.33% entries were identified as resistance; 5.6% and 2% entries were identified as susceptible to highly susceptible, respectively. Totally, 200 YLD free samples in R category and 143 samples under the MS, S and HS category representing all the major sugarcane growing places of India were collected and total RNA and DNA were isolated following the standard protocols for genome wide association study (GWAS). For RT-PCR and real time PCR assay, coat protein (CP) nucleotide sequences of *sugarcane yellow leaf virus* available from National Centre for Biotechnology Information (NCBI) were collected and aligned using different bioinformatics tools. The most conserved regions identified through multiple sequence alignment tools were selected for designing the real time primers using fast PCRsoftware. Two sets of real time primers *viz.* q-SCYLV-FP 5″-ATGGATACGGGCGCT A A C C G C T C A C - 3 ′) , q - S C Y L V - R P (5″- CCGGTTGAGTTGG CCTTGAGATCG-3′) and qYLSRT-FP (5″-GGACCGAACC TATCTCAGTAC-3′), and qYLSRT-REV (5″-TAGTAATCTTGGAGCCTGTTGTTG-3′) were designed from the entire coat protein region of SCYLV to amplify the different sites. Amplification conditionsfor both the primers were standardized through gradient PCR assay. Thep q-SCYLC-FP and q-SCYLV RP were chosen for the further work as the amplified products were very clear. RT-PCR assays using the SCYLV-CP gene specific primers were performed for all the samples, in that all the susceptible samples had shown the expected positive amplification of 615 bp whereas 99 of 200 apparently resistant samples including *S. spontaneum*, *S. barberi* and *Erianthus* sp. were negative to the SCYLV. Quantitative real time PCR analysis was also carried out. Further, through single nucleotide polymorphism (SNP) based genotyping of resistant and susceptible DNA samples through 40K sugarcane axiom array, the true YLD resistance parents will be identified and can be effectively utilized in the future breeding programmes to develop resistant varieties to sustain the sugarcane productivity.

(B. Parameswari)

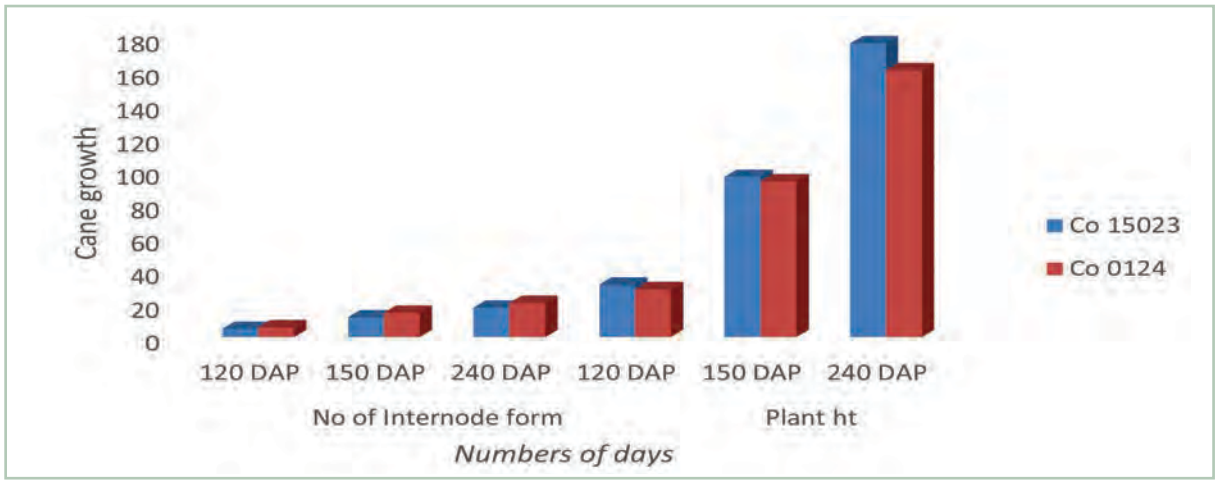


Fig. 97. Growth pattern in Co 15023 and Co 0124 at different crop intervals

Unraveling the molecular mechanism of early maturing responsive genes in sugarcane through transcriptome analysis

The experiment consisting of Co 15023 (early maturing clone) and Co 0124 (midlate maturing variety) was evaluated for early growth parameter and cane quality at different crop intervals. Data on morphological, physiological and other parameters such as plant height, numbers of internode formation, leaf area, tillers and NMC population recorded. The tillers population at 120 DAP in Co 15023 and Co 0124 recorded was 1.27 lakh/ha, 1.32 lakh/ha respectively. NMC population at 240 DAP in Co 15023 and Co 0124 recorded was 0.98 lakh/ha and 1.05 lakh/ha respectively. Cane height and numbers of internode formation at different crop intervals of 120 dap, 150 DAP and 240 DAP were recorded (Fig. 97). The crop growth rate was estimated by following formula of Watson (1952) and workout in gm per m^2day^{-1}.The crop growth ratein early clone Co 15023 was (48.42 gm m^2 day^{-1}) almost 10 unit higher than midlate variety Co 0124 (38.16gm m^2 day^{-1}). Leaf area was recorded by Li-cor leaf area meter and LAI estimatedper unit area. At initial crop stage during 120 DAP Co 15023 had higher LAI (>3) compared to Co 0124 (LAI <3). However, at 150 days after planting, Co 15023 had slight lower leaf area index compared to Co 0124(LAI>3.5) and at 240 DAP variety Co 0124 had significantly higher leaf area index which might be due to high translocation of photo -assimilate into sink in clone Co 15023 compared to Co 0124. HR brix value in Co 15023 at 7th month and 8th month was 17.4 % and 21.77% respectively, whereas it was 13.4% and 17.40% in Co 0124 at 7th month and 8th month respectively. The juice analysis was carried out at 8th month crop stage and Co 15023 had 20.98 % pol in juice with 92.5 % purity whereas Co 0124 had 17.65 % pol in juice with 91.27 purity. Cane height, single cane weight in Co 15023 and Co 0124 recorded were 258 cm, 181.6 cm and 1.30 kg and 1.06 kg respectively (Fig. 97).

(M.R. Meena)

5.7 ICAR-SUGARCANE BREEDING INSTITUTE, RESEARCH CENTRE, KANNUR

Breeding superior sugarcane varieties of different maturity with improved cane yield, quality and resistance to biotic and abiotic stresses

Breeding varieties resistant to waterlogging

A final clonal evaluation was conducted with eleven clones in replication and three check varieties. Yield and quality traits recorded to select the best performing clone. The germination count of the clones at 30th day ranged from 35-52, on 90th day tillering was in the range of 39-72 and NMC in the range of 31-56, respectively. The clone WL 15-806 had the highest tiller count and NMC, while the clone WL -15-953 had highest germination count among the test clones. The cane thickness of the clones varied from 2.5-3.0 cm, the clone WL-15-806 with highest tiller

count and NMC had the lowest cane thickness. The cane length ranged from 184 cm to 247 cm. Among 14 clones 12 clones recorded cane length above 200cm and two clones were below 200 cm height. The cane length of the test clones showed poor performance in comparison to the check varieties. WL-15-806 was the longest of the test clones and the single cane weight varied from 0.89 to 1.56 kg. Similar to cane length test clones showed poor performance for single cane weight compared to the check varieties. Seven clones had single cane weight above 1kg. WL15-1463 recorded maximum SCW (1.46 kg) highest among the test clones. All the clones except WL 15-1403 and variety Co 62175 recorded > 20% HR brix. Clones WL15-808 and WL15-1179 at 8th month recorded an HR brix of 23.7% and 23.5% respectively. The brix% at 10th month ranged from 16.39 to 22.38 %. The clone WL -15-808 recorded the maximum brix % of 22.38 at 10th month. The clones WL-15-787, WL 15-806, WL15-808, WL15-1002, WL15-1177, WL15-1179 and WL15-1463 along with the standard variety Co 99006 recorded more than 20% brix at 10th month. The clones had better brix% at 8th and 10th month compared to the standard varieties in the trial. The sucrose content at 10th month ranged from 13.09 to 20.66 %. The lowest sucrose content was recorded in the variety Co 62175 and highest was for the clone WL 15-808. The clones WL15-787, WL15-806, WL15-808, WL15-1177, WL15-1179 and WL15-1463 can be genetic stocks for better sucrose content. The yield per plot ranged from 33.7 to 64.3kg. The CCS yield per plot ranged from 4.2 to 8.5. The clone WL 15-1463 recorded the higher CCS yield per plot compared to the check Co 99006. The clones WL15-787, WL-15-806 and WL 15-1177 recorded significantly higher CCS yield per plot compared to the standard variety Co 86032. Four clones *viz*., WL 15-787, WL15-806, WL 15-1177 and WL 15-1463 were selected for PZVT.

In the second clonal trial with 24 test clones and three check varieties, NMC ranged from 8.7 to 31, cane thickness from 2 to 3.1cm and SCW from 0.5 to1.4 kg. The clones WL 16-469, WL16-469, WL 16-271 and WL16-785 were the best clones for NMC, cane thickness and SCW, respectively. The clones performed better for brix and sucrose % at 10th month compared to the standard check varieties. The clones WL16-469, WL16-271 and WL16-475 had significantly higher CCS yield compared to the best check.

In the first clonal trial, 137 clones and three check varieties evaluated in single replication and germination, tillering at 90th day, NMC, cane thickness and HR Brix at 8th month were recorded. The NMC of the clones ranged from 1-49. The clone WL 17-755 (WL 15-1179 X WL 13-456) recorded the highest NMC. The cane thickness of the clone WL17-789 (WL 15-1179 X WL 13-456) (3.6 cm) was highest among the clones and the lowest value of 1.6 cm for the clone WL 17-1080 (WL 13-368 x WL 10-20). HR brix at 8th month of the clone ranged from 14.7-25.6. The highest brix was recorded for the clone WL 17-641(WL13-33 x WL 10-40).

Three hundred and nineteen progenies of six intra specific crosses evaluated in ground nursery for NMC, cane thickness and HR brix at 7th month. The NMC ranged from 1-19, thickness from 1.3-3.3 and Brix from 12-24.4. The highest NMC was recorded in the clone WL-18-858 (Co 99006 x WL10-85), thickness for the clone WL-18-689 (WL 15-1177 X Co 09008) and brix for clone WL 18-562 (WL15-1177 X Co 09008). Sixteen intra specific crosses made to develop clones resistant to water logging. The parents used were foreign hybrids, 'Co' canes and 'WL' clones.

Physiological evaluation of sugarcane clones for waterlogging tolerance: In trial I, the morphological and physiological traits were recorded in seven month old sugarcane crop including plant height, leaf area, chlorophyll index (SPAD), NMC/sqm, number of internodes, internode length and internode thickness were recorded in the eleven entries of WL15 series along with three standards (Co 86032, Co 99006, Co 62175) in three replications subjected to natural waterlogged conditions. Plant height was maximum (224.0 cm) in Co 99006 and minimum (190.0 cm) in WL 15-1403, with a mean of 206.8 cm. Maximum leaf area was recorded in WL 15-1177 (3.65 m^2). Chlorophyll index measured as SPAD was significantly different among the entries, with highest (38.7) in Co 99006 and lowest (21.2) in WL 15-1403, with a mean of 32.6. Number of millable canes per 0.5 m^2 varied from 5 (WL 15-1013) to 8 (Co 62175). Number of internodes

varied significantly among the clones, with Co 62175 recording the maximum (14). Similar trend was observed for internode length, which was highest in WL 15-808 (15.2 cm) followed by WL 15-1177 (14.8 cm), while WL 15-806 recorded the least (11.0 cm) internode length. Internode or cane thickness being one of the traits important for juice yield varied significantly among the entries. WL 15-1177 recorded maximum (3.2 cm) internode thickness, while least (2.4 cm) was noted in WL 15-761.

In II, the morphological and physiological traits were recorded in 7-month old sugarcane crop including plant height, leaf area, chlorophyll index (SPAD), number of millable canes per square meter, number of internodes, internode length and internode thickness were recorded in the 36 entries of WL 16 series and three standards (Co 86032, Co 99006, Co 62175) with two replications subjected to natural waterlogged conditions.

Out of the 13 clones sent to Balrampur Chini Mills, UP for evaluation, 12 were evaluated in two separate replicated trials and the data showed that in the first trial three clones (WL 10-37, WL 06-182, WL 10-102) were numerically superior for CCS yield over the 'Co' canes tested (Co 06030, Co 10026) and in the second trial WL 10-118, WL 10-40 and WL 06-85 were promising for CCS yield and numerically superior to Co 99006.

(M. Nisha K. Chandran and V. Krishnapriya)

Enhancement of sugarcane germplasm and development of pre-breeding material

Utilisation of germplasm resources for developing new genetic stocks

A final clonal trial was conducted with ten progenies of interspecific back crosses. The clone GUK 15-34 showed significantly higher cane yield and CCS than the check varieties and GUK 15-390 showed significantly higher cane yield but CCS yield was only numerically higher and GUK 15-558 had significantly higher cane yield. GUK 15-394 and GUK 15-390 were identified as genetic stock and selected for PZVT trial.

In the second clonal trial, 16 clones of back cross progenies from inter specific crosses and selfs of exotic hybrids were evaluated and three clones GUK 16-933, GUK 16-975, GUK 16-967 were found promising for CCS yield. Eleven clones were advanced to final clonal trial.

Forty-five clones were evaluated in un replicated clonal trial. Based on NMC, cane thickness and HR brix 20 clones were advanced to 2nd clonal trial. 540 seedlings from 9 interspecific/ back crosses were evaluated in ground nursery. Progenies of the cross GUK 15-398 x Co 1148 had higher number of clones with high brix, high tillers and cane thickness. Fifty-four clones were selected for further testing. Twenty two BC_1/ BC_2 crosses involving *S. robustum* were attempted.

Three clones *viz*., GUK 14-129, GUK 14-722 and GUK 14-732 which were found to be free of internode borer (INB) incidence from the clonal evaluation trial of 2017 and 2018 were taken for further field level evaluation. It was noticed that clone GUK 14-732 was found free from INB incidence in the field level, whereas other two clones namely GUK 14-722 and GUK 14 had INB infestation percentage of 9.09% and 4.76% on cane basis recorded, respectively.

(K. Chandran, M. Nisha and B. Mahendran)

Maintenance of world collection of sugarcane germplasm

Maintenance and evaluation of germplasm

Maintenance: The world collection of sugarcane germplasm is maintained in field gene bank by annual re-planting. The flowering per cent among the clones were found to be low compared to previous years and it ranged from 4.3% (*S. officinarum*) to 32% (Indian hybrids) with an average of 23.1%.

Preliminary screening of germplasm: There was unprecedented waterlogging due to heavy and continuous rain during July-August at Kannur center and the germplasm clones were exposed to prolonged waterlogging condition. The Species clones comprising 753 *S. officinarum*, 30 *S. sinense*, 145 *S. robustum*, 42 *S. barberi* were evaluated in this natural waterlogged condition to obtain a preliminary data on the tolerance to waterlogging situation. Three cane characteristics *viz*., cane length, internode length and cane thickness during pre and

post waterlogging condition were observed. Based on the number of dried leaves 1-5 scale of waterlogging index was given to the clone where Scale 1 indicates less than 10 % dried leaves, Scale 2 indicates 10 to 25 % dried leaves, Scale 3 indicates 25 to 50% dried leaves, scale 4 indicates 50 to 75% dried leaves and scale 5 indicates more than 75% leaf drying.

Saccharum officinarum: The pre monsoon number of nodes ranged from 4.5 to 25 with a mean of 12 nodes per clone. The post monsoon node number varied from 3.5 to 40 with a mean value of 10 nodes per clone. The clones 21 NG 1 and NS 19 recorded highest pre monsoon number of nodes and post monsoon node number, respectively. Around 8% of the clones did not show any difference in post and pre monsoon node number, 29 % showed more number of nodes after the waterlogged condition and 63% showed reduction in the number of nodes after waterlogged condition. The mean pre monsoon internode length was 9.5 cm and post monsoon internode length was 5.6 cm. Ninety percentage clones showed reduction of internode length after the waterlogging condition. Similarly 93 % of the clones showed reduction in cane thickness after waterlogged condition. Significant difference existed between mean plant height, number of nodes, internode length and cane thickness before and after the monsoon. Rating of clones based on the percentage leave drying showed that 15 (2%) clones recorded the more than 75% leaf drying and 36 (5%) clones had less than 10% leaf drying. Fourty four percent clones showed 25 to 50% leaf drying.

Saccharum robustum: The mean premonsoon number of nodes varied from 6 to 21 with an average of 11.9 and the post monsoon number of nodes from 3 to 19 with an average of 9.4. Average pre monsoon internode length was 13 cm and post monsoon internode length was 9.3 cm. The premonsoon and post monsoon average internode length was 1.3. Significant difference was observed between mean plant height and number of nodes before and after the monsoon whereas the mean internode length and cane thickness before and after the monsoon did not show any significant difference. Around 21 %, 18% and 26% of the clones showed increased number of internode, internode length and cane thickness respectively after the waterlogging stress. Rating of clones based on the percentage leaf drying showed that none of clones recorded the more than 75% leaf drying and 21 (14%) clones had less than 10% leaf drying. Fourty six percent clones showed 10 to 25% leaf drying.

Saccharum sinense: Average pre monsoon number of nodes was 14.5 and post monsoon number of nodes was 13.2. The mean pre and post monsoon number of nodes did not have any significance difference. The mean pre and post monsoon plant height, internode length and cane thickness showed significant difference. Only 33 % of the clones showed increased node number after the waterlogging stress whereas none of the clones showed improved internode length and cane thickness after the waterlogging stress. Rating of clones based on the percentage leaf drying showed that none of clones recorded the more than 75% leaf drying and 2 (5%) clones had less than 10% leaf drying. Sixty per cent of clones showed 25 to 50% leaf drying.

Saccharum barberi: Average pre monsoon number of nodes was 13.8 and post monsoon number of nodes was 13.0. The mean pre and post monsoon number of nodes did not show any significance difference. The mean pre and post monsoon plant height, internode length and cane thickness showed significant difference. Only 46 % of the clones showed increased node number after the waterlogging stress whereas none of the clones showed improved internode length and cane thickness after the waterlogging stress. Rating of clones based on the percentage leaf drying showed that 63% clones recorded the 50- 75% leaf drying and 37 % clones had 25-50% leaf drying.

Documentation: Three digital catalogues of *Saccharum* species clones *viz.*, 1. *S. robustum*, 2. *S. sinense*, 3. *S. barberi* were brought out.

(K. Chandran, M. Nisha and V. Krishnapriya)

Monitoring of diseases and quarantine

Diseases recorded were leaf spot, rust and leaf blight *etc*. Leaf spot was noticed in almost all the germplasm clones. The incidence was very less in pink leaved clones of *S. officinarum*, while *S.*

robustum clone (Mol 4503, 4861, 5099, 5698, NG 77-3, NG 77-21, NG 77-23, NG 77-24, NG 77-32, NG 77-34, NG 77-35, NG 77-38, NG 77-39, NG 77-73, NG 77-75, NG 77-76, and NG 77-122) were found free from leaf spot incidence throughout the year. For the first time leaf blight (Fig. 98) caused by *Rhizoctonia solani* was observed in NG 77-145 of *S. robustum*, Agoul, Baroukha, Chin and Dark Pindaria of *S. barberi* and IS 76-168 of *S. officinarum*. Rust appeared in September and it was noticed in IND 81-20, IND 81-74, IND 81-82, and IND 81-83 clones of *S. spontaneum* and 26 clones of Indian hybrids. The incidence was maximum in Co 376, Co 377, Co 699, Co 62161 and CoS 568.

(R. Gopi)

Monitoring for pest incidence, biological control of the pests

Sugarcane germplasm maintained at SBIRC, Kannur was monitored for occurrence of insects and their natural enemies. Insect pests *viz*., Internode borer (INB) *Chilo sacchariphagus indicus,* Pink borer *Sesamia inferens*; *Pyrilla perpusilla* and leaf mites were found to be occurring at various ranges. In addition to that, sporadic infestation of mealy bugs, scale insects, and sugarcane aphid, *Melanaphis sacchari* were noticed. A light trap was also kept in the field in order to monitor *Pyrilla* and other light attracted insect pests and daily observation has been done. INB incidence was noticed less than 5% of the accessions across all crop assemblages with percent infestation ranging from 0-28% on cane basis. In respect to symptoms of INB, mostly bore hole in top most internodes with dead heart and side shoots were observed. Pink borer incidence was recorded to be 0-8% across all accessions based on dead heart symptom. The soil based application of insecticide Fipronil 0.3% GR was undertaken at the time of sett planting for the management of pink borer in *S. officinarum,* hybrids of Indian and Foreign origin. *Pyrilla* population was effectively suppressed by natural epizootics of entomopathogenic fungi, *Hirsutella sp.* and *Metarhizium anisopliae* along with other natural enemies viz., egg parasitoid, *Parachrysocharis javensis* and nymphal parasitoid, *Dryinus pyrillae.*

Fig. 98. Leaf blight in Agoul of S. barberi

(B. Mahendran)

In vitro conservation of germplasm

Saccharum officinarum (115) and Indian hybrids (12) clones having poor crop stand in the field are multiplied *in vitro* through meristem culture and maintained through sub culturing.

(K. Chandran and M. Nisha)

DNA fingerprinting

Molecular profiling of 30 *S. sinense* clones were carried out using eight selected SSR primers available in the public domain. Six primers were genomic sequence based and two were EST sequence based primers. The level of polymorphism varied from low to high. The eight primers produced a total of 31 amplified products with an average of 4 amplified products per primer. The maximum number of five fragments was produced by the primer NKS 50 and SEGM 291; both are genomic DNA based primers. The polymorphism information content (PIC) value of the primers ranged from 17% to 56%. The primer mSSCIR9 had the highest PIC value and the lowest for the primer SCC08. The resolving power (RP) of the primers ranged from 0.4 to 1.2. The primer mSSCIR 9 had the highest RP value and the primers SCC09 and UGSM446 recorded lowest RP value. The similarity coefficient ranged from 35 % to 100%. The clone tekcha chung tseng showed the least similarity with the other 29 clones. The clones agaul, bamboo lalkhadi and uba white produced similar amplified products with all the primers used; tekcha and uba reunion were 100 % similar.

Molecular profiles were developed for 42 *S. barberi* clones using nine SSR primers available in the public domain. Of the total nine primers, seven are genomic sequence based and two are EST sequence based. The nine primers produced

a total of 43 amplified products with an average of 5 amplified products per primer. The maximum number of eight fragments were produced by the primer mSSCIR9, a genomic DNA based primers. The PIC value of the primers ranged from 7% to 59%. The primer mSSCIR had the highest PIC value and the lowest for the primer NKS50. The resolving power of the primers ranged from 0.9 to 6.9. The primer mSSCIR 9 had the highest RP value and the primers NKS49 and SOMS156 recorded lowest RP value. The pair wise similarity was calculated based on the jaccards similarity coefficients and the clustering was done using NYSYS PC 2 software.

(M. Nisha and K. Chandran)

Harnessing antagonistic microbes for the management of wilt and rot diseases in sugarcane

Isolates of bacteria from the sugarcane rhizosphere were studied for *in-vitro* efficacy against wilt (*Fusarium sacchari*) and sett rot (*Ceratocystis paradoxa*) pathogens. In the dual culture study, the bacterial isolate PF 4 and PF 59 was most effective and recorded 54.54% inhibition over control (Fig. 99, followed by PF 60 (46.96%), PF 100 (46.75%) and PF 101 (46.75%) and recorded maximum inhibition for *F. sacchari*. The bacterial isolate BC 29 was most effective with 52% inhibition followed by PF 4 (44.11%) for sett rot pathogen *C. paradoxa.*

(R. Gopi and K. Nithya)

Evaluation of seasonal dynamics and biological control of sugarcane pyrilla, *Pyrilla perpusilla* in crop island scenario

Seasonal incidence of Pyrilla *and its natural enemies:* Observations recorded on population dynamics of pyrilla and its natural enemies on sugarcane germplasm across different crop assemblages from June to December 2019. Pyrilla population abundance, comprising nymphs and adults showed a resource concentration pattern with most abundant on *S. officinarum* and hybrids of Indian and foreign origin that are in high density crop patches, and least abundant on other crop assemblages *viz., S. robustum*; *S. sinense* and *S. barberi* that are in low density patches in the ecosystem. *P. perpusilla* has shown less host preference towards other wild sugarcane, *S. spontaneum* and sugarcane allied generas. The peak population of pyrilla was recorded in the month of July followed by gradual decrease in the population during the month of August-October and then population became negligible from November onwards.

The activity of egg parasitoid, *Parachrysocharis javensis* was noticed throughout cropping season

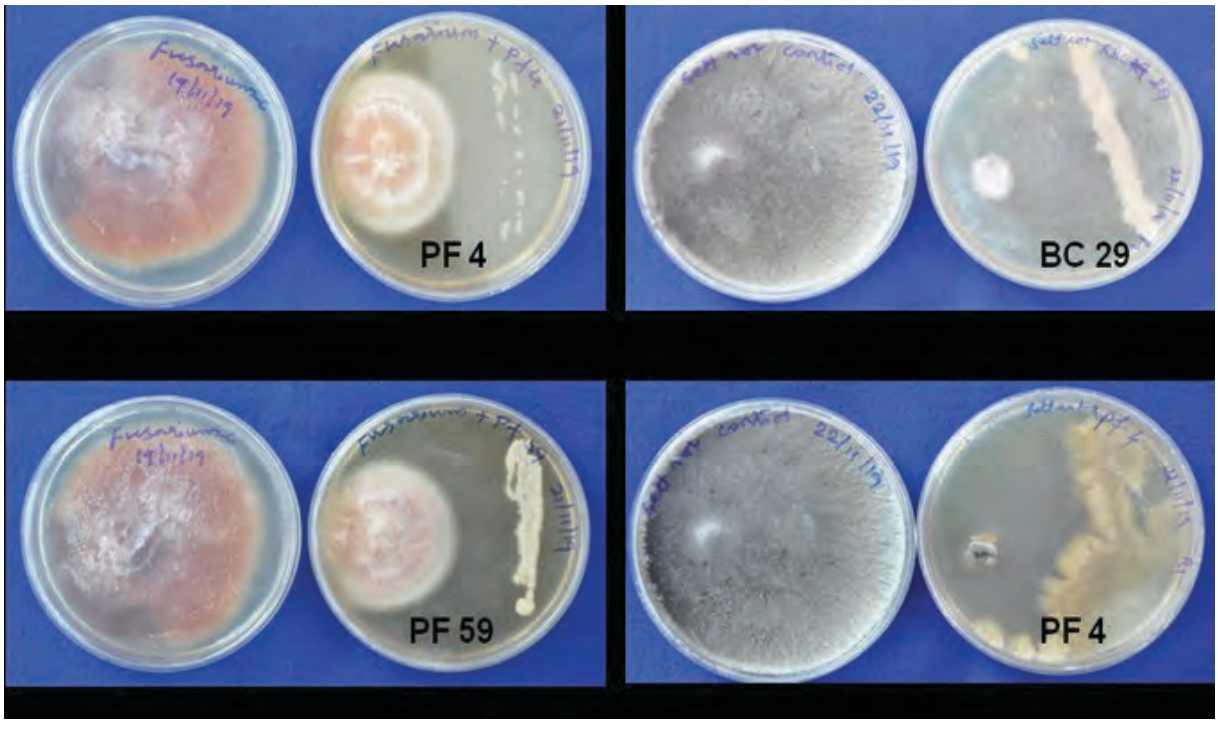


Fig. 99. Efficacy of bacterial isolates against wilt

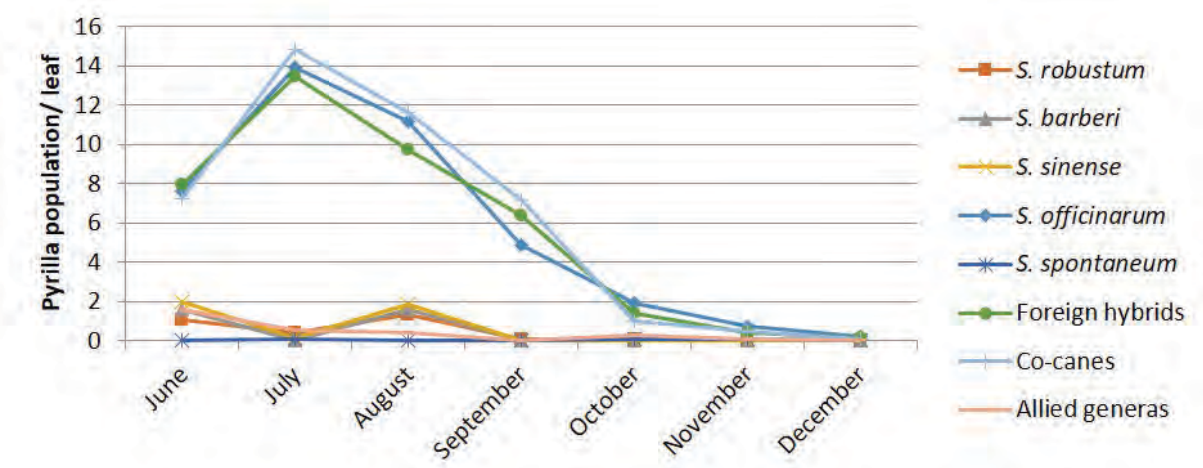


Fig. 100. Pyrilla population per leaf

with mean parasitizaton percentage of 78.28% (egg mass basis) and 54.28% (within egg mass basis) recorded. The parasitization by *Dryinus pyrillae* on nymphs of *P. perpusilla* was noticed from June to October with peak level of activity (16.04% mean parasitization) recorded in the month of August (Fig. 100).

Pathogenicity and augmentation of entomopathogenic fungi: The *Pyrilla* population comprising nymphs and adults peaked during the month of June-July due to low level of nymphal parasitization and negligible or absent of natural pathogenicity by entomopathogenic fungi at field level. The augmentation of *M. anisopliae* (Strain *SBIRC ma1* isolated from *P. perpusilla*) at field level (Foreign hybrid crop assemblage) was attempted in the month of July with three pronged strategies *viz.*, spray of spore suspension on leaf surfaces, distribution of mycosed adult cadavers and release of spore-laden adults. In the first fortnight of August, initial pathogenicity of *M. anisopliae* was noticed in the field with highest mortality in terms of mean number of mycosed nymphs (2.64) and adults(0.23) per leaf was recorded in the foreign hybrid crop assemblage (i.e *M. anisopliae* augmented block). The highest number of mycosed dead cadavers killed by *M. anisopliae* was recorded during the month of November. The natural pathogenicity of *Hirsutella* sp. was also noticed on nymphs and adults causing mycosis in the second fortnight of August. The mortality caused by *Hirsutella* sp. was higher than the *M. anisopliae* throughout the cropping season. Moreover, *Hirsutella* sp. had showcased remarkable natural epizootics in the month of October-November with at least one dead cadaver per leaf to maximum of 22 cadavers per leaf and helped in the complete suppression of the *Pyrilla* population at field level. The highest mortality by *Hirsutella* sp. and *M. anisopliae* was recorded in the 'Co'canes (73.21%) and foreign hybrids (42.30%), respectively.

(B. Mahendran, R. Gopi and P. Mahesh)

5.8 ICAR-SUGARCANE BREEDING INSTITUTE, RESEARCH CENTRE, AGALI

Enhancement of sugarcane germplasm and development of pre-breeding material

Germplasm maintenance, hybridization and Off-season nursery (Agali)

Germplasm maintenance: A total of 1380 germplasm including 'Co' canes, 'Co' allied clones, exotic clones, inter-specific and inter-generic hybrids, core collection of *Saccharum officinarum,* species clones of *S. barberi, S. sinense, S. robustum, Erianthus* spp., *Sclerostachya* and *Narenga* are clonally maintained in field.

Flowering during 2019 season: Out of 1380 germplasm, 611 accessions flowered in 2019. The intensity of flowering was 44.28% which is lower than the flowering intensity (51.9%) recorded in the previous season. This year only 26 clones of *S. officinarum* flowered, which is fewer than previous year flowering intensity. Two clones of *S. robustum,* one in each of *S. sinense* and *S. barberi* flowered in 2019 season. Intensity of flowering

in 'Co' cane, 'Co' allied clones and exotic clones were lower in this season in comparison to 2018 flowering season. Flowers (opening of spikelets) began from 25 September 2019 and lasted up to 12 December 2019. IJ 76-436, Monget gayam, Naz, Otaheiti, Sugar doctor, White transparent, BM 135, LS 89-2064 were the early flowering clones flowered during last week of September 2019.

Hybridization: A total of 170 crosses were made during 2019 season. Breeders from 12 AICRP(S) Centres namely, Cuddalore, Kapurthala, Lucknow, Mandya, Padegaon, Pantnagar (Kashyapur), Pune, Pusa, Sankeshwar, Shahjahanpur, Seorahi and Uchani made crosses. Scientists from ICAR-SBI Coimbatore and ICAR-SBI RC, Karnal also made few crosses at Agali Centre. In total, 69 crosses were made for Agali Centre and 101 crosses were made for fluff receiving Centres. Open pollinated fluffs (GCs) from 45 clones were collected. Crossed fluffs were harvested and processing are in progress.

Seedling evaluation in ground nursery: A total of 1787 seedlings derived from back crosses involving cold tolerant *S. spontaneum* (SES 114) as one of a parent were transplanted in ground nursery during Oct 2019.

Clonal evaluation: About 37 clones in first clonal nursery and 65 clones in second clonal nursery were planted during March 2019. The clones were screened for red rot (in CCT). Juice analysis was made at 8th and 10th month. Two clones in first clonal nursery (Agl2018-27, Agl2018-35) and one clone in second clonal nursery (Agl2019N-42) recorded higher sucrose% at 8th month than the standards with R to red rot. Selection will be effected in February 2020.

(R. Karuppaiyan and A. Annadurai)

DUS Testing Project-Sugarcane (Agali Centre)

Maintenance of reference varieties: Maintained 223 reference varieties (RV) in field. Seed cane of 25 new varieties from different research stations in India were collected during January-March 2019 and were included in the reference collection. Thus, a total of 236 sugarcane reference varieties are maintained at Agali Centre as on 31 December 2019.

Multiplication of FV: Two farmers' varieties (FV) namely, Sugam Kattari and Jeet Katari were received from Karnal Centre in April 2019 for multiplication and conduct of DUS test at Agali Centre. They belong to the species *S. officinarum*. These, varieties showed very poor germination, Moreover, the germinated settlings did not survive after a month. Hence, fresh seed cane was again obtained from Karnal Centre in December 2019 and were planted in cavity trays.

Conduct of DUS test: For conducting DUS test for three FV namely, Desi 1, Desi II and Meitei Chu Angangba during 2019-20 season, setts of these clones along with closely resembling seven reference varieties namely as IJ 76-317, Tahiti-3, NG 77-137, 57 NG 192, NG 77-015, HM Black and Red sport were planted in 4 row plots on 25 January 2019. Observations on 18 DUS traits of FV and RV were recorded.

(R. Karuppaiyan)

6. EDUCATION AND TRAINING

6.1 EDUCATION - M.Phil. / Ph.D. PPROGRAMME

Bharathiar University: The Institute has been recognized by Bharathiar University, Coimbatore to conduct M.Phil. / Ph.D. programme in the disciplines of Biotechnology, Botany, Zoology, Agricultural Chemistry, Agricultural Entomology and Plant Pathology.

Bharathidasan University: The Institute has also been recognized by Bharathidasan University, Tiruchirappalli to conduct Ph.D. programme in the discipline of Biotechnology.

Undergraduate and Postgraduate students training and project work: A total of 141 students from different parts of the country participated in the exposure training programme and 25 students carried out their UG/PG project work at the institute. The revenue generated from training and project work is Rs. 12,05,000.

Ph.D. awarded: Mr. Kaverinathan was awarded Ph.D. degree by Bharathiar University w.e.f. 08 May 2019 for the thesis entitled 'Genomic and proteomic approaches to characterize pathogenicity related genes/proteins in *Colletotrichum falcatum* causing sugarcane red rot' under the guidance of Dr. P. Malathi, Principal Scientist (Pathology). Ph.D. degree was awarded to Mrs. M. Scindiya for the thesis entitled 'Molecular characterisation and functional analysis of pathogenecity related genes in *Colletotrichum falcatum* causing red rot in sugarcane' under the guidance of Dr. P. Malathi, Principal Scientist (Pathology) on 27 December 2019.

M.Sc. (Sugarcane Technology) course in Open and Distance Learning mode is being offered in collaboration with Tamil Nadu Agricultural University, Coimbatore. Eleven students in their IV semester are undergoing the course.

6.2 TRAINING PROGRAMMES ORGANIZED

At ICAR-SBI, Coimbatore

- Nine national level training programmes on 'Advances in sugarcane cultivation' were organized during June-August 2019 for cane development personnel from the states of Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Odisha, Uttar Pradesh, Uttarakhand, Bihar, Punjab and Gujarat.
- Conducted three three-days training programs on 'SSI planting and drip fertigation in sugarcane' for 42 farmers from Salem district, Tamil Nadu during 28-30 August 2019; 38 sugarcane farmers from Thoothukudi district, Tamil Nadu during 25-27 September 2019; 35 farmers from Ramanathapuram district during 11-13 November 2019.
- Conducted 34 one-day training programs benefitting 1225 farmers and 176 cane development personnel of the country.
- Conducted 14 one-day Exposure Visits for 767 school students, 39 input dealers from MYRADA KVK, Erode, 30 Cane Officers / Cane Assistants from M.R.K. Cooperative Sugar Mills Ltd., Sethiathope and 33 students of Agri-Clinic and Agri-Business Centre from Vanavarayar Institute of Agriculture, Pollachi.

At ICAR-SBI,RC, Karnal

- Conducted a one-day training to 54 sugarcane farmers visited under ATMA from Muzaffarnagar, Uttar Pradesh on 09 August 2019 (Fig. 101).

Fig. 101. Training on 09 August 2019

- Conducted Exposure Visit for 80 graduation course students of AC&RI, Madurai on 16 September 2019 and explained about the Centre and delivered a lecture on sugarcane pests and their management.
- Conducted a one-day training on 'Settling transplanting technology' for 100 mill staff and farmers of Saraswati Sugar Mill, Yamunanagar on 17 September 2019.

- Conducted a five-days farmers training program on 'Technologies to improve sugarcane productivity' during 23-27 September 2019.
- Conducted a one-day training programme on 'Autumn planting of sugarcane and settling transplanting technologies for healthy seed production and maximization of sugarcane yield' for Cane manager/CDO/CMO of Karnal Co-operative sugar mills on 01 October 2019.
- Demonstrated 'Settling transplanter' to different progressive farmer and Sugar mills officials and conducted brain storming session on 04 October 2019.

6.3 INTERNATIONAL VISIT

- Dr. P.T. Prathima attended Trop. Ag. International Tropical Agriculture Conference at Brisbane, Australia during 11-13 November 2019.
- Dr. R. Viswanathan, Acting Head, Division of Crop Protection made a Consultancy visit to Pantaleon SA, Monte Rosa, Nicaragua to inspect dry canes affected sugarcane in Nicaragua and suggesting management solutions during 06-08 August 2019.

6.4 TRAINING AND CAPACITY BUILDING

Participation in training programme by officials

- Shri. Vishal Goel - Training on Motivation, positive thinking and communication skills for Technical Officers at ICAR-IISWC, Dehradun during 02-07 May 2019.
- Dr. P. Govindaraj - Training programme on 'Management Development Programme on Leadership Development' organized by ICAR - National Academy of Agricultural Research Management (NAARM), Hyderabad during 11-22 June 2019.
- Drs. K. Hari and A. Ramesh Sundar - Training programme on 'Stress Management' organized by ICAR - National Academy of Agricultural Research Management (NAARM), Hyderabad during 26-29 June 2019.
- Smt. Amsaveni: Training on 'Hospitality Management' at ICAR-NAARM, Hyderabad from 26 June 2019 to 02 July 2019.
- Dr. C. Palaniswami: Training on 'PME of Agricultural Research Projects' at ICAR-NAARM, Hyderabad during 18-23 July 2019.
- Dr. K. Elayaraja and Dr. H.K. Mahadevaswamy: Training on Statistical advances in designing agricultural experiments and data analysis at ICAR-Indian Agricultural Statistics Research Institute, Pusa, New Delhi during 19 July to 8 August 2019.
- Mrs. D. Subhadra: Certificate course on 'Cyber security and ethical hacking' at Bengaluru from 29 July 2019 to 02 August 2019.
- Dr. A. Suganya: Training programme on Development of taxonomic keys for identification of plants and varieties and its software at Nagpur during 19-25 August 2019.
- Dr. R. Manimekalai: Training on Advance statistical analysis of breeding data at ICAR – Indian Agricultural Statistics Research Institute, Pusa, New Delhi during 27 August 2019 to 16 September 2019.
- Dr. B. Singaravelu: CAFT Training programme on Next generation sequencing and its application to crop science at ICAR-NIPB, New Delhi during 03-23 September 2019.
- Dr. K. Hari: Training on Intellectual property valuation and technology management at NAARM, Hyderabad during 15-19 October 2019.
- Dr. B. Mahendran and Dr. R. Gopi: Winter School Training programme on Novel techniques in mass culturing of smart microbial agents for the development of biopesticides at ICAR- National Bureau of Agricultural Insect Resources, Bangaluru during 03-23 December 2019.
- Shri S. Karuppasamy: Training on Motivation, positive thinking and communication skills for Technical Staff (T1-T4) at NIANP during 05-11 December 2019.
- Dr. M. L. Chabbra: Management Development Programme on Leadership Development at NAARM during 02-13 December 2019.

7. AWARDS / RECOGNITIONS

- Dr. Bakshi Ram received the NAAS Fellowship 2019 from the President, NAAS, Prof. Punjab Singh on 5 June 2019 (Fig. 102).

Fig. 102. Dr. Bakshi Ram receiving NAAS Fellow award

- Dr. B. Parameswari was awarded Associateship of the National Academy of Agricultural Sciences, New Delhi on 5 June 2019 (Fig. 103).

Fig. 103. Dr. Parameshwari receiving NAAS Associateship award

- ICAR-Sugarcane Breeding Institute, Regional Centre has received TOLIC award held at ICAR-NDRI, Karnal for the outstanding award for promotion Hindi activities on 28 June 2019 (Fig. 104).

Fig. 104. Receiving TOLIC Award

- Dr. Bakshi Ram, Director, ICAR-SBI received Rafi Ahmed Kidwai Award for Outstanding Research in Agricultural Sciences-2018 from Sh. N.S. Tomar, Honourable Minister of Agriculture and Farmers Welfare, GoI during the 91st Foundation Day of ICAR on 16 July 2019 (Fig. 105).

Fig. 105. Dr. Bakshi Ram receiving Rafi Ahmed Kidwai award

- Dr. R. Viswanathan, Head i/c Division of Crop Protection received Hari Om Ashram Trust Award in Crop and Horticultural for the biennium 2016-17 during the 91st Foundation Day of ICAR on 16 July 2019 (Fig. 106)

Fig. 106. Dr. R. Viswanathan receiving Hari Om Ashram Trust award

- The Institute received Ganesh Shankar Vidhyarthi Award for Hindi magazine 'Ganna Prakash' for the year 2018-19 during the 91st Foundation Day of the ICAR on 16 July 2019 (Fig. 107).
- A certificate of 'Excellent Performer' was awarded to the ICAR- SBI, Coimbatore by the All India Coordinated Research Project on Sugarcane during the Annual Group Meeting of AICRP (S) held at UAS, Dharwad on 16 October 2019).

Fig. 107. Ganesh Shankar Vidhyarthi award being received

- Dr. R. Viswanathan, Head i/c Division of Crop Protection received Best research paper award from Dr. T. Mohaptra, DG, ICAR during the National symposium on Potential crops for food and nutrition security at TNAU, Coimbatore during 14-15 December (Fig. 108).

Fig. 108. Dr. R. Viswanathan reciving Best research paper award

- Dr. R. Gomathi, Principal Scientist received Fellowship of Indian Society of Plant Physiology during National Conference of Plant Physiology 2019 organized by Kerala Agricultural University, Thrissur & Indian Society for Plant Physiology, New Delhi on 19 December 2019.

8. LINKAGES AND COLLABORATIONS IN INDIA INCLUDING EXTERNALLY FUNDED PROJECTS

The Institute has established linkages with ICAR Institutes like IARI, NBPGR, NRCPB, NBAIR, IISR, Sugarcane Research Centres of SAUs under AICRP, International Centre for Genetic Engineering and Biotechnology (ICGEB), Ministry of Consumer Affairs, Food and Public Distribution, Ministry of Agriculture-and Farmers Welfare, GoI, Ministry of Food Processing Industries, DST, DBT/GoI, Directorate of Sugarcane Development, TNPL (a Govt. of Tamil Nadu Undertaking), MSSRF, Chennai and sugar industry in critical areas in emerging technologies for deriving maximum benefit.

Project title and scientist involved	Source of funding	Total outlay (Rs. in lakhs)
Sub cellular targeting of invertase inhibitory proteins : A novel approach to enhance sucrose yield in sugarcane- G.S. Suresha	DST-SERB	30.48
National Level training for implementation of Sugarcane Development Programme under NFSM (Commercial crops) - T. T. Rajula Shanthy	Min. of Agri, GoI	4.50
Disecting the molecular interface between biotrophic pathogen *Sporisorium scitamineum* and its host sugarcane - A. Ramesh Sundar, R.Viswanathan and P. Malathi	DBT	48.9
Identification of new genetic resources for drought tolerance from Erianthus, a related wild genus of sugarcane through GWAS- R. Valarmathi	DST-SERB	42.2

Project title and scientist involved	Source of funding	Total outlay (Rs. in lakhs)
Characterisation of root system traits in sugarcane germplasm- Krishnapriya Vengavasi	DST-SERB	36.37
Identification of salt responsive genes and micro RNA Targets from salt tolerant arundinaceus clone IND 99-884 through transcriptome analysis - C. Mahadevaiah	DST-SERB	12.99
A whole genome based reduced representation approach for identification of resistance against *sugarcane yellow leaf virus* in Indian sugarcane- B. Parameshwari	DST-SERB	45.24
Genetic control and genomic selection for important traits in sugarcane and comparison of elite Indian and Australian germplasm- R. Manimekalai, G. Hemaprabha, R.Viswanathan, A. Selvi, K. Mohanraj and S. Vasantha	DBT	175
Tribal Sub Plan – T. Rajula Shanthy, C. Sankaranarayanan, C. Jayabose, R. Karuppaiyyan, A.S. Tayade	Ministry of Tribal Affairs	50.00
ICAR-CRP on Development and application of diagnostics to viruses infecting sugarcane-R.Viswanathan, B. Parameswari, D. Neelamathi and K. Nithya	ICAR	75.82
State Level training on 'Advances in Sugarcane Cultivation- T. Rajula Shanthy	Min. of Agri,GoI	3.20
Isolation, functional characterization and evaluation of water deficit stress tolerance responsive genes from high drought tolerant *E.arundinaceus* by comparative drought transcriptome analysis- C. Appunu	DBT	53.91
Network project of transgenics in crops-Transgenic development in sugarcane- C. Appunu	ICAR-NPTC	30.00
Deciphering *in planta* secretome of *Sporisorium scitamineum* and sugarcane interaction – A. Ramesh Sundar, R. Viswanathan and G.S. Suresha	DST	24.55
Deciphering interacting partners of PAMPs/ Effectors of *Colletotrichum falcatum* that trigger innate immunity in sugarcane- A. Ramesh Sundar, R. Viswanathan, P. Malathi, C. Appunu and Rajeev Sukumaran	DBT	75.03
Identification, characterization and verification of new sugarcane varieties for DUS testing-Karnal - M.R. Meena	MoA/GoI	5.50
Enhancing sugar productivity in Tamil Nadu through Institute-Industry participatory approach- A collaborative project with SISMA (TN)- Bakshi Ram	SISMA	46.20

Project title and scientist involved	Source of funding	Total outlay (Rs. in lakhs)
Identification of location specific sugarcane varieties suitable for different agro-climatic zones of Tamil Nadu (Cooperative sugar factories)- Bakshi Ram	Dept. of Sugar, Govt. of TN	7.00
Sugarcane breeder seed production and demonstration of intercropping- N. Kulshreshtha	NFSM	8.50
Digital inclusion of rural youth for sustainable development a comparative assessment – D. Puthira Pratap	RGNIYD	3.90
Identification, characterization and verification of new sugarcane varieties for DUS testing- R. Karuppaiyan	PPVFRA	7.00
ICAR seed project: Seed production in agricultural crops and fisheries- Sugarcane- Coimbatore- A.J. Prabakaran	ICAR	11.00
Physiological approaches for winter ratoon management in sugarcane under subtropical conditions - Pooja	RKVY	100.00
Biogenesis of nanomaterials from effective *Trichoderma sp*. for the management of red rot in sugarcane – P. Malathi	DST-SERB-TARE	18.30
Development of sugarcane bacilliform virus (SCBV) based VIGS vector for functional genomic in sugarcane – R. Viswanathan, B. Parameswari, C. Appunu and K. Nithya	DST-SERB	40.73

9. ALL INDIA COORDINATED RESEARCH PROJECT ON SUGARCANE

The All India Coordinated Research Project on Sugarcane was started in the year 1971. A National Hybridization Garden was established in the Institute to facilitate the national breeding programmes. The following are the research areas under this project:

- Fluff supply to various sugarcane research institutes / centres.
- Evaluation of 'Co' canes for different sugarcane growing regions and acting as the coordinating unit for the identification of 'Co' and other Co- regional selections.
- To gather information on general and specific combining ability of biparental crosses.
- Collaboration for development of national varieties.
- Collaborative research on Agronomy, Soil science, Plant Physiology, Entomology and Plant Pathology.

Dr. Bakshi Ram, Director is the Principal Investigator of Crop Improvement and Dr. R. Viswanathan, Head I/c, Division of Crop Protection is the Principal Investigator of Plant Pathology.

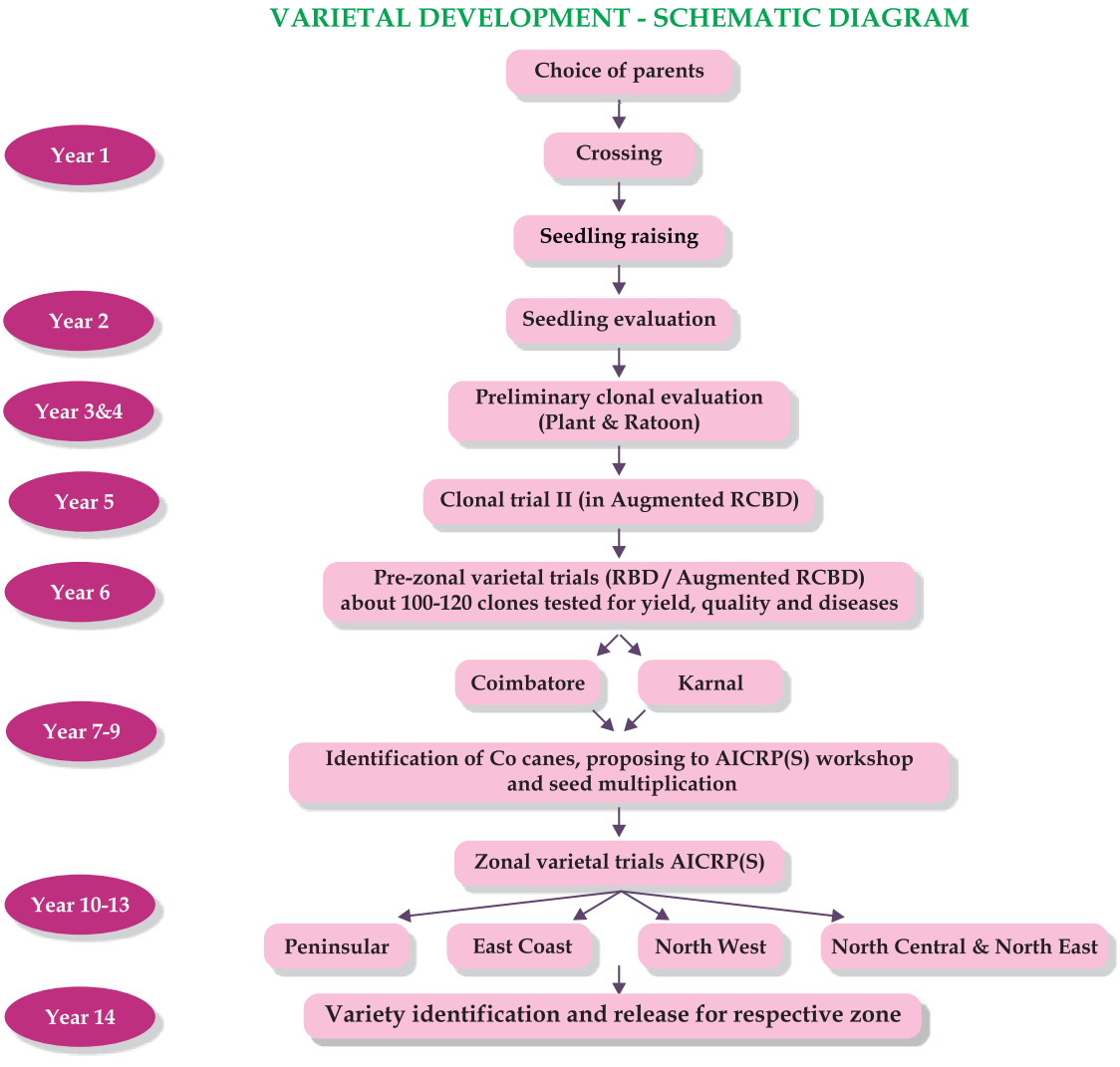


Fig. 109. Varietal Development - Schematic Diagram

10. PUBLICATIONS

Research Papers

1. Alarmelu, S., R. Nagarajan, R. M. Shanthi, S. Damodharan, G. Hemaprabha, A. Anna Durai, C. Mahadevaiah and Bakshi Ram. 2019. Co 10026 (Upahar): New early maturing variety released for cultivation in Peninsular Zone. *Journal of Sugarcane Research* 9 (1): 94-96.

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11. RESEARCH PROJECTS

1. Breeding superior sugarcane varieties of different maturity with improved cane yield, quality and resistance to biotic and abiotic stresses
2. Enhancement of sugarcane germplasm and development of pre-breeding material
3. Sugarcane genomics and molecular markers
4. Gene discovery and genetic transformation in sugarcane
5. Development of cropping systems and improved agronomic practices to enhance sugarcane productivity
6. Enhancing physiological efficiency of sugarcane
7. Natural resource management for enhancing productivity and sustainable sugarcane production
8. Host resistance, interactomics, pathogen variability, diagnosis and disease management in sugarcane
9. Studies on sugarcane pests and their management
10. Basic and applied studies of sugarcane phytonematodes and entomopathogenic nematodes
11. Economic and statistical studies in sugarcane and sugar production system
12. Transfer of sugarcane technologies
13. Standardization of true seed production technique through developing homozygous parental lines and apomixes
14. All India Coordinated Research Project (Sugarcane)

12. CONSULTANCY, PATENTS, COMMERCIALIZATION OF TECHNOLOGIES

Institute Technology Management Unit

Two ITMC meetings were conducted to discuss different aspects pertaining to patent registrations and commercialization of technologies developed by ICAR-SBI.

Three new sugarcane variety applications for Co 09004 (Amritha), Co 10026 (UPAHAR) and Co 12029 (Karan13) were submitted with PPV&FRA for registration.

ICAR-SBI varieties registered with PPV&FRA viz., Co 94012, Co 99004, Co 0118, Co 05011, Co 0403 and Co 0238 were renewed for 2019-20.

MoUs signed for commercialization of the ICAR-SBI technologies:

- Tranalab, Bengaluru and ICAR-SBI signed MoA for colloborative research on Expression of Recombinant Proteins In Sugarcane on 22 June 2019 (Fig. 110).
- Hanzra Agro Engg Works, Karnal signed an MoU with ICAR-SBI for QUATRO Sugarcane single bud cutter technology on 13 September 2019 (Fig. 111).

Fig. 110. Tranalab and ICAR-SBI signing MoA for colloborative research on 22 June 2019

Fig. 111. Hanzra Agro Engg Works, Karnal signing MoU for Quatro sugarcane single bud cutter on 13 September 2019

- Signed an MoU between ICAR-SBI and KSNM Marketing Ltd., for commercializing Sugarcane Detrashing Device on 26 October 2019 (Fig. 112).

Fig. 112. KSNM Marketing Ltd., Coimbatore signing MoU for commercialization of Sugarcane Detrashing Device on 26 October 2019

- SKR Agrotech, Nagpur signed a MoU for commercialization of Soil moisture indicator on 22 November 2019 (Fig. 113.)

Fig. 113. SKR Agrotech, Nagpur signing MoU for commercialization of Soil Moisture Indicator on 22 November 2019

- Pragmatix, New Delhi signed an agreement for field research trails with high end automation system and promotion of sustainable sugarcane practices with sugarcane farmers through Agricultural Technical Service Providers (ATSPs) by applying established package of practices on 28 November 2019 (Fig. 114).

Fig. 114. Pragmatix, New Delhi signing an agreement for promotion of sustainable sugarcane practices on 28 November 2019

- M/s KPIT Technologies Ltd., Pune signed a MoU for studying suitability and viability of energy canes as a feedstock for green energy industries on 28 November 2019.
- Labtronics, Panchkula, Haryana signed a MoU for commercialization of Soil moisture indicator on 16 December 2019 (Fig. 115).

Fig. 115. Labtronics, Panchkula,Haryana signing MoU for commercialization of Soil Moisture Indicator on 16 December 2019

Revenue of Rs. 1,77,819 was realised in terms of license fee and royalty pertain to Soil Moisture Indicator and Sugarcane Detrashing Tool. Also a revenue of Rs. 2,56,271 was realised as technology fee for Expression of Recombinant Proteins in Sugarcane.

Techno-commercial assessment committee meeting of AGRINNOVATE was held on 22 October 2019 by SKYPE video conferencing tool and finalized the licensing terms for four technologies viz., Sett Treatment Device, EPN formulation for white grub control, Soil Moisture Indicator and Sugarcane Detrashing tool.

A meeting was held on 12 December 2019 between ICAR-SBI and M/s T.Stanes Company Ltd., Coimbatore to introduce two technologies of ICAR-SBI viz., Control of white grub *Holotrichia serrata with (1) Bacillus thuringiensis and (2)* EPN biopesticide formulation.

Agri Business Incubator

ICAR-SBI has initiated sugarcane based Agri Business Incubator for commercialization of potential technologies developed by the institute. Among the prospective technologies, sugarcane based innovative products such as sugarcane jam, spread, sugarcane fibre rich bread have been developed for farm entrepreneurs, startups, rural based cottage industries and farm women. These products having high potential and scope in the niche market and food value chain. It is envisaged for increasing the profitability of the sugarcane farmers to achieve self reliance in the farm income.

13. EVENTS

INTERNATIONAL YOGA DAY

International Yoga Day was celebrated at the Institute on on 21 June 2019. Sister. Rajeswari along with other Sisters and Brothers of Brahmakumari's Coimbatore Centre were the Chief Guests of the function. Sister Rajeswari delivered a lecture on 'Healthy mind, body & environment' followed by demonstration on physical exercise and meditation (Fig.116). All the staff of the Institute attended and got benefitted by the lecture.

Fig. 116. International Yoga Day

INDEPENDENCE DAY

Independence Day was celebrated in the Institute on 15 August 2019. Dr. Bakshi Ram, Director, ICAR-SBI hoisted the National flag and addressed the staff (Fig. 117).

Fig. 117. Independence Day celebration (15 August 2019)

HINDI DAY CELEBRATION

Hindi Day was celebrated on 26 September 2019. Shri Durga Charan Dash, Chief Commissioner of Income Tax was the Chief Guest (Fig. 118). Various competitions were conducted and the winners were awarded. The Hindi magazine 'Ganna Prakash' was released during the Hindi Day by the Chief Guest.

Fig. 118. Hindi Day Celebration

HINDI WORKSHOP

Quarterly Hindi Workshops were conducted on 7 June 2019, 22 October 2019, 28 December 2019 wherein Shri Hari Ganesh, Hindi Pradhyapak

was the Chief Guest and he spoke on Noting and drafting in Hindi. (Fig. 119)

Fig. 119. Hindi workshop

Gandhi Jayanthi celebration

The 150th birth anniversary of Mahatma Gandhi, the 'Father of our Nation' was celebrated at ICAR-Sugarcane Breeding Institute on 2 October 2019 (Fig. 5).

Meetings conducted

Fig. 120. Gandhi Jayanthi celebration (02 October 2019)

- Selection Committee meeting for SRF held on 16 April 2019.
- 94th Institute Management Committee meeting held on 24 April 2019.
- Institute Bio-Safety Committee meeting conducted on 29 April 2019.
- Senior Officers Committee meeting held on 04 April 2019, 04 May 2019 & 12 June 2019, 04 July 2019, 03 August 2019 & 03 September 2019, 05 October 2019, 16 November 2019 & 19 December 2019.
- Women Cell meeting held on 08 May 2019, 20 August 2019 and 05 November 2019.
- Assessment Committee meeting for considering promotion cases of Technical staff held on 09 May 2019.
- Typing Test for the post of Assistant held on 10 June 2019.
- Selection Committee meeting for regularization of TSCL's as SSS held on 26 April 2019 and 23 May 2019.
- Grievance Committee meeting held on 25 April 2019, 14 May 2019, 10 June 2019, 12 July 2019, 14 August 2019, 12 September 2019 15 October 2019, 16 November 2019 and 12 December 2019.
- International Yoga Day was observed on 21 June 2019.
- Institute Joint Staff Council meeting held on 26 June 2019, 23 September 2019, 19 December 2019.
- Guest lecture by Dr. M. Chakravarthy, Research Scientist, University of Florida on 08 July 2019
- National workshop on Digital Field Book on 11 July 2019.
- Review Assessment Committee meeting for considering promotion cases of Technical staff held on 08 August 2019.
- A meeting was held at the institute on 26 August 2019 with the Director, ICAR-SBI to discuss about setting up of a Sugarcane Research Institute at Punjab. The following members attended the meeting: Dr. R.B Doule, Chief Sugarcane Advisor, NFCSF, Dr. Baldev Singh, VC-PAU, Shri. Rana Inder Pratap Singh, MD Rana Sugars Ltd, Shri. Devender Singh IAS, MD Sugarfed (Punjab) and Shri Ajnala Shivaraj Pal Singh.
- Departmental Promotion Committee meeting for probation clearance / confirmation of Skilled Support Staff held on 30 August 2019.
- Selection Committee meeting for Young Professional-I and Project Assistant held on 05 July 2019, 06 July 2019 & 07 August 2019.
- 'Sadbhavna Diwas' was observed on 20 August 2019 with a pledge at 11.00 AM.
- 150th Birth Anniversary of Mahatma Gandhi was celebrated on 28 September 2019.
- 95th Institute Management Committee

meeting held on 14 November 2019.

- Assessment Committee meeting for considering promotion cases of Technical staff held on 05-06 November 2019 and 27 December 2019.
- Screening Committee meeting for grant of MACP of Administrative Staff held on 06 November 2019.
- Selection Committee meeting for Young Professional-II and Junior Research Fellow held on 09 October 2019, 13 November 2019, 27-28 December 2019.
- *Rashtriya Ekta Diwas* (National Unity Day) was observed with a pledge on 31 October 2019.
- Vigilance Awareness Week was observed from 28 October 2019 to 02 November 2019.
- Constitution Day was celebrated on 26 November 2019.

At Karnal

Brainstorming session on sugar recovery and cane cultivation practices in Punjab

Dr. Neeraj Kulshreshtha attended the brainstorming session on status of sugar recovery and cane cultivation practices in Punjab at Punjab Agricultural University, Ludhiana, Punjab on 08 April 2019. The session was chaired by the honourable Vice Chancellor of PAU. A number of issues were discussed to improve the sugar recovery status in Punjab by giving emphasis on better production technology and healthy seed production so that the potential of variety Co 0238 can be exploited in increasing yield and sugar recovery as being exploited by many sugar mills in Uttar Pradesh. ICAR-SBIRC Karnal promised to provide all help in providing healthy seed to different state agencies of Punjab.

Demonstration of sugarcane harvester

Dr. Neeraj Kulshreshtha, Dr. Ravinder Kumar and Dr. M.R. Meena visited the demonstration of sugarcane harvester village Malikpur on 20 April 2019 (Fig. 121). The performance of sugarcane harvesters was satisfactory and with minor modification, the harvesters can be widely utilized by the sugar mills. ICAR-SBIRC Karnal is popularizing wide row spacing planting in sugarcane so that a sizable sugarcane area can be brought under such intervention of using cane harvester on sustainable basis.

Fig. 121. Demonstration of sugarcane harvester

Demonstration of sugarcane production technology and intercropping

A demonstration plot of sugarcane crop planted in wider row spacing with intercrop of gram was demonstrated in the Institute farm (Fig. 122). The gram crop was harvested in the month of April. The production technology was demonstrated to different farmers, extension workers and sugar mill officials to popularize wide row spacing in sugarcane.

Fig. 122. Demonstration on intercropping in wider row spacing

TRIBAL SUB PLAN INTERVENTIONS

Tribal farmers meet at ICAR-SBI, RC, Agali

A Tribal Farmers Meet was organized in ICAR-SBI RC, Agali on 6 August 2019 and materials were distributed to tribal people from seven tribal villages (Vellamari, Kalkandiyoor, Omapadaiyoor, Chalayoor, Palakayoor,

Soriyanoor and Kudapatti) benefitting 300 tribal families by Dr. R.S. Paroda, Chairman, RAC and other members (Fig. 123). The materials included rose can 5 litres-300, crow bar 5'-300, digging fork-300, spade-300, hand hoe-300, measurement tape (30 m)-300, plastic pan-300, plastic shears-300, bill hook-275, raincoat-140, pick axe-300, gumboot-300, sickle-300, battery sprayer-60, coconut dehusker-300, tarpaulin sheet (200 gsm)-145, induction stove-120, citrus seedlings-500, coconut seedlings-525, arecanut seedlings-625, LED tube & bulb-300, torch light-300, emergency light-300, plastic table-230, plastic chair-300, storage drum-260, irrigation green hose-160, mango seedlings-500, sapota seedlings-300, pomegranate seedlings-600, jack fruit seedlings-300, nutmeg seedlings-350.

Fig. 123. Distribution of materials under TSP

Surveys were conducted in Sirumugai and Karamadai hill ranges to identify new tribal villages for implementation of Tribal Sub Plan during 2019-20 (Fig. 124). Accordingly, Kaanthavayal and Uliyur tribal villages in Sirumugai range with 60 tribal families were selected as beneficiary villages. Focus group discussions were held with the Tribal Head and other tribal people in the respective villages. Discussions were also held with the Headmaster of a tribal school in the village. Transect analysis in Kanthavayal helped us to get first-hand information about the local resources, ongoing agriculture and related activities, livelihood pattern and their felt needs. Based on the observations made, technological interventions were identified for the two villages. Subsequently, surveys were conducted in Karamadai range and Domanur and

Fig. 124. Survey in Kaanthavayal, Sirumugai range

Sembukkarai tribal villages with over 130 tribal families were identified as beneficiary villages. Based on the discussions held with the Tribal

Head and other tribal people in the respective villages and observations made, the tentative technological interventions were identified for the two villages (130 families) and a tribal school. It was finalized to purchase and distribute the following inputs: sewing machine, induction stove, blankets, torch lights, led tube & bulb, umbrellas, bicycles, storage drum, rain coat, pick axe, gum boot, sickle, battery sprayer, coconut dehusker, tarpaulin sheet 200 gsm, emergency light, plastic chair, irrigation green hose, rose can 5 litres, crow bar-5 feet, digging fork, spade, hand hoe, measurement tape (30m), plastic pan, plastic shears, bill hook, induction stove, torch lights, tiffin box, umbrellas, thick bed spread, school items- swing, slide, white boards, chairs, tables, utensils, sport items, induction utensils.

(T. Rajula Shanthy, C. Jayabose, C. Sankaranarayanan, R. Karuppaiyan, Arjun Tayade, Malakappa B. Medegar, R. Kannaian)

MERA GAON MERA GAURAV

Eighteen teams comprising four scientists had identified 90 villages (Coimbatore - 75, Karnal - 10 and Kannur - 5) for adoption. Baseline surveys were conducted initially and information on the demographic details, description of farming situation, major crops grown, cropping pattern, infrastructural facilities available, problems in agriculture and organizations working in the village were collected. Preliminary analysis indicated that the major crops in Coimbatore district were coconut, banana, paddy, pulses, vegetables, turmeric, onion and arecanut. Major problems were drought, non-availability of inputs in time, poor marketability of the produce, high cost and unavailability of labour and livestock health issues. Wheat, paddy and sugarcane were the major crops grown in Karnal district whereas paddy, coconut and banana were the major crops grown in Kannur district. Visits were made to the adopted villages and technical guidance was provided to the farmers for improving their livelihood.

Group meetings and demonstrations on important technologies were organized in the adopted villages. Extension literature on 'Sugarcane varieties', 'Organic farming in sugarcane', '101 Agricultural technologies', 'Wid

Fig. 125. Activities under Mera Gaon Mera Gaurav

boar management' was distributed. Several meetings, campaigns and training programs were organized in the adopted villages (Fig. 125).

SWACHCH BHARAT ABHIYAN

Cleanliness campaigns were conducted at the Institute and the residential quarters among the employees and the residents. Campaigns were also conducted in the adopted tribal villages among the tribal people. The participants were made to realize the importance of clean

surroundings, collection and segregation of household and office wastes as bio-degradable, non-degradable, recyclable and toxic wastes. In each campaign, all the participants were involved in cleaning the pathways and surroundings, collection and segregation of wastes. 'Swachta Abhiyan' was observed in the institute with special cleanliness drive campaigns during Swachchhta Pakhwada (Fig. 126).

Fig. 126. Swachchh Bharat Abhiyan activities

SADHBHAVANA DIWAS

''Sadbhavna Diwas' was observed in the Institute on 20 August 2019 with a pledge at 11.00 AM (Fig. 127).

Fig. 127. Taking of Sadhbhavana Pledge

Constitution Day

Constituion Day celebrations was initiated at the Institute on 26 November 2019. All the staff took the pledge on Constitution Day followed by a lecture by Dr. J. Srikanth on the formation of Indian Constitution. Later a Run for rally was conducted at the Institute and subsequently visitors to the Institute are explained about the importance of Indian Constitution (Fig. 128.)

Fig. 128. Special lecture about Constitution Day by Dr. J. Srikanth

Fig. 128. Run for rally on Constitution Day

14. COMMITTEES

Research advisory committee meeting

The XXV Research Advisory Committee meeting of the Institute was held during 5-6 August 2019 at Coimbatore (Fig. 129). Dr. R.S. Paroda, Former Secretary, DARE and DG, ICAR served as the Chairman. Other expert members were Dr. S.R. Sree Rangasamy, Former Director, CPMB, TNAU, Coimbatore, Dr. M. Velayudham, Former Director, NBSS&LUP, Nagpur, Dr. R.K. Sairam, Former Head, Crop Physiology, IARI, New Delhi, Dr. J.P. Sharma, Joint Director, IARI, New Delhi, Dr. R.K Singh, ADG Commercial Crops, ICAR, New Delhi, Dr. Bakshi Ram, Director, ICAR SBI, Mr. Pointmoney, Farmer Representative and Dr. G. Hemaprabha Member Secretary. The meeting was attended by the Heads of Divisions / Regional Station Karnal, Research Centres at Kannur and Agali and Heads of Sections and all scientists from the main Institute.

Fig. 129. RAC meeting in progress

Dr. Bakshi Ram formally welcomed the expert members and presented the global and Indian sugar scenario and major achievements of the Institute during 2017-18. Dr. G. Hemaprabha, Member Secretary presented the Action Taken Report of the recommendations of previous RAC. This was followed by presentations on the achievements of the Divisions/ Centres/ Sections by Drs. G. Hemaprabha, C. Palaniswami, K.P. Salin, Neeraj Kulshrestha, T. Rajula Shanthy, Chandran, R. Karuppaiyan and P. Murali.

Dr. R.S. Paroda, Chairman and the members congratulated Director and staff of the Institute for the commendable progress made during the period.

Dr. R.S. Paroda and the members gave their views based on the reports presented and sought more clarifications on specific research aspects. There were deliberations to take the research activities of the institute to greater heights. The recommendations of RAC are:

1. Waterlogging may turn out to be a major problem for sugarcane cultivation in the future. So research on waterlogging to be intensified. Traits responsible for imparting tolerance to waterlogging need to be studied.
2. Marker related and genomic research has led to the identification of several markers and candidate genes responsible for different traits in sugarcane. It is time to give due focus on molecular breeding. Gene harvesting from germplasm should continue and used in marker assisted selection to speed up the breeding process.
3. The ideotype concept of sugarcane should be given due focus and the best end product need to be used in breeding.
4. India has to be a part of the genome sequencing and mapping efforts by the international sugarcane consortium to make ICAR-SBI a globally recognized Institute.
5. Cryopreservation as well as *in vitro* storage of germplasm should be given priority for maintaining and preserving the wealth of germplasm. Care should be taken to ensure lack of somaclonal variation in the germplasm thus preserved *in vitro*.
6. Targeted approach to ensure maximizing efficiency of each and every input to achieve the yield target at farmers' level (inter cropping with soybean varieties, black gram, green gram, coriander etc.) with plus or minus 10% deviation has to be worked out as an industry farmer collaboration at bench mark site for land to land horizontal extension and education among farmers.
7. Physiological aspects for optimizing yield and quality need to be identified and validated for crop improvement activities.

8. Pest management with linkage with private sector should be in place.
9. As a post-facto analysis Agri-Business has to be integrated to double farmer income.
10. In order to use the wisdom of farmers the practices followed by the innovative farmers need to be documented along with their achievements to promote farmer led innovations. For this there is need to organize Innovative Farmers' Conference from tropical and sub-tropical India for identifying successful crop management and production technologies, validation of the identified technologies and upscaling farmer led innovations. A Manual on such viable technologies to be brought out involving technical feasibility, economic viability and support available for the products.

Institute Research Council Neeting

The Institute Research Council meeting was conducted from 27 May to 1 June 2019. The progress of the ongoing research projects was reviewed and suggestions were offered. Seven sub-projects were concluded and six new sub-projects were approved for the coming year.

15. PARTICIPATION IN CONFERENCES, MEETINGS, WORKSHOPS, SYMPOSIA AND SEMINARS

Title	Date	Participant (s)
Kissan Gosthi at Superior Food Grains (P) Ltd., Unn. Uttar Pradesh	03 April 2019	Dr S.K. Pandey Dr. M.L. Chhabra Dr. Ravinder Kumar
Joint Annual Group Meeting of 34th AICRP –NSP (Crops) and 14th ICAR –Seed Project at CCSHAU, Hissar, Haryana	07 April 2019	Dr. A.J. Prabhakaran
Interview board constituted for SRF at ICAR- IIWBR, Karnal as Expert Member	09 April 2019.	Dr. M.L. Chhabra
Germplasm Evaluation Committee meeting at ICAR-CSSRI, Karnal	10 April 2019	Dr. Neeraj Kulshreshtha
Interaction meeting with Cane advisors, Sugarfed for setting of goal on vision 2022 and work plan for 2019-20 at Karnal Cooperative Sugar Mill	11 April 2019	Dr. Neeraj Kushreshtha, Dr. S.K. Pandey Dr. Ravinder Kumar
KVK Action Plan Meeting at Tamil Nadu Agricultural University	22-23 April 2019	Dr. T. Rajula Shanthy
IMC meeting at ICAR-Sugarcane Breeding institute, Coimbatore	24 April 2019	Dr. Neeraj Kulshreshtha

Title	Date	Participant (s)
Project Appraisal Committee (PAC) meeting at Department of Biotechnology, New Delhi and presented the project proposal entitled 'Sugarcane genomics to support product diversification' under Indo-Australian Biotechnology Fund (IABF) collaboration 11th round	30 April 2019	Dr. Bakshi Ram Dr. P.T. Prathima
Second World Conference on Palmyrah Economy – 2019 organised by World Palmyrah Agro Economy Consortium and Thavathiru Santhalinga Adigalar Arts, Science and Tamil College, Coimbatore held at Perur Adheenam, Perur, Coimbatore	03-05 May 2019	Dr. T. Arumuganathan
Conference on Advance technologies in bio-energy and market potential at Pune	14 May 2019	Dr. P. Govindaraj
25th meeting of Board of Governing Council (Directors) of Agricultural Skill Council of India at Pune, Maharashtra	20 May 2019	Dr V. Venkatasubramanian
International Conference on Exploring the scope of plant genetic resources- PROVECTUS PLANTAE 19 at Department of Botany, University of Kerala, Karyavattom, Trivandrum, Kerala.	22-24 May 2019	Dr. V.P. Sobhakumari
4th National Convention of NISSTA held at NSI, Kanpur	29-30 May 2019	Dr. Ravinder Kumar
Foundation Day celebration of National Academy of Agricultural Sciences in NASC, New Delhi and gave a presentation on 'Co 0238 - A wonder variety of sugarcane and its impact in sub-tropical India'	04-05 June 2019	Dr. Bakshi Ram
AGM Business Session of NAAS and the Foundation Day Lecture delivered by Dr. Peter Carberry, DG, ICRISAT, Hyderabad.	05 June 2019	Dr. Bakshi Ram Dr. R. Viswanathan
Advisory Board Meeting of the National Sugar Institute, Kanpur	07 June 2019	Dr. Bakshi Ram
55th Expert Committee meeting on ABS, National Bio Diversity Authority at Chennai	13-14 June 2019	Dr. V. Venkatasubramanian
Special State Varietal Release Committee Meeting in the Secretariat, Chennai	14 June 2019	Dr. Bakshi Ram Dr. G. Hemapraba Dr. C. Appunu

Title	Date	Participant (s)
Interaction meeting with farmers at Shree Chalthan Vibhag Khand Udyog Sahakari Mandali Ltd. Surat, Gujarat	15 June 2019	Dr. Bakshi Ram
Interaction meeting of Sugar Mills Associations / Federations under the Chairmanship of the Chairman, Commission for Agricultural Costs and Prices, Ministry of Agriculture and Farmers Welfare, Government of India at Krishi Bhawan, New Delhi	25 June 2019	Dr. Bakshi Ram
National Conference on Emerging Techniques in Food Processing Technology organized by IIFPT, Thanjavur	27-28 June 2019	Dr. G.S. Suresha
49th Annual Convention of SISSTA at Chennai	28 June 2019	Dr. P. Govindaraj
188th Meeting of the Board of Management of Tamil Nadu Agricultural University held at Secretariat, Chennai	02 July 2019	Dr. Bakshi Ram
Interaction meeting convened by Managing Director, Sugar fed, Punjab to discuss strategies to increase sugarcane recovery in Punjab at Mohali.	04 July 2019	Dr. Neeraj Kulshreshtha
National workshop on Digital Field Book organized by ICAR-Indian Institute of Millets Research, Hyderabad held at ICAR-Sugarcane Breeding Institute, Coimbatore, Tamil Nadu	11 July 2019	All the Scientists, ICAR-SBI, Coimbatore
International Agricultural Exhibition (Agri-Intex 2019) at CODISSIA Trade Fair Complex, Coimbatore	12-15 July 2019	Dr. T. Rajula Shanthy Dr. D.P. Pratap Dr. V. Jayakumar Dr. A.S. Tayade Dr. L. Saravanan Dr. K. Mohanraj Dr. R. Arun kumar Dr. Mahadevaiah Dr. V. Krishnapriya Dr. P. Geetha Dr. P. Mahesh Dr. Mahadevaswamy Dr. K. Illayaraja Smt. R. Nirmala Dr. K. Kaverinathan Shri. N.M.R. Ashwin Shri. Nithianantham Mrs. C. Yogampal

Title	Date	Participant (s)
Meeting for setting up Punjab Sugar Research and Training Institute chaired by Sh. S.S. Randhawa, Honourable Minister of Cooperation and Jails held in Punjab Bhawan	15 July 2019	Dr. Bakshi Ram
91st Foundation Day of the ICAR in New Delhi	16 July 2019	Dr. Bakshi Ram Dr. R. Viswanathan
Director's and Vice Chancellors' Conference held in New Delhi	17 July 2019	Dr. Bakshi Ram
STAI 77th Annual Convention and International Sugar Expo 2019 held at Biswa Bangla Convention Centre, Kolkata, West Bengal	17-19 July 2019	Dr. G. Hemaprabhu, Dr. S. Alarmelu Dr. K. Mohanraj
26th meeting of Board of Governing Council (Directors), Agricultural skill Council of India, (ASCI) at Gurugram, New Delhi	20 July 2019	Dr V. Venkata subramanian
Seminar on Application of Drone Technology in Sugarcane Agriculture organized by S. Nijalingappa Sugar Institute (SNSI), Belagavi held at SNSI, Belagavi, Karnataka	24 July 2019	Dr. T. Arumuga nathan
Interaction meeting with Managing Director, Sugarfed to discuss strategies to increase sugarcane recovery in Punjab at Mohali.	29 July 2019	Dr. Neeraj Kulshreshtha
Interaction meeting to discuss policy on varietal planning and seed production in Co-operative sugar mills of Punjab at National federation of co-operative sugar mills, New Delhi.	02 August 2019	Dr. Neeraj Kulshreshtha
Core Group Agricultural Economists for studying impact of selected ICAR technologies at ICAR- NIAP, New Delhi	03 August 2019	Dr. P. Murali
Interaction meeting on ongoing activities and trials of SBI-RC, Karnal with MD and Officials of Sugarfed, Punjab and Scientists PAU, Ludhiana at ICAR-SBI RC, Karnal	07 August 2019	Dr. Neeraj Kulshreshtha, Dr. M.L. Chhabra, Dr. Ravinder Kumar Dr. M. R. Meena
Multi-stakeholder consultaion meeting on Achieving sustainable development goals and strengthening science of climate resilience at MSSRF, Chennai	07-08 August 2019	R. Valarmathi

Title	Date	Participant (s)
56th Expert Committee meeting on ABS, National Bio Diversity Authority at Chennai	08-09 August 2019	Dr V. Venkatasubramanian
First International Conference on Software Defined Networking (ICSDN) at Anna University Campus, Chennai	09-10 August 2019	Dr. P. Murali
Interaction meeting with Cane Commissioner, Haryana to discuss different issues to related projects funded by RKVY at Panchkula, Haryana	21 August 2019	Dr. Neeraj Kulshreshtha
Second Meeting of Agriculture and Sugarcane Sub-committee of Indian Sugar Mills Association held at ICAR Sugarcane Breeding Institute, Coimbatore	21 August 2019	Dr. Bakshi Ram Dr. G. Hemaprabha
Interaction meeting held on with Additional Cane Commissioner, Haryana to discuss about the performance of variety Co 05011	28 August 2019	Dr. Ravinder Kumar Dr. M. R. Meena
National workshop on Best Management practices for sustaining the soil health and enhancing quality productivity at ICAR-SBI, Coimbatore.	29 August 2019	Dr. Bakshi Ram Dr. G. Hemaprabha Dr. R. Viswanathan Dr. C. Palaniswami Dr. T. Rajula Shanthy Dr. D. Puthira Prathap Dr. P. Murali Dr. P. Geetha Dr. T. Arumuganathan Dr A. Vennila
National Level Seminar on Unmanned Aerial System (UAS) – Design and Applications organized by Department of Aeronautical Engineering, Hindustan College of Engineering and Technology, Coimbatore held at Hindustan College of Engineering and Technology, Coimbatore	30 August 2019	Dr. T. Arumuga nathan
26th meeting of ICAR Regional Committee No. VIII at ICAR-IIHR, Bengaluru.	06-07 September 2019	Dr. Bakshi Ram Dr. C. Palaniswami Dr. A. Vennila Dr. R. Karuppaiyan Dr. T. Ramasubramanian Dr. P. Murali Dr. N. Thiraviam Mrs. Nici Ashok Mrs. Lalitha Rani Mr. S. Kandasamy

Title	Date	Participant (s)
National conference on Climate smart Agriculture for livelihood Security: Challenges and Opportunities at Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University, Tiruchirappalli.	13-14 September 2019	Dr. C. Sankaranarayanan
Technical Seminar on Improved Sugarcane Cultivation organized by Kothari Sugars and Chemicals Limited for Kattur Unit	26 September 2019	Dr. A. Vennila
Technical Seminar on Improved Sugarcane Cultivation by Kothari Sugars and Chemicals Limited for Sathamangalam Unit	27 September 2019	Dr. A. Vennila
Governing Council Meeting of KIAAR at Sameerwadi	30 September 2019	Dr. Bakshi Ram
Annual Convention on Deccan Sugars Technologists Association at Pune	01-02 October 2019	Dr. Bakshi Ram Dr. C. Appunu
Brainstorming session on Improving Sugarcane productivity, sugar recovery and quality held at Sugarcane Research Station, Cuddalore	04 October 2019	Dr. C. Palaniswami Dr. A. Annaduarai
AICRP (Sugarcane) Annual Group Meeting at University of Agricultural Sciences, Dharwad, Karnataka	14-16 October 2019	Dr. Bakshi Ram Dr. G. Hemaprabha Dr. R. Viswanathan Dr. K.P. Salin Dr. S. Alarmelu Dr. P. Govindaraj Dr. A. Annadurai Dr. Arjun Tayade Dr. N. Kulshreshta Dr. S.K. Pandey Dr. M.L. Chhabra Dr. Ravinder Kumar
50th Sugarcane Research & Development Workshop of Tamil Nadu & Puducherry at Singaperumal Kovil, Chennai	23-24 October 2019	Dr. Bakshi Ram Dr. G. Hemaprabha Dr. A.J. Prabakaran Dr. D. Puthira Pratap Dr A. Vennila Dr. C. Appunu
16th DUS Review Meeting held at NASC Complex, New Delhi	26 October 2019	Dr. M. R. Meena

Title	Date	Participant (s)
Core Group Agricultural Economists for studying impact of selected ICAR technologies at ICAR- NIAP, New Delhi	31 October 2019	Dr. P. Murali
National workshop on Impact Assessment of ICAR Technology organized by NIAP, New Delhi	08 November 2019	Dr. P. Murali
National Conference on Integrative plant Biotechnology & Biochemistry at ICAR-Indian Institute of Rice Research (IIRR), Hyderabad	08-09 November 2019	Dr. G.S. Suresha
57th Expert Committee meeting on ABS, National Bio Diversity Authority at Chennai	08-09 November 2019	Dr V. Venkata subramanian
XIX International Plant Protection Congress- 2019 held at ICRISAT, Hyderabad Telangana.	10-14 November 2019	Dr. N. Geetha Dr. B. Mahendran
International Tropical Agriculture Conference-TropAg 2019 held at Brisbane, Australia	11-13 November 2019	Dr. P. Prathima
2nd IUBMB Education Conference and 46th PSBMB Annual Convention hosted by Philippine Society of Biochemistry and Molecular Biology (PSBMB) at Manila Hotel, Manila City, Philippines	13-15 November 2019	Dr. M. R. Meena
'Ganna and Makka Kisan Mela' at CCS HAU, Regional Research station, Uchani, Karnal	14 November 2019	Dr. B. Parameswari Dr. Pooja
3rd International conference in plant and soil science	25-26 November 2019	Dr. P. Geetha
Core Group Agricultural Economists for studying impact of selected ICAR technologies at ICAR- NIAP, New Delhi	28 November 2019	Dr. P. Murali
International Conference on Human, Animal and Plant Mycoplasmas organized by National Centre for Microbial Resource (NCMR) and National Centre for Cell Science (NCCS), Pune, India.	02-05 December 2019	Dr. R. Manimekalai

Title	Date	Participant (s)
Brainstorming Session on Post-harvest Technology and Value Addition organized by ICAR-Sugarcane Breeding Institute (SBI), Coimbatore in association with Society for Sugarcane Research and Development (SSRD), Coimbatore and National Academy of Agricultural Sciences (NAAS) Regional Chapter, Coimbatore held at ICAR-SBI, Coimbatore	04 December 2019	All Scientists of ICAR-SBI, Coimbatore
International Conference on Genomics and Breeding for Crop Improvement held at Meerut, Uttar Pradesh.	04-06 December 2019	Dr. C. Appunu
Workshop on Phytoplasma Detection and Taxonomy organized by National Centre for Microbial Resource (NCMR) and National Centre for Cell Science (NCCS), Pune	05 December 2019	Dr. R. Manimekalai
Monitoring of AICRP (S) East Coast Zone	04-13 December 2019	Dr. S.K. Pandey
27th meeting of Board of Governing Council (Directors), Agricultural skill Council of India, (ASCI) at Gurugram, New Delhi	06 December 2019	Dr. V. Venkata subramanian
International Conference on Innovations in Plant and Animal Sciences for Sustainable Agriculture and Rural Development (IPASSARD 2019) at Rajasthan Agricultural Research Institute, (SKNAU), Jaipur	07-09 December 2019	Dr. P. Murali Dr. C. Appunu Dr. C. Mahadeaiah Dr. V. Sreenivasa
4th National workshop on KRISHI PORTAL and Nodal officer meeting at NASC, New Delhi.	10-11 December 2019	Dr. P. Murali
Seminar for developing curricula and syllabi for introducing a Ph.D program in Remote Sensing and Geographic Information System from the academic year 2020-21 organized at Department of Remote Sensing and GIS, Tamil Nadu Agricultural University, Coimbatore	13 December 2019	Dr. T. Arumuganathan
National Symposium on Potential Crops for Food and Nutritional Security held at Tamil Nadu Agricultural University, Coimbatore	14-15 December 2019	Dr. G. Hemaprabha Dr. R. Viswanathan Dr. H.K. Mahadevaswamy
32nd Biennial Workshop of All India Coordinated Research Project on Sugarcane at UAS, Dharwad	14-16 December 2019	Dr. Neeraj Kulshreshtha Dr. S.K. Pandey Dr. M. L. Chhabra Dr. Ravinder Kumar

Title	Date	Participant (s)
International Conference on Extension for Strengthening Agricultural Research and Development organized by ICAR –ATARI & ICAR –KVK, Suttur at Suttur	14-16 December 2019	Dr. D. Puthira Prathap
58th Expert Committee meeting on ABS, National Bio Diversity Authority at Chennai	16-17 December 2019	Dr. V. Venkatasubramanian
National Symposium on Mitigation of emerging plant diseases under changing climate scenario held at Tamil Nadu Agricultural University, Coimbatore	16-17 December 2019	Dr. R. Viswanathan Dr. A. Ramesh Sundar
National conference of Plant Physiology. Plant productivity and stress management at Kerala Agricultural University, Thrissur, Kerala	19-21 December 2019	Dr. R.M. Shanthi Dr. V.P. Sobhakumari Dr. R. Gomathi Dr. C. Appunu Dr. Valarmathi
Seminar on restructuring of primary and secondary education to address the issue of education curriculum weaning students from farmers and farming community organized by NAAS Haryana chapter at ICAR-National Dairy Research Institute, Karnal	20 December 2019	Dr. B. Parameswari
Review Meeting of SLSC, RKVY-RAFTAAR at Krishi Bhawan, Panchkula, Haryana	20 December 2019	Dr. S. K. Pandey Dr. Ravinder Kumar
Regional Farmers Day (Kisan Divas) at ICAR- CSSRI, Karnal	23 December 2019	All the scientists of ICAR- SBI-RC, Karnal
Joint TOLIC meeting of Karnal and Panipat held at Panipat Refinery	24 December 2019	Dr. S. K. Pandey Dr. M. R. Meena

16. DISTINGUISHED VISITORS

At Coimbatore

Eight Board of Directors from Natural Sugar Mills, Osmanabad, Maharashtra visited ICAR –SBI, Coimbatore on 21 May 2019 and they were appraised about the sugarcane research activities being carried out in the institute (Fig. 130).

Dr. W.S. Dhillon, ADG (Horticulture), ICAR, New Delhi visited ICAR-Sugarcane Breeding Institute on 06 June 2019 (Fig. 131).

Dr. M. Chakravarthy, Research Scientist, University of Florida delivered a lecture at ICAR –SBI on 08 July 2019.

Dr. R.B Doule, Chief Sugarcane Advisor, NFCSF, Dr. Baldev Singh, VC-PAU, Shri. Rana Inder Pratap Singh, MD Rana Sugars Ltd, Shri. Devender Singh IAS, MD Sugarfed (Punjab) and Shri Ajnala Shivaraj Pal Singh (Fig. 132).

Fig. 130. Board of Directors visiting Institute Museum (21 May 2019)

Fig. 131. Dr. Dhillon visiting Institute museum (6 June 2019)

Fig. 132. Visit of delegates (26 August 2019)

17. PERSONNEL

Name	Designation & Discipline	E-mail ID
Bakshi Ram Ph.D.	**Director**	**bryadav2003@yahoo.com**
Division of Crop Improvement		
G Hemaprabha Ph.D.	Pr. Scientist (Plant Breeding) & Head I/c	ghemaprabha1@gmail.com
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A. Anna Durai Ph.D.	Pr. Scientist (Plant Breeding)	ayyadu@gmail.com
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K. Elayaraja Ph.D.	Scientist (Plant Breeding)	elayarajagenetics@gmail.com
R. Valarmathi Ph.D.	Scientist (Eco. Bot. and PGR)	valarmathi.r@icar.gov.in
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A.K. Remadevi	Chief Technical Officer	A.K.Remadevi@icar.gov.in
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