SUGARCANE RESEARCH INSTITUTE

RESEARCH PROGRESS

2012 - 2022

CONTENTS

Introduction

The year 2022 is marks 38th year of the Sugarcane Research Institute (SRI) since its main research station was inaugurated in Kantale in the year 1984. SRI gave the leadership and assistance to the sugar industry by conducting research, extension and development activities under the nine research divisions up to the year 2010. At present, research, extension and development activities in SRI are being conducted under the seven programs i.e. crop improvement, crop and resource management, crop nutrition, crop protection, processing and product development, farm mechanization and technology transfer and development under the following eight research divisions to strength systematically its role of research, technology transfer and development activities effectively:

1. Crop Improvement
2. Crop and Resource Management
3. Crop Nutrition
4. Crop Protection
5. Processing Technology
6. Mechanization Technology
7. Economics, Biometry and Information Technology
8. Technology Transfer and Development

The crop improvement program aims at developing sugarcane varieties superior to the existing ones. It is a multi-disciplinary and multi-staged program conducted with the involvement of all research divisions of the institute. The crop and resource management program is mainly conducted by Crop and Resource Management and Economics, Biometry and Information Technology Divisions. It aims at recommending crop management practices to increase productivity, minimize cost and/or increase incomes with greater stability by more efficient utilization of sugarcane lands and water by diversified farming. The crop nutrition program is conducted mainly for recommending soil and fertility management practices for sugarcane by the Crop Nutrition Division. The crop protection program is undertaken to recommend practices for controlling diseases and pests and to provide crop protection services to prevent from and/or control of diseases and pests in sugarcane plantations by the Crop Protection Division. The processing and sugarcane-based product development is conducted by the Processing Technology Division to increase efficiency of processing of sugarcane and its by-products and to develop sugarcane-based products for diversification of the sugarcane industry. The farm mechanization program targets at developing mechanization technologies to increase efficiency of farming practices and reduce cost. The Mechanization Technology Division gives the leadership for this. Economics, Biometry and Information Technology Division undertakes economic and biometrical researches and analyses related to the main research programs. The Technology Transfer and Development Division transfers the findings of the above-mentioned research programs to cane growers/millers/sugar companies to promote adoption of new technologies and improved management practices for the development of the sugarcane industry of Sri Lanka. This report presents the achievements in each research division of SRI in the below eight sections.

1. Crop Improvement Division

The Division of Crop Improvement of SRI has focus mainly on conventional breeding for the development of high cane and sugar yielding, pest and disease resistant sugarcane varieties suitable for cultivation in commercial fields under different agro-ecological regions in the country. The division conducted three major research projects; (i) collection conservation evaluation and utilization of *Saccharum* germplasm, (ii) sugarcane hybridization and clonal selection, (iii) sugarcane tissue culture and sugarcane biotechnology. The project sugarcane tissue culture and biotechnology assists the conventional sugarcane breeding in the creation of genetic variability through somaclonal variation and classification and identification of genetic variability in development of new sugarcane varieties. Development of disease free sugarcane plants is done through mericloning.

1.1 Goals/objectives of the division

Increasing productivity and profitability of the sugar industry through incorporation of better sugarcane varieties for commercial cultivation

1.2 Priority areas of the division

i. Collection, conservation, evaluation and utilization of *Saccharum* germplasm.
ii. Hybridization of sugarcane to develop varieties with high cane and sugar yields, resistance to major disease, early, mid and late maturity, good ratooning ability and tolerance to drought for rain-fed and irrigated cultivation in different sugarcane-growing areas in Sri Lanka.
iii. Selection of sugarcane clones with commercial attributes, determining proven parents and proven crossing combinations, selecting true hybrids of inter-specific, inter-generic and backcrosses in the mobilization of wild species.
iv. Tissue culture of sugarcane to develop new sub-clones resistant to diseases from disease susceptible high-yielding varieties, produce disease-free planting materials from newly-released varieties for rapid multiplication by *in-vitro* culture and lateral shoot multiplication under poly tunnel conditions, develop disease elimination techniques, and to produce in-vitro-cultured materials for varietal exportation.
v. Studying molecular biology of sugarcane varieties to identify genetic relatedness and distinctness among commercial and locally-collected sugarcane varieties, confirm the identity of varieties through parental identification, identify of true hybrids, and the molecular markers for high-yielding varieties with disease resistance, and to adopt marker-assisted selection in the existing breeding program and studying the gene expression during maturity of sugarcane.

1.3 Summary of the achievements in each priority area

This section carries the achievements of the research projects conducted by the Crop Improvement Division during the year 2012-2022.

1.3.1 Enrichment of *Saccharum* germplasm through variety exchange programs

- Ninety-three (93) sugarcane varieties were imported from Pakistan under the collaborative research project “Sugarcane plant improvement through traditional and modern breeding

technologies" with the Sugarcane Research Institute, Faisalabad, Shakarganj Sugar Research Institute, Jhang-Punjab and Agricultural Biotechnology Institute, Faisalabad, Pakistan.

- One hundred sugarcane varieties and fuzz samples generated from 1800 crosses were exported to Pakistan.
- Six sugarcane varieties were imported from Sugar Research Australia and nine locally-developed improved varieties were dispatched to Sugar Research Australia.
- Thirty three sugarcane varieties were imported from Vietnam and Sri Lanka has dispatched 32 sugarcane varieties to Vietnam. Only 20 varieties were released from quarantine station, Hantana and others were destroyed due to abnormal yellowing of leaves and some pests.
- Importation of 40 improved sugarcane varieties and true seeds from 65 proven crosses from the Yunnan Sugarcane Research Institute of Yunnan Academy of Agricultural Sciences of People's Republic of China. Ninety-three sugarcane accessions and fuzz samples generated from 20 crosses were exported to People's Republic of China.

1.3.2 Enrichment of *Saccharum* germplasm through local expedition

- Ninety-six sugarcane accessions were collected and incorporated during local expedition from Matale, Kandy and Nuwara Eliya Districts.
- Seventy-five accessions were collected and incorporated during local expedition from Matara, Galle and Kalutara Districts.
- Adding 70 *Saccharum officinarum*, 3 *Saccharum spontaneum* and 2 *Erianthus rockii* accessions to the existing *Saccharum* germplasm collection. These accessions were collected during the local germplasm expedition undertaken in Kandy and Matale Districts.
- Adding 80 *Saccharum officinarum* and *Saccharum spontaneum* accessions to the existing *Saccharum* germplasm collection. These accessions were collected during the germplasm expedition undertaken in Nuwara Eliya Districts.

1.3.3 Evaluation of *Saccharum* germplasm

- Evaluating 1,000 germplasm accessions for their breeding values for cane and sugar yield components. The accessions with high breeding values for cane and sugar yield parameters can be used as parents for directional breeding for sugar and cane yields.
- Evaluating 500 sugarcane accessions for breeding of new sugarcane varieties for resistance to smut, leaf scald and white leaf diseases.
- Identification of phenotypic correlation among the cane and sugar yield and fiber content.
- Preparation of germplasm catalogue *(e-version)* for 500 sugarcane accessions evaluated under NRC funded project (Grant no. 15-030).
- Development of parental core-collections for high cane and sugar yield, disease resistance (smut/leaf scald/white leaf) based on breeding values of accessions and directional and simultaneous breeding for the above characteristics.
- Development of computer program for identification of proven crosses.

1.3.4 Hybridization of sugarcane

- A total of 1171 crosses were done at Enselwatta hybridization garden and at the Sugarcane Quarantine Station, Ooduwella Estate, Hantane during 2012 crossing season under the 2012 series and for fuzz exportation program with Pakistan.

- A total of 1534 crosses were done at the Sugarcane Breeding Sub-Station, Enselwatte, Deniyaya and at the Sugarcane Quarantine Station, Ooduwella Estate, Hantane during 2013 crossing season under the 2013 series and for fuzz exportation program with Pakistan.
- A total of 1770, 1650 and 974 crosses respectively, were done during 2014, 2015 and 2016 crossing seasons using the field lantern and solution crossing techniques at the Sugarcane Breeding Sub-Station, Enselwatte, Deniyaya. Few crosses (30) were directed for QTL mapping for sugar content.
- A total of 1094 and 1209 crosses respectively, were done during 2017 and 2018 crossing seasons using the field lantern and solution crossing techniques at the Sugarcane Breeding Sub-Station, Enselwatte, Deniyaya.
- A total of 1238, 1270, 1025 and 908 crosses respectively, were done during 2019, 2020, 2021 and 2022 crossing seasons using the field lantern and solution crossing techniques at the Sugarcane Breeding Sub-Station, Enselwatte, Deniyaya. These crosses are directional for sugar and cane yield improvement and disease resistance (smut, leaf scald and white leaf diseases) and QTL mapping for disease resistance.

1.3.5 Sugarcane variety selection

- Two hundred and eighty-three varieties belongs to 2002 – 2011 series are being evaluated in Replicated Yield Trials (RYT) at Uda Walawe and large blocks evaluation at different sugarcane growing areas.
- The varieties SL 86 13 and SL 92 5588 were identified as the suitable varieties for cultivation in WLD-prone environments.
- The varieties SL 86 13, SL 92 5588 and the promising varieties SL 99 3384, SL 89 309 and SL 95 4225 were identified as the suitable parents for hybridization program due to their low incidences of WLD.

1.3.6. Sugarcane tissue culture

Callus culture technique

- About 3000 cali-clones were established in stage 1 of the each clonal selection program per year until 2016.
- Undifferentiated callus of SL 98 2087, Co 775 and SL 98 2118 was exposed to gamma rays. The treatment number 4 (22 Gy) and 5 (25 Gy) are most suitable treatments to develop mutations genetically.

Meristem culture technique

- Meri clones of nine commercial sugarcane varieties SL 83 06, SL 90 6237, SL 92 4918, SL 95 4430, SL 95 4033, SL 96 128, SL 96 328, SL 98 2524 and SL 97 1442 were produced and exported them to Australia under collaborative variety exchange program.
- Production of 8000 mericloned plants of the variety SL 83 06 and 3000 of variety SL 95 4033 and SL 95 4430 supplied to the farm for seed multiplication.
- Meri clones of 43770, 19190 and 14175 of commercial sugarcane varieties were dispatched to the Lanka Sugar Company Ltd., Pelwatte and Sevanagal, Gal Oya plantations, Hingurana respectively, for their nursery program during 2012 to 2016.
- Developing an *in-vitro* culture protocol for elimination of Sugarcane Bacilliform Virus (SCBV) from infected sugarcane. The disease can be eliminated through manipulating the *ex-plant* size 0.5 mm -1.5 mm.

- Developing an *in-vitro* culture protocol for eliminating Sugarcane Streak Mosaic Virus (SCSMV) from infected sugarcane. Chemotherapy (Ribavirin and Aciherpin), thermotherapy (1 min., 3 min. and 5 min. in 37 ^{0}C, 1 min., 3 min. and 5 min. in 40 ^{0}C and 1 min., 3 min. and 5 min. in 42 ^{0}C) and different size of *ex-plants* (0.5 mm, 1 mm and 1.5 mm, 3 mm and 5 mm) were used as treatments. The mericlones produced in Ribavirin (30 mg/L) incorporated tissue culture media free from SCSMV.
- Developing an *in-vitro* culture protocol for eliminating Sugarcane White Leaf disease (WLD) from infected sugarcane. The disease can be eliminated through manipulate the *ex-plant* size 0.5 mm -1.5 mm.
- Findings of *in-vitro* direct plant generation for sugarcane.

Suggested protocol for *in-vitro* direct plant generation for sugarcane

	Process	**Description**
1.	*Ex-plant* preparation	Best age of the mother plant is five to six months (Mother plants should be originated through mericloning) *Ex-plants* size is 3 mm in diameter and 2 mm in thickness
2.	Preparation of culture medium supplemented with phyto- hormone combinations	Benzylaminopurine (BAP) 1.5 mg/L, Kinetin 0.5 mg/L, 2,4-D 0.5 mg/L, IAA mg/L and Cysteine Hydrocholride 400 mg/L
3.	Dark incubation	Two weeks of initial dark incubation
4.	Light incubation	*Ex-plants* after dark incubation should be transferred to light and 10 weeks of light incubation generates highest number of shoots
5.	Rooting	Two weeks in rooting media
6.	Hardening process	Transfer to poly-tunnel at the age of 14 weeks of incubation

- The phyto-hormone combination with 1.5 mg/L of BA, 0.5 mg/L of Kinetin together with 0.5 mg/L of 2,4-D, 1 mg/L of IAA and 400 mg/L of Cysteine Hydrochloride was identified as the best hormone combination to use with modified MS medium for direct plant regeneration.

1.3.7 Biotechnology for sugarcane

- Characterization of 900 accessions from sugarcane germplasm using simple sequence repeat (SSR) technique
  - Identifying six genotypically more or less similar clusters from 25 *Saccharum spontaneum* accessions.
  - Identifying five divergent groups between 81 *Saccharum officinarum* accessions tested and sugarcane accessions from the same geographical regions tend to cluster with the same group.
  - The accessions collected through local expedition were clustered with Badila confirming that Sri Lanka is enrich with pure *S. officinarum*.
  - The varieties imported from Pakistan are clustered with pure *S. officinarum* accessions. Therefore, it has a genetic relationship with the pure *S. officinarum.*
  - The genetic variability is poor in locally developed sugarcane hybrids.

- Developing a PCR based disease identification protocol for Sugarcane Streak Mosaic Virus (SCSMV).
- Identification of sugarcane streak mosaic virus isolates related to the Indian and Iran strains from locally collected sugarcane accessions and sequence data submitted to the GenBank as SRI-SL1 (GenBank accession no: MK994186.1).
- Sugarcane streak mosaic virus (SCSMV) and WLD infected parents can transmit the respective disease to F1 progeny through hybridization. Sugarcane WLD and SCSMV can be transmitted through true-seeds.
- Identifying 16 superior inter-specific hybrid progenies from *Saccharum officinarum* × *Saccharum spontaneum* crosses for back crossing leading to development of superior commercial sugarcane varieties with high cane and sugar yields and biotic and abiotic stresses.
- The genetic similarity between the regenerated-plantlets is comparatively higher than the plants generated through seed setts.

1.4 Recommended sugarcane varieties for commercial cultivation

- The sugarcane variety releasing committee recommended varieties namely; SL 90 6237, SL 95 4443 and SL 96 128 and were subsequently released for commercial cultivation in year 2012.
- The sugarcane variety, SL 98 2524 recommended for commercial cultivation in the year 2015. This variety was named as “Krishna” for the admirable work extended to the Sugarcane Research Institute by world renowned sugarcane breeder late Dr. M Krishnamurthi.
- Releasing five new-improved sugarcane varieties; SL 00 95, SL 00 354, SL 00 603, SL 00 652, and SL 04 624 for commercial cultivation. The varieties SL 00 95, SL 00 603 and SL 00 652 were for cultivation under both irrigated and rain-fed conditions, the variety SL 00 354 was for cultivation under irrigation only. The variety SL 04 624 was for jaggery production.

2. Crop and Resource Management Division

The Crop and Resource Management (CRM) Division is doing sugarcane agronomic researches to identify and recommend better crop management technologies from land preparation to harvesting that maximize productivity and profitability of sugarcane cultivation. The division mainly focuses on how the existing resources are utilized to achieve better crop growth and finally produce maximum sugar yield.

2.1 Goals/objectives of the division

Increase productivity of sugarcane lands and profitability of sugarcane farming in a sustainable manner through appropriate improved crop, land and water management practices.

2.2 Priority areas of the division

The CRM divisional program was conducted under the following priority areas.

i. Sugarcane variety testing
ii. Crop physiology
iii. Cultural practices
iv. Weed management
v. Water management
vi. Sugarcane-based farming systems
vii. Sugarcane development projects

2.3 Summary of the achievements in each priority area

The summary of the progress and achievements during last 10 year period are as follows based on the each priority area.

2.3.1 Sugarcane variety testing

- Identification of agronomic and physiological characteristics in Co 775, SLI 121, M 438/59, SL 7103, SL 7130, SL 8306, SL 8613 and SL 88116 under irrigated and rain-fed conditions at Uda Walawe.
- Identification of better-ratooning varieties: SL 90 6237 and SL 93 945 for both rain-fed and supplementary irrigated conditions and SL 92 4918 for supplementary irrigated conditions.
- Large scale field evaluation of eight near commercial varieties of 1997 and 1998 series at the locations of Sevanagala, Pelwatte and Hingurana for identifying superior varieties to release for commercial cultivation.
- Identifying the genetic potential of sugarcane and its wild relatives (*Saccharum spontaneum and Erianthus arundinaceous*) for improvement of shoot and root growth and drought tolerance.
- Identifying maturity patterns of SL 2000 series varieties. The variety SL 00 95 recorded highest POCS% compared to all other varieties in the series and retained greater than 12% POCS from 10 to 16 months. The SL 00 95, SL 00 354, SL 00 603, and SL 00 652 were identified as mid maturing varieties (Mature at 12-14 months age).
- Identification of variation in Pol% cane in varieties Co 775, SL 71 30, SL 83 06, SL 88 116, SL 90 6237, SL 92 4918, SL 96 128 and SL 96 328 versus crop age in collaboration with Lanka Sugar Company Pvt (Ltd) Sevanagala.

- Identification of the variation in juice quality parameters with crop age of 2003 series varieties i.e. SL 03 336, SL 03 341, SL 03 425, SL 03 442, SL 03 762, SL 03 983, SL 03 1025, SL 03 1077, SL 03 1134, SL 03 5428, SL 03 5441 and SL 03 5445 when the crop was planted in both *Maha* and *Yala* seasons. SL 03 983 was identified as early matured variety (Matured at 10-11 months age). All other varieties were identified as mid maturing (Mature at 12-14 months age) varieties. SL 03 983, SL 03 5428, SL 03 5441 and SL 03 5445 were recorded significantly high POCS% compared to Standard (Co 775) variety.
- Identification of the response of the varieties Co 775, SL 71 30, SL 83 06, SL 88 116, SL 90 6237, SL 92 4918, SL 96 128 and SL 96 328 to the changing climate and soil conditions in different locations in Sri Lanka.
- Identification of the effects of elevated temperature and CO_2 on agronomic and physiological characteristics in the varieties Co 775, SL 71 30, SL 83 06, SL 88 116, SL 90 6237, SL 92 4918, SL 96 128 and SL 96 328 at Uda Walawe.

2.3.2 Cultural practices

- Confirmed that mulching of sugarcane fields with cane trash and *gliricidia* leaves has significant positive effects on cane yield under rain-fed conditions.
- Successfully completed large scale evaluation and economic analysis of spaced transplanting technique (STP) as an economical propagation method of sugarcane.
- Identification of green gram (*Vigna radiata*) and Sunhemp (*Crotalaria juncea*) as a good green manure species to improve sugarcane grown soils.
- Identification of that, application of polythene mulch increase tilletring capacity of sugarcane crop under rain-fed condition.

2.3.3 Weed management

- Identifying troublesome creeping weed "*kiriwel*" which reported in Sevanagala sugarcane plantations as *Ichnocarpus frutescens* (L.) R. Br. in the family Apocynaceae and its propagation and spreading behaviour in Sevanagala sugarcane fields.
- Confirmation of application of "kerosene oil" as an effective treatment in controlling problematic creeping weed in sugarcane, *Ichnocarpus frutensus* "*kiriwel*" and recommending application 20 – 50 ml "kerosene oil" at the base depending on thickness of stem 3 – 5 mm and repetition of this treatment 2 - 3 times on regenerated and unaffected plants until killing the plant.
- Identifying that Diuron + Basta herbicide mixture at the rate of 3-4 kg + 1-2 L/ha was an alternative to banded herbicides Paraquat for controlling weeds in sugarcane.
- Identification of effective new herbicides, Glufosinate ammonium 280 g/L SL to control weeds in sugarcane at post-emergent stage.
- Confirmed that Glufossinate ammonium 280 g/L SL is not suitable herbicide to apply at early stage of sugarcane growth since higher crop damage and retarded growth.
- Recommending the herbicide, Glufosinate ammonium 150 g/L (Basta), at the rate of 0.75 – 1.5 L/ha as an alternative to the restricted herbicide, Paraquat, and to be applied mixing with Diuron to control weeds in sugarcane.
- Confirmation of "Palagonic acid 57%" as an effective herbicide that could be used to control weeds at early post-emergent stages of weeds and best performing concentration of this weedicide was application of 4 - 5% solution (6 – 8 a.i. kg/ha) for controlling weeds in sugarcane.

- Recommending application of Diuron 46.8% + Hexazinone 13.2% formulation at the rate of 3.0-3.5 kg/ha mixing with 350-400 L of water, at pre-emergent stage to control grasses and broad-leaved weeds in sugarcane.
- Identifying that application of new herbicides, Hexazinone 25% SL and Isoxaflutole 75 WG are effective to control weeds in sugarcane fields at pre-emergent stage.
- Studying the effect of Isoxaflutole 75 WG in detail, for weed controlling in sugarcane and identification of that, application of 175 g/ha mixing with 450 L of water at pre-emergent stage is effectively control weeds in sugarcane fields.
- Re-evaluation of Diuron 80 WP and Metribuzin 70 WG herbicide as pre-emergent herbicides for weed controlling in sugarcane as pilot scale testing at Sevanagala.
- Identifying that application of new herbicides, Tiafenacil 5% ME is effective to control weeds in sugarcane at post-emergent stage.
- Identification of effective new herbicides, Tembotrione to control weeds in sugarcane at pre-emergent stage.
- Identification of effective new herbicides, Imazapic 240 g/L SL to control weeds in sugarcane at pre-emergent stage.

2.3.4 Water management

- Identification of that, alternate-row furrow irrigation technique was successful for *Maha* planting sugarcane in reducing irrigation water requirement without yield loss and confirming that the alternate-row furrow irrigation method saves 35 – 42% of irrigation water and irrigation labor cost while maintaining yield as in every furrow irrigation.
- Developing location specific irrigation schedules based on rainfall, evaporation, soil properties and crop requirement to increase irrigation efficiency at Hingurana sugar project by increasing field application efficiency. Two zones (A and B) were demarcated based on irrigation interval values, and the zone A requires irrigation at 6-8-day intervals and zone B requires irrigation 8 – 10-day intervals. The requirement of irrigation depths for zone A and B in one irrigation were 49 mm and 39 mm respectively.
- Developing a new drainage layout for safe removal of rainfall run-off water on undulating terrain. This study confirmed the significant reduction of soil erosion (gully formation) due to new design in sugarcane fields in Uda Walawe and Sevanagala.
- Optimizing planting schedules of sugarcane for saving irrigation water in Sevanagala and Uda Walawe, Sri Lanka.
- Recommendations were given for management of physical properties of reddish brown earth soils at Uda Walawe for sustainable sugarcane production.
- Identification of measures for rectifying ratoon yield declining issue in Hingurana sugarcane plantation.
- Developing a GIS model for selecting suitable water pumps with appropriate power for lift irrigation of farmers' fields in the rain-fed sector at Sevanagala.
- Introduction of newly design, low-cost and easy handling device for furrow line demarcating in furrow bed preparation.
- Studying the effect of starch based super-absorbent (ZEBA) on growth and yield of sugarcane in Uda Walawe, Sri Lanka and it revealed that the application of ZEBA can enhance the sugarcane yield only under 10 days irrigation intervals. So that, application of ZEBA cannot be used as a management tool for increasing irrigation intervals aiming at irrigation water saving.
- Cost analysis and giving recommendation for commencing sprinkler irrigation project in Sevanagala.

- Development of a tipping bucket device for measuring runoff in small catchments.
- Identification of climate change projections and their consequences on agro-climate in sugarcane growing areas of Sevanagala, Sri Lanka.
- Estimating the climatic threat due to dry spells in rain-fed sugarcane cultivation.
- Developing a mathematical model to simulate sugarcane crop canopy height and the leaf area index in commercial plantations using GIS technology.
- Assessment of potential of solar powered lift irrigation technology for Sri Lanka.
- Developing an appropriate technology to estimate effective rainfall in sugarcane plantations in Sri Lanka.
- Identification of probable reasons for low ratoon yield related with water management situation in Hingurana.

2.3.5 Sugarcane-based farming systems

- Identification of that, sugarcane tops left behind after harvesting cane fields is a widely available and potential roughage that could be fed to cattle.
- Identification of that none of the farmers in Hingurana area used sugarcane top in a useful manner; it is either burnt in-situ or left as a soil mulch.
- Production of sugarcane top based fresh rations and silage and introducing to dairy cattle.
  Fresh ration: Ration 1: Chopped sugarcane tops 5 kg + 200 g molasses, Ration 2: Chopped sugarcane tops 3 kg + Concentrate 2 kg (Concentrate formula: Rice bran 96.5%, Urea 1.0% and dicalcium phosphate 2.5%).
  Sugarcane top silage: 1-1.5 inch size small pieces of sugarcane tops mixed with molasses (2-3% weight of cane tops) and tightly packing in plastic barrels or polythene bags and store for 3-4 weeks.
- Analysis of nutritional quality of sugarcane top silage compared to commonly used *Gini* grass silage.
- Identification of that the preservation of cane tops as silage is a highly palatable feeding method for dairy cattle.
- Conducting demonstrations of sugarcane top ration preparation to dairy farmers in Hingurana.
- Developing management techniques to use cattle-shed waste as manure to sugarcane fields and integrating management practices of dairy cattle husbandry with sugarcane.
- Developing a rotational system of sugarcane cultivation for medium- to large-scale sugarcane farms by introducing staggered planting system and integrating management practices of dairy cattle husbandry in to this system by adding cow dung and cattle shed waste as manure to sugarcane fields during fallowing parts of land to facilitate soil re-habitation, feeding cane tops-based rations to dairy cattle, in order to develop an integrated system of sugarcane cultivation and dairy cattle management.

2.3.6 Sugarcane development project in Kilinochchi

- Established 8 ha (20 ac) sugarcane plantation in 23 farmers field in Kilinochchi in *Maha* season 2012 using 50 t of seedcane obtained from 07 multiplication plots established with SL 83 06 in Skandapuram, Kilinochchi in 2011 and starting jaggery production successfully in 2012.
- Expanding sugarcane plantations by 3.4 ha belonging to 18 farmers in Skandapuram, Anavillunthan, Vennarikulum, Maniyakulum and Kannagipurum areas in Kilinochchi District.

- Developing land for proposed sugarcane nursery in Vennarikulum and preparing 4 ha for sugarcane planting in 2015.
- Establishment and maintenance of about 3.5 ha nursery in Vannerikulum, Kilinochchi and production of 150-200 t of cane. In addition, a research on jaggery processing was successfully conducted. Also, 1469.5 kg of Jaggery and 40 bottles of syrup were produced from harvested cane of 35466 kg.
- Maintaining 3.5 ha nursery at Vannerikulum, Kilinochchi and harvesting 10 t of seedcane for planting in the farm belonging to the Civil Security Department (CSD) in Vishvamadu in 2017.
- Identification of 30 new farmers to start sugarcane cultivation relevant to the Kilinochchi sugarcane development project in 2018.
- Providing technical support for establishing the sugarcane processing unit at Anavillunthan.
- Establishment of a building for starting sugarcane processing unit at Vishvamadu, Bharathipuram farm in collaboration with CSD.
- Maintaining 3.0 ha nursery at Vannerikulum, Kilinochchi and harvesting 15 t of seedcane for planting in the farm belonging to the CSD in Vishvamadu and Establishing and maintaining new sugarcane plantation of about 2 ha in Vishvamadu, Bharathipuram farm in collaboration with the CSD in 2018.
- Providing technical support to established 15 ac sugarcane plantations in 45 farmer's fields at Anavillunthan, Kilinochchi in 2019.
- Completion of supplying utensils (Sugarcane crusher with engine, jaggery pans, jaggery moulds and spoons) for jaggery processing unit at Anavillunthan in 2019.
- Construction a new security hut at Kilinochchi substation.
- Providing technical support to maintain 15 ac sugarcane plantations in 45 farmer's fields at Anavillunthan, Kilinochchi.
- Providing seedcane to establish 1 ac plantation at Skandapuram.
- Establishing 2.75 ac new plantations in farmer's fields at Anavillunthan and 2.0 ac plantation in Vishvamadu CSD farm in 2020.
- Starting the manufacturing of jaggery/syrup in Anavillunthan processing unit, Kilinochchi. collaboratively with sugarcane cultivators society at Anavillunthan in 2020
- Starting a sugarcane juice selling center at Kilinochchi in 2020 collaboratively with private entrepreneur.
- Processing of 20 t of sugarcane and produced 226 kg of jaggery and 661 L of syrup (880 bottles) in 2020.
- Supplying of sugarcane crusher and jaggery processing utensils to Vishvamadu CSD farm in 2020.
- Expansion of sugarcane cultivation to Skandapuram area in Kilinochchi and providing technical support to maintain 1 ac plantation at Skandapuram in 2021.
- Introducing jaggery and syrup for Kilinochchi local market by Anavillunthan processing unit in 2021.

2.4 Recommendations to be issued to stakeholders

Thematic area	Recommendations/technologies/knowledge developed
Sugarcane variety testing	Recommendation on better ratooning varieties under irrigated and rain-fed conditions
	Recommendation on maturity pattern/proper maturity time of 1996, 1998 and 2000 series varieties
Crop physiology	Knowledge generation on growth physiology and yield of commercial sugarcane varieties under irrigated and rain-fed conditions in *Yala* and *Maha* seasons at different locations
	Knowledge generation on the response of growth physiology and yield of commercial sugarcane varieties to the simulated future climatic conditions (elevated air temperature and CO_2)
Cultural practices	Recommendations on land preparation techniques (depth of ploughing), planting techniques (spaced and space transplanting technique), inter-row cultivations, irrigation, weed controlling, planting density, seed rate, trash management, *Gliricidia* and trash mulching and ratoon management practices
Weed management	Recommendations on weed management in sugarcane cultivations
	Introducing weedicides for sugarcane weed management
	Recommendation of weedicide spray nozzle
	Recommendations on problematic weed species management (*Ichnocarpus frutescens*-Kiri Wel)
Water management	Introduction of new device for demarcating furrow lines for sugarcane fields
	Introduction of location specific irrigation schedule for Hingurana
	Introduction of optimum furrow length and slope for maximizing irrigation efficiency in Hingurana
	Introduction of new land drainage layout for minimizing soil erosion through safe removal of runoff water
	Introduction of optimum furrow length for maximizing irrigation efficiency in Sevanagala
	Introduction of optimum land layout for maximizing sugarcane harvester efficiency in Sevanagala
	Introduction of GIS model for selecting suitable water pumps with appropriate power for lift irrigation of farmers' fields in the rain-fed sector at Sevanagala
	Introduction of alternate-row furrow irrigation technique
	Introduction of optimizing planting schedules of sugarcane for saving irrigation water in Sevanagala and Uda Walawe
	Introduction of sub surface drip irrigation technology for Sevanagala
	Introduction of polythene based water ponds for Sevanagala
	Development of tipping bucket device for measuring runoff in small catchments
	Introduction of optimum land layout for maximizing sugarcane harvester efficiency in Sevanagala
Sugarcane-based farming systems	Recommendations for sugarcane intercropping practices

	Introduction of sugarcane top based cattle feed
	Integration of sugarcane and cattle management as a farming system
Sugarcane development projects	Introduction of suitable sugarcane varieties for Kilinochchi area
	Expansion of sugarcane cultivation and introduction of jaggery and syrup processing technology to Northern province

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3. Crop Nutrition Division

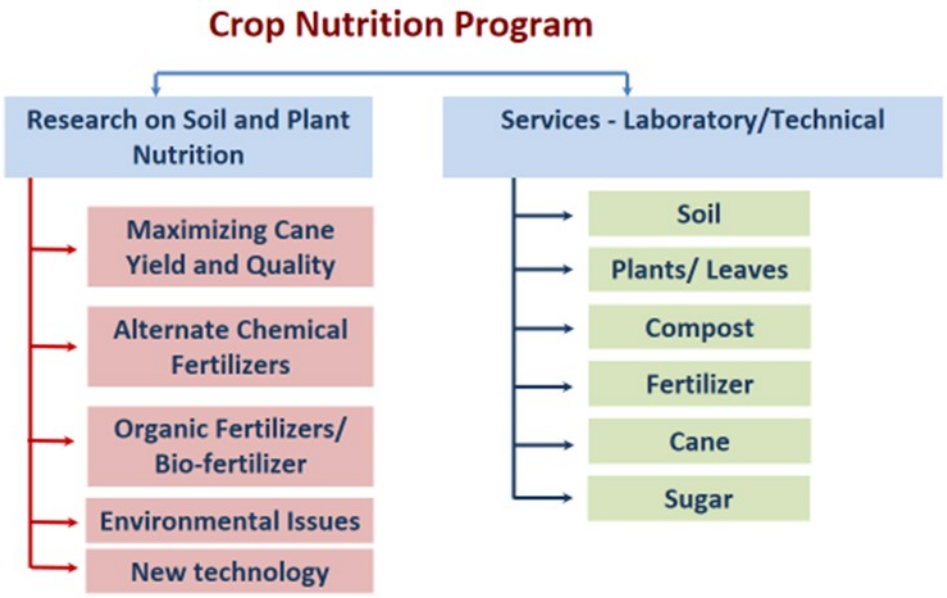
Sugarcane Crop Nutrition is one of the main thrust areas of research and development at the Sugarcane Research Institute since 1984. During the mid-1990's, research had been focused to get knowledge on the fertility status of sugarcane-growing soils, fertilizer application efficiencies and the quantities of nutrient removed with the properly conducted fertility trials. However, the planned work at the Sugarcane Research Institute had been interrupted during the period from 2000 -2004, due to number of issues related to human resources availability. After 2009, the Crop nutrition program was re-designed to achieve the program goals considering the importance of all sub-sections and also use of advanced technology for better sugarcane cultivation in the country.

3.1 Goals/objectives of the division

The crop nutrition divisional goal is, to work for a sustainable increase in productivity and profitability of the sugar industry through improved soil fertility.

3.2 Priority areas of the division

The following flow diagram highlighted the important sub-sections planned to be executed in the crop nutrition program.



3.3 Summary of achievements in soil and plant nutrition

3.3.1 Maximizing cane yield and quality

- The main highlights of the research work completed before year 2004 included, determination of optimum nutrient requirements for sugarcane, nutrient removal from soil, fertilizer application times and cane yield productivity classes under rain-fed and irrigated conditions. However, there were many limitations in the results and needed further clarifications. As there was a dearth of information on fertilizer recommendations and fertilizer response of sugarcane in Sri Lanka, studies were initiated accordingly.

- A study was carried out to investigate the effects of N, P and K on yield and cane quality of the plant crop and the first ratoon crop of two new sugarcane varieties, SL 96 128 and SL 96 328 and determines the most economic level of N. A field trial was carried out in a confounded factorial design with 18 treatment combinations with 5 levels of N and 4 levels of each P and K, and 3 replicates at the research farm of the Sugarcane Research Institute (SRI), Uda Walawe from September 2010 to November 2011. Cane yield and quality parameters such as brix, pol, and fibre percent of cane were measured and pure obtainable cane sugar (POCS) was calculated at harvest of 12-month-old crop. Sugar yields were estimated using cane yield and POCS. The analysis of variance was performed on cane yield, POCS and sugar yield to examine the effects of N, P and K on these three variables. The most economic level of nutrients was determined by estimating the income and value: cost ratios for each fertilizer level. The results showed that the both varieties were responsive to N, and not so to P and K. Both the plant crop and the ratoon crop showed similar pattern of response to N. The most economic level of N for the variety SL 96 128 was between 150 and 200 and that for the variety SL 96 328 was between 100 and 150.
- The next study was carried out to investigate the effects of N, P and K on yield and quality of sugarcane cultivated on *Alfisol* soil under rain-fed and irrigated conditions. A field trial in 3^3 factorial structured Randomised Complete Block Design was carried out under each condition, with 27 treatment combinations comprising of three levels of each N (0, 150 and 300 kg/ha), P (0, 30 and 60 kg/ha) and K (0, 150 and 300 kg/ha) at the research farm of SRI, Uda Walawe, Sri Lanka, from 2012-2016 for the plant crop and three ratoon crops of the variety SL 83 06. Cane yield and quality parameters namely brix, pol and fibre percent of cane were determined to estimate pure obtainable cane sugar (POCS) at harvest of a 12-month old crop. Sugar yield was estimated using cane yield and POCS. Analysis of variance was performed on cane yield, POCS and sugar yield to examine the effects of N, P and K on these three variables. The results showed that in the plant crop and three ratoon crops under both rain-fed and irrigation, cane yield and sugar yield at 150 kg of N per ha was significantly ($P<0.05$) higher than that without added N. Potassium and, N and K interactions affected cane and sugar yield significantly however, inconsistent. On the other hand there was no significant effect of P on both cane and sugar yields of plant crop and ratoon crops under both growing regimes. The results revealed the need for application of nitrogen and potassium at 150 kg/ha for achieving higher cane and sugar yields and monitoring P levels to maintain the fertility of the soil.
- Previous and current information, and soil analysis was used to provide fertilizer recommendations for sugarcane-growing soils. Thereafter the situation was to upgrade the procedure of providing fertilizer recommendations and extending up to site-specific level. This was initiated as a model considering rain-fed and irrigated cropping systems in one location at Sevanagala and carried out series of studies to develop a fertilizer recommendation on a scientific basis and extend it up to site-specific level. Detail surveys and fertilizer response trials were executed. Further, technology is used to digitise maps, develop nutrient maps for the areas and use images (drone and satellite images) to predict characteristics of the crop.

3.3.2 Alternate chemical and mineral fertilizers

The importance of identifying alternate fertilizers was considered and carried out studies wherever possible. As an initial step alternate fertilizer for the Phosphorous source was carried out.

- The study evaluated the possibility of incorporating High-grade Eppawala Rock Phosphate (HERP) as an alternative to Triple Super Phosphate (TSP), a Phosphorous (P) fertilizer for

sugarcane cultivation in Sri Lanka. A field trial was carried out with 6 treatments comprising of different levels of TSP and HERP in a Randomised Complete Block Design (RCBD) with 3 replicates at Kowul-Ara, Sevanagala from October 2007 to August 2011 using the sugarcane variety Co 775. Soil, leaf and cane yield and quality parameters, such as brix, Pol and fibre percent of cane were measured. The analysis of variance was performed on cane yield and sugar yield to study the effects of TSP:HERP treatment combinations on cane and sugar yields. The initial soil P was deficient, but was not reflected in the leaf P content or in cane and sugar yields. Further, the cane yields and sugar yields at the different levels of TSP and HERP were not significantly different. The residual P level had declined over the years, and therefore, further investigations on the critical level of P and the fate of P in HERP are required to confirm the possibility in substituting TSP with HERP.

- The importance of advanced fertilizer was noted and carried out studies on compound fertilizer as it is with advance technology to increase efficiency by making fertilizers more plant-available while reducing the environmental losses thereby reducing the overall fertilizer usage and cost of production. One such technology is compound fertilizer. Thereby the crop nutrition division initiated a collaborative project with CIC Agri businesses (Pvt. Ltd) with the objective of investigating the performance of cane and sugar parameters of sugarcane with the usage of compound fertilizer as a substitute in 2020.
- The other research area was to evaluate the response of the sugarcane variety SL 96 128 for N, K and Zn on its cane yield and quality parameters. (Project was initiated on year 2020).
- Investigated the possibility of reducing chemical fertilizer dependency and to promote organic and natural fertilizers for sugarcane cultivation in Sri Lanka, the crop nutrition division initiated research studies in incorporating organic compost and technologies in pelleting. Different types of fertilizer pellets were produced using different natural and synthetic nutrient sources and laboratory and field trial experiments are continuing to determine the quality of fertilizer pellets and effects on the sugarcane cultivation. The research studies are in progress and will investigate the effect of organic base fertilizers on the yield and quality of sugarcane production in Sri Lanka.
- The future of the crop nutrition program will be directed on investigating possibilities in developing organic mixed pelleting technologies and precision nutrient management.

3.3.3 Organic fertilizers and bio-fertilizers

- The incorporation of organic matter to sugarcane-growing soils were considered important to improve and restore its fertility status where organic fertilizer can be an important solution.
- Investigated the potential of using selected microbial combinations including fungal-bacterial biofilms (FBB) for rapid decomposition of sugarcane trash. Two studies were carried out at laboratory level namely, identify the sugarcane trash decomposition process and then evaluated selected microbial combinations in enhancing sugarcane trash decomposition. The results of the first study there was a positive correlation in between weight loss and FTIR peak degradation of organic molecular functional groups, particularly O-H of carboxylic group, C-H of aromatic methyl group and Si-O of cuticle wax layer. The results of the second study showed that the urea treatments were significantly effective in reducing the C/N ratio of decomposed trash. However one microbial combination (B2) was effective on trash fragmentation and another microbial combination (F1F2B1B2) was effective on both trash fragmentation and reducing C/N ratio of decomposed trash. This

highlighted a good microbial combination would be very effective on trash decomposition in the long run of the sugarcane crop cycle.

- Developed a low-cost organic fertilizer using sugarcane crop residues, factory by-products and distillery effluent (2012). The preliminary investigation was conducted to find out the feasibility to produce organic fertilizer from the sugarcane industry by-products and to evaluate their nutritional characteristics favorable for sugarcane plant growth. The results indicated that incorporation of trash slow down the decomposing process and the using only filter-mud and vinasse was more effective in organic fertilizer preparation and they are rich in macro and micro plant nutrients.
- The compost prepared using sugarcane industry by-products were enriched using synthetic fertilizers to enhance the nutritional quality of the composts. Different combination ratios were tested and mixtures were formed into pellets (organomineral pellets). The effectiveness of different pellets on sugarcane cultivation are testing using field trials.
- Thereafter, with the current government policy change to utilize organic fertilizer (2021) for crop the prepared composed was used to carryout research. A detail research study to evaluate the nutrient supply of organic compost and required quantities were established and is in progress.
- Biochar was produced from crop residues and bagasse using the muffle furnace and the barrel. The results were compared.

3.3.4 Environmental issues

- Vinasse is the main component of the sugar and ethanol industries that could cause an environmental damage. The crop nutrition division has provided recommendations and has re-verified the recommendation recently.

3.4 Summary of laboratory analysis

The crop nutrition division carried out analyses mainly on cane, soil, plant, fertilizer, compost and sugar for SRI and the Sugar Industry. The total number of cane analyses carried out over the last 10 years was 30416. Apart from that considerable amount of other sample analyses have been carried out.

3.5 Recommendations to be issued to stakeholders/farmers

The crop nutrition division has provided valuable contribution to the improvement of sugarcane industry in Sri Lanka and following shows the major outcomes of the crop nutrition program since 2009.

- Interim fertilizer recommendation for Gal Oya Plantation, Hingurana – 2010
- Revision of fertilizer recommendation for all sugarcane-growing soils – 2013
- Development of quality organic compost from factory by-products – 2017
- Re-confirmation of application of vinasse to the fields and recommendation on filter-mud 20-30 t per hectare
- Application of 10-20 t of quality compost per hectare along with inorganic fertilizer for rehabilitation of soils – 2020
- Revision of fertilizer recommendation for all sugarcane-growing soils with an alternative source for Triple Super Phosphate – 2020
- Fertilizer recommendation for sugarcane-growing nurseries – 2020

4. Crop Protection Division

Sugarcane industry of Sri Lanka affected by several pest and disease problems over the decade and Crop Protection Division (CPD) has address the issues successfully marking several milestones, providing new recommendations and strengthening available intergraded pest ,disease and vector management packages via knowledge gathered by conducting research trials, laboratory experiments and field surveys.

4.1 Goals/objectives of the division

Goals
Increase productivity and profitability of the sugar industry through managing the pest and diseases in plantations.

Objectives
1. Management of identified pests and diseases
2. Avoidance of new pests and diseases

4.2 Priority areas of the division

CPD conducted research on two thematic areas viz., pest and disease management of sugarcane.

i. Priority areas during 2011 to 2021 under sugarcane pest management
- Sugarcane Wooly Aphid (SWA),
- *Pyrilla perpusilla*,
- termite,
- *Sesamia infarance* (Shoot borer; SB),
- *Chilo schariphagus* (Internode borer; INB)
- *Deltocephalus menoni*; vector of Sugarcane White Leaf Disease (WLD)
- Fall Army Warm (FAW)
- Sugarcane spider mite

ii. Priority areas during 2011 to 2021 under sugarcane disease management
- White leaf disease (WLD)
- Smut disease
- Leaf scald disease(LSD)

4.3 Achievements in each priority area

4.3.1 Achievements in sugarcane pest management

a. Sugarcane wooly aphid (SWA)
Threat of SWA has addressed and managed in a successful manner during the period and SWA has become occasional pest in the sugarcane industry.
- Identifying resistant and susceptible varieties; SL 00 589, SL 00 601, SL 00 603, SL 00 619, SL 00 652 are zero incidence varieties. SL 97 1442 is highly susceptible variety.

- Introducing spraying Tobacco extraction with liquid dish wash (Tobacco extraction 100 ml + Water 400 ml + 1 ml of liquid dish wash) as ecofriendly alternative to manage SWA population.
- Identifying that the weight of the honeydew excreted as an accurate method to determine the feeding rate of woolly aphid on different sugarcane varieties.
- Laboratory rearing and field releasing technologies were developed natural enemies (*Dipha aphidivora* and *Micromus igoratus*) were introduced to the SWA infested field regularly to manage the condition successfully.

b. Pyrilla perpusilla

- Successful control of *Pyrilla perpusilla* Walker achived *E. melanoleuca* in seed cane nursery in 2013 and 2015 at Kantale nursery.

***c.* Termite**

- Identifying resistant and susceptible varieties; SLI 121 is less susceptible.
- Identifying 5 termite species attached to sugarcane and confirmed the requirement of more attention on seed setts at germination to control termite damage than other stages.
- Recommending two insecticides for seed sett treatment to prevent termite infestation in setts; Thiomethoxam 20% + Chlorantriniliprole 20% (W/W) WG: 4 g/16L water and Imidacloprid 700 g/Kg WG: 2.5 g/16l water.

***d. Sesamia infarance* (Shoot borer; SB) and *Chilo schariphagus* (Internode borer; INB)**

- De-trashing have significant effect on borer damage in commercial varieties
- Developing mass rearing techniques for larval parasitoid: *Cotecia flavipes*, developing augmentation techniques and confirming initial establishment in the Hingurana sugarcane fields.
- Identifying four flowering plant species in sugarcane ecosystem enhance the life span of *Cotecia* and introducing them as companion plants (*Ocimum sanctum, Oxalis corimbosa, Cleome viscose, Phylanthus viridis*).
- Identifying Synthetic sex pheromone blend of Z-13-Octadecenyl acetate and Z-13-Octadecenol in ratio of 7:1 effective trapping and monitoring technique for *Chilo sacchariphagus*; trapping device: delta trap, replacement period: 2 weeks period Optimum trap density: 20 pheromone traps/ ha.
- Identification of new larval pupal parasitoid (*Xanthompla* spp) of Internode borer, *Chilo scashariphagus* which showed the potential of incorporating into efficient borer management program.

e. *Deltocephalus menoni*; vector of sugarcane white leaf disease (WLD)

- Identifying natural enemy spectrum and laboratory techniques
  - Ground beetle spp, *Harpalus pensylvenicus* (Coleoptera:Carabidae) and *Bembidion quadrimaculatum* (Coleoptera:Carabidae are efficient egg predators of WLD vector.
  - Identification of Earwig species (Order: Dermoptera) and Rover beetle species (Order: Coleoptera) as nymphal and adult predators of vector.
  - Six predatory Coccinelid beetle spp were identified and among them *Micrapis discolor, Micrapis alardi, Scymnus nubilus, Jairavio dorsialis, Propylea dissector* and *Pseudaspidimerus trinotatus* over WLD vector and *M. discolor* was identified as the most efficient and abundant predatory coccinellid beetle spp in sugarcane ecosystem.

- Identifying *Saccharum spontaneum* (Wild cane) and *Sorghum bicolor* are alternative hosts of the WLD vector and recommending to avoid them around fallowing fields and nursery areas.
- Identifying WLD infected plants are augmenting its vector by attracting, enhancing survival and population build-up which promotes the transmission of WLD phytoplasma itself. There recommended regular inspection and rogueing out of WLD infected clumps make a great impact on secondary transmission of WLD by vector.
- Identifying resistant varieties SL 83 06, SL 92 5588 and SLT 4921.
- Recommending most appropriate population techniques and durations,
  - sweep net monitoring is be : as 2000 sweeps/ ha during 6.00 to 9.00 am and 4.00 to 7.00 pm (Avoid rainy and windy days).
  - light traps: use white light during at 7.00 to 8.00 pm in evening as 7.00 to 8.00 pm (avoid the full moon period of the Luna phase).
- Identifying four-month age of the sugarcane hybrids is the most vulnerable stage for vector feeding, and the three to five-month period is the susceptible period for feeding.
- Identifying border treatment of Fipronil 0.3 GR (soil application of 18 Kg/ha) as an effective treatment to manage the WLD vector and incidence in sugarcane plantations.
- Identification of the Mustard (Brassica juncea (L.) Czern & Coss) as a repellent crop for WLD vector.
- Identifying *Erianthus* as effective barrier crop (3 rows) to minimize invasion of vector in to the sugarcane fields.
- Maximum flight distances of WLD vector is identified as 75 m. This should be minimum distance between commercial plantations and nurseries in order to minimize the secondary transmission of WLD to nurseries.
- Identification of behavioral characteristics of *D. menoni*, plant physicomorphic and leaf characteristics associated with high WLD incidence and development of variety evaluation system for WLD vector.

f. Fall army warm (FAW)

- Identifying natural enemy complex of Fall Army Warm
  - Larval and Egg Predators: Coccinellid larvae
  - Egg Parasitoids: *Trichogramma chilonis*, *Telenomus dignus*
  - Larval Parasitoids: *Cotesia spp*
  - Endo-parasite: Mermithid nematode species
  - Pupal parasitoids: *Campoletis sonorensis*

g. Sugarcane spider mite

Identifying fenpyroxymate 5% EC (at 14 ai g/ha) as effective miticides against sugarcane spider mite.

4.3.2 Achievements in sugarcane disease management

a. White leaf disease (WLD)

- Screening of 500 sugarcane accessions from the available germplasm pool of sugarcane accessions and identification of 74 accessions to be used as potential parents for directional breeding for WLD resistance under Sri Lankan condition.
- Identification of 15, 4, 45, 26 and 6 sugarcane hybrids with low WLD incidence in three crop cycles in SL 2000, SL 2001, SL 2002, SL 2003 and tissue culture varieties respectively

and giving recommendation to the crop improvement division for further activities before releasing for commercial plantation.

- Confirmation of that exciting HWT recommendation is not effective in total elimination phytoplasma through molecular methods and qPCR analysis revealed that, exciting HWT recommendation can reduce the initial available amount of phytoplasma in seed cane only by 70.00%.
- Reevaluation of the effectiveness of hot water treatment to elimination of the WLD diseases from infected seedcane and adoption of cold soak treatment as a seedcane treatment to minimize the level of pathogen in seedcane. Based on the results two treatment combinations namely 48 hr cold soak+ 54 ^{0}C for 50 min, and 48 hr cold soak+ 54 ^{0}C for 80 min were selected for further evaluation to giving a new recommendation for HWT and CS treatments.
- Study the effectiveness of chemicals namely Salicylic acid, Streptomycin and tetracycline for elimination of WLD phytoplasma in sugarcane and qPCR analysis revealed that, Salicylic acid, Streptomycin and tetracycline can reduce the available amount of WLD phytoplasma by 98%, 84 % and 83% respectively.
- Reconfirmation of Sugarcane white leaf disease phytoplasma belongs to 16 Sr XI group and identification of that it belongs to B sub group in 16 Sr XI group was done.
- Confirmation of non-availability of different WLD phytoplasma strains in Sri Lanka using molecular methods.
- Development of Molecular-based phytoplasma identification methods based on standard PCR, probes development, LAMP assays and q PCR were developed for more accurate identification of disease and quantification of available amount of WLD phytoplasma in sugarcane.
- Introducing a time schedule to inspect the smut diseases in primary and secondary nurseries.
- Giving recommendations to spot application of Glyphosate to kill WLD-infected plants in the primary and secondary nurseries.

b. Smut disease

- Screening of 500 sugarcane accessions from the available germplasm pool of sugarcane accessions and identification of 128 potential resistant parents for directional breeding for smut resistance under Sri Lankan conditions based on the results of two crop cycles.
- Identification of 13, 29, 71, 28 and 39 resistant hybrids from SL 2004, SL 2005, SL 2007, SL 2008, SL 2009 and SL 2010/2011 respectively by artificial inoculation method and giving recommendation to the crop improvement division for further activities before releasing for commercial plantation.
- Giving the recommendation to release SL 95 4430, SL 95 4443, 96 128, SL 96 328, SL 98 2524 based on the results of artificial inoculation trials, and natural incidence records in different locations.
- Identification of a new Triazole fungicide (Hexaconazole) and a synthetic elicitor (Salicylic acid) to be used as a pre-planting dip treatment for effective management of sugarcane smut under field conditions.
- Development of a PCR protocol for molecular detection of sugarcane smut pathogen using direct use of teliospores of the pathogen.
- *In-vitro* identification of two soil microorganisms, with bio-control ability on smut pathogen (*Bacillus subtilis* and *Aspergillus flavus*).
- In-vitro identification of 5 plant extracts (*Lantana camera*, *Tagetes erecta*, *Cinnamomum* spp., *Kaempfena* spp., and *Zinger Officinale* Roscoe) for controlling smut disease pathogen

- In- vitro identification of potential entophytes with bio-control ability on smut pathogen.
- Based on the survey results it was re-evaluated and confirmed that SL 83 06 is now susceptible for sugarcane smut disease. Therefore, recommendations were given to reduce the extension of variety SL 83 06 in susceptible areas and replace the areas with a smut resistant varieties.
- Identification of morphological and biochemical indices namely, total phenolic content in leaves, hardness of the bud, FIA and the number of scale leaves could be used as indirect markers for smut disease resistance in sugarcane.
- Identification of variability of the smut pathogen using ISSR markers and confirmation of that a composite of isolates collected from locations should be used in crop improvement programs to screen for smut-resistance varieties for commercial sugarcane production in Sri Lanka.
- Giving recommendations to rough out the disease-infected clumps from the field after covering the smut whip.
- Introducing a time schedule to inspect the smut diseases in primary and secondary nurseries.
- Identification of three genes varied between resistant and susceptible sugarcane varieties to develop molecular-based disease screening method for sugarcane smut.

c. Leaf scald disease(LSD)

- Identification of 125 resistant sugarcane accessions for sugarcane leaf scald disease (LSD) under Sri Lankan condition from the available sugarcane germplasm for the directional breeding for sugarcane LSD.
- Identification of 34, 2, 2,12, 5, 19, 25 and 29 sugarcane hybrids with resistant to LSD in artificial inoculation field trails in SL 2000/2001, SL 2002, SL 2003, SL 2004, SL 2004, SL 2007, SL 2008 and SL 2009 series respectively and giving recommendation to the crop improvement division for further activities before releasing for commercial plantation.
- Evaluation of the effectiveness of hot water treatment to eliminate the LSD from infected seed cane and adoption of cold soak treatment as a seed cane treatment to minimize the level of the pathogen. Based on the results two treatment combinations such as 48 hr cold soak + 54 °C for 50 min, and 48 hr cold soak+ 54 °C for 80 min have been selected for the final stage of the evaluation to give a new recommendation for HWT and CS treatments.

4.4 Recommendations to be issued to stakeholders/farmers in each area

4.4.1 Recommendations to manage sugarcane wooly aphid (SWA)

- Tobacco extraction as ecofriendly alternative to manage SWA population.
- Laboratory rearing and field releasing technologies for Natural enemies (*Dipha aphidivora* and *Micromus igoratus*).
- Resistant varieties to adapt and susceptible to eliminate.

4.4.2 Recommendations to manage sugarcane termites

- Insecticides for seed sett treatment to prevent termite infestation in setts.

4.4.3 Recommendations to manage sugarcane moth borers

- De-trashing older leaves in the cane.
- Synthetic sex pheromones for the internode borer in Sri Lanka as a monitoring tool and a mass trapping tool for male moths.
- Laboratory rearing and field releasing technologies for natural enemies (*Cotecia flavepis*).

- Companion plants enhance the life span of *Cotecia.*

4.4.4 Recommendations to manage whit leaf disease (WLD) vector

- Population monitoring techniques (Sweep net & Light Trap).
- Removing symptomatic clumps to reduce vector population.
- Vector management in the means of synthetic chemicals (Border treatment and foliar application).
- Intercropping with mustard to repel vectors from sugarcane.
- Increasing spacing between two planting rows to reduce vector population.
- Selection land, seed materials and soil amendments in a way minimize damage of WLD vector.
- Resistant varieties to adapt and susceptible to eliminate WLD vector.
- Laboratory rearing and field releasing technologies for natural enemies (2 ground beetle *spp,* Earwig species and *M. discolor*).

4.4.5 Recommendations to manage sugarcane spider mite

- Chemical recommendation for sugarcane spider mite.

4.4.6 Recommendations to manage sugarcane white leaf disease

- Resistant varieties to adapt and susceptible to eliminate WLD.
- Revised HWT combination (will be confirmed in the near future).
- Time schedule to inspect the WLD in primary and secondary nurseries.
- Spot application of glyphosate to kill WLD-infected plants in the nurseries.

4.4.7 Recommendations to manage sugarcane smut disease

- Resistant varieties to adapt and susceptible to eliminate smut disease.
- Effective fungicides and a synthetic elicitor to be used as a pre-planting dip treatment for seed-sets.
- Plant extracts for controlling smut disease pathogen.
- Soil microorganisms with bio-control ability on smut pathogen.
- Revised HWT combination (will be confirmed in the near future).
- Time schedule to inspect the smut disease in primary and secondary nurseries.

4.4.8 Recommendations to manage sugarcane leaf scald disease

- Resistant varieties to adapt and susceptible to eliminate sugarcane scald disease.
- Revised HWT combination (will be confirmed in the near future).
- Dipping the cutting implements in a detergents solution when cutting seed cane.

5. Processing Technology Division

The Processing Technology Division has mainly focused its research program to increase the productivity and profitability of the sugar industry through improving efficiencies of sugarcane and its co-products processing and diversifying the industry with value-added products while minimizing adverse effects on the environment. Researches of the processing technology division are being carried out in two research disciplines; mill technology and microbiology.

5.1 Priority areas of the division

The division gives priority to the following research areas to achieve the divisional goal:

i. Reduction of post-harvest losses of sugarcane.
ii. Improvement of processing efficiencies of sugar mills and distilleries.
iii. Development of yeast strains with genetically-improved characteristics for efficient fermentation of sugarcane molasses into ethanol.
iv. Production of sugarcane juice-based beverages and other products.
v. Improvement of quality of sugarcane jaggery and syrup.
vi. Diversification of utilization of sugar industry co-products.

5.2 Divisional achievements in each priority area

- Isolation of 134 phosphate –solubilizing bacteria strains and evaluation of their phosphate –solubilizing ability to producing bio-fertilizer and evaluated the potential of using sugar factory and distillery wastes for the production of a carrier medium for phosphate-solubilizing micro-organisms.
- Production of sugarcane pineapple- flavored ready –to-serve drink.
- Identification of SL 04 618, SL 04 624, SL 04 1004, SL 04 5187 and SL 04 5378 as better varieties for making jaggery.
- Estimation of post-harvest loss of sugarcane; nearly 4 t/ha under irrigation and 9 t/ha under rain-fed, at Sevanagala.
- Identified the possibility of producing fodder yeast from the distillery yeast sludge and identified the nutrient composition of the fodder yeast by conducting proximate analysis.
- Isolation of 98 yeast strains and evaluation of their alcohol production ability for efficient fermentation of sugarcane molasses into ethanol.
- Isolation of 134 phosphate –solubilizing bacteria strains and evaluation of their phosphate –solubilizing ability to producing bio-fertilizer and evaluated the potential of using sugar factory and distillery wastes for the production of a carrier medium for phosphate-solubilizing micro-organisms.
- Identification of SL 04 618, SL 04 624, SL 04 1004, SL 04 5187 and SL 04 5378 as better varieties for making jaggery from SL2004 series.
- Identification of SL 06 224 and SL 06 93 as better varieties for making jaggery from SL2006 series.
- Identified the best ratio for making sesame, ginger, vanilla and puff rice-flavored sugarcane jaggery to improve its flavor for 40 L of juice, the requirement for sesame, ginger and vanilla and puff rice are 150 g, 250 g, 28 ml, and 150 g respectively.
- Development of a process for granulated jaggery production and analyzing the biochemical properties of the granulated jaggery.
- Development of a recipe for jaggery -incorporated chocolate production and conducting biochemical analysis for the product.

- Development of a recipe for bagasse-incorporated biscuit production and conducting biochemical analysis for the product.
- Development of a recipe for bagasse-incorporated muffin production and conducting biochemical analysis for the product.
- Isolated nitrogen fixing and phosphorus solubilizing bacteria from the soil and root sample collected from Sevanagala sugarcane cultivated fields.
- Conducted large mill test for SL 96128, SL 00603, SL 0095, and SL 00354 varieties at Pelwatte Sugar Factory and SL 0095 variety performed best juice quality parameters among them.
- Technical assistance to the Kilinochchi jaggery production project.
- Designing drawings of semi-automated agitator and jaggery pans for Semi-automated agitation system for conventional sugarcane jaggery manufacturing process at SRI.
- Conducting large mill test at the sugar factory in Ethimale Plantation (Pvt) Ltd for analyzing the performances of the variety SL 96 128 at the factory level.
- Analyzing post-harvest deterioration of SL 96 128 and SL 98 2524 based on months of February and July.
- Conducting large mill test for the variety SL 96 128 to analyze the performance of flowering sugarcane fields (8 months) with comparison to non-flowering (12 months) sugarcane fields under irrigated conditions.

5.3 Recommendations to be issued to stakeholders/farmers

5.3.1 Sugarcane-based value-added product

Different shapes of jaggery
The desired shapes and sizes of sugarcane jaggery cubes were square, rectangular, and spherical shapes. For square cubes, the best length, width, and thickness was 2.5 cm. For rectangular shapes, there were two sizes of 2 cm thickness, and their length and width were 8*2 cm and 15.5*7 cm. For spherical shape, the diameter was 11 cm and the height was 6 cm.

Different flavored jaggery
The best ratio for making sesame, ginger, vanilla and puff rice-flavored sugarcane jaggery to improve its flavor, for 40 L of juice, the requirement for sesame, ginger ,and vanilla, and puff rice are 150 g, 250 g, 28 ml, and 150 g respectively.

Granulated jaggery
Development of a process for granulated jaggery production. Granulated jaggery is a type of jaggery in granular form, which is obtained from boiled sugarcane syrup by scraping and rubbing during the solidifying process. It is an unrefined healthy sweetener with high fiber and mineral content.

5.3.2 Varieties for jaggery production

Recommending SL 06 93 and SL 06 224 as a superior variety for quality jaggery production from SL 2006 series.

5.3.3 Jaggery and bagasse incorporated health product

Recommendation to develop cookies enriched with 5% sugarcane bagasse as a fiber source with no added sugar.

5.3.4 Ready-to-serve, ascorbic acid-added and pineapple and lime-flavored sugarcane juice beverage

Recommendation to enhance the shelf-life of the pineapple and lime-flavored sugarcane juice by adding ascorbic acid. Addition of 200 ppm ascorbic acid extended the shelf-life of the product up to two months without affecting its sensory attributes. The proximate analysis revealed that the drink consisted of 78.8% moisture, 1.2% ash, 0.19% crude fat, 2.3% crude protein and 17.51% total carbohydrates and gives 80.95 kcal energy per 100 ml.

5.3.5 Recipe for bagasse and sugarcane jaggery incorporated muffin production

Recommendation to produce gluten-free suwandel rice flour muffin with incorporation of 5% sugarcane bagasse and 80% solid sugarcane jaggery.

5.3.6 Recipe for sugarcane jaggery incorporated chocolate production

Recommendation to develop cocoa-based confectionery incorporated with 100% sugarcane jaggery.

6. Mechanization Technology Division

The Mechanization Technology (MT) division of the Sugarcane Research Institute (SRI) is responsible for the use of practical applications of science to the cane sugar industry for maximizing industry and farmer profit in a sustainable way. The research activities of the MT division are designed based on nine event system (9ES) approach (Figure 1). The 9ES approach covers the three main areas that are essential to technologize the sugar industry in Sri Lanka. Those three areas are 1. Mechanization, 2. Cradle-to-gate energy and material analysis 3. Automation, smart control, and decision support.

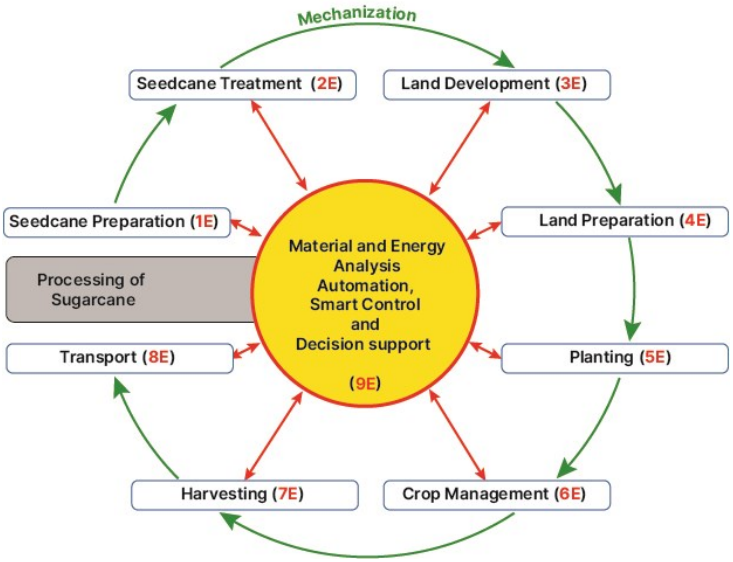


Figure 1 Nine event system (9ES) approach to technologizing the sugar industry

Other than the main research activities, the MT division is responsible for supporting other research activities of the SRI by providing engineering solutions to overcome practical barriers. Those research projects are conducted as research service projects.

6.1 Goals/objectives of the division

Goals

Integration of smart farming system technology and energy optimization strategies to reduce the cost of sugar production by 25% within the next 10 years.

Objectives

- To increase the farm mechanization level up to 70%
- To optimize the energy use in cane and sugar production
- To integrate a data-driven decision-making framework

6.2 Priority areas of the division

- Farm machinery design and development
- Farm machinery testing and evaluation
- Automation system development
- Energy auditing, material balance, and lifecycle analysis

- Data engineering and data science
- UAV technology

6.2 Summary of achievements in each priority area

- Development of tyne cultivator and distribution among the farmers
- Construction of two-wheel tractor-mounted furrow opener and distribution among the farmers.
- Modification and fabrication of two-wheel tractor-mounted disk ratooner
- Hot-water treatment plant (HWT)
- Combine steam generator (CSG) for sugarcane hot-water treatment plant
- Design and development of blow pollinator for sugarcane
- Cane and dry leaves harvesting (CDLH) Concept
- Integrated bagasse utilization system based on hydrothermal liquefaction in sugarcane mills
- Design and fabrication of sugarcane trash cutting machine
- Introduction of the framework for data-driven decision making
- Introduction of IoT-integrated machinery management framework
- Design and construction of a two-wheel tractor-mounted fertilizer applicator

The Mechanization Technology Division of SRI has developed several technologies, concepts, recommendations during the last few years. The successful stories of MT division in the main priority areas of research will be explained in the following sections.

6.2.1 Development of tyne cultivators and distribution among the farmers

This equipment (Figure 2) can be used to weed control after attaching a two-wheel tractor.

Figure 2 Tyne cultivator

6.2.2 Construction of two-wheel tractor-mounted furrow opener and distribution among the farmers

This equipment (Figure 3) is used to convert a ridge into a furrow in the sugarcane field. A two-wheel tractor can be used to operate this equipment.

Figure 3 Furrow opener

6.2.3 Modification and fabrication of two-wheel tractor-mounted disk ratooner

The use of the mechanical device to perform the earthing-up or hilling-up is one of the best solutions to improve the labor productivity of sugarcane farming. The main objective of this research was to optimize a two-wheel tractor-mounted implement to improve the productivity of the earthing-up operation and reduce the cost of operation in sugarcane farming in Sri Lanka. For this optimization SolidWorks parametric 3D modeling and simulation package was used to reduce the cost of prototype development. The optimized model (Figure 4) was fabricated and tested in the Sugarcane field in Hingurana Sri Lanka compared to the existing practices. The test result reviewed that the newly designed equipment can be used successfully for earthing- up in sugarcane farming. Furthermore, the cost of operation of earthing-up was reduced by 72 USD.

Figure 4 Disk ratooner

6.2.4 Hot-water treatment plant (HWT)

Heat therapy has been identified as the most efficient and economical method of eliminating pathogens causing most of the important sugarcane diseases; smut, leaf scald, and white leaf disease, which causes significant crop loss in terms of yield and quality of sugarcane in Sri Lanka. According to SRI recommendation, seed cane has to be treated in hot water at 54 °C for a period of 50 minutes to eliminate the pathogens causing the above-mentioned sugarcane

diseases. In this treatment, the temperature-time combination used is critical for the successful elimination of the pathogens of the diseases.

MT Division of the SRI has designed semi-automatic HWT plants (Figure 5) to meet the requirement of each sugar industry. For example, the heating system of the HWT plant could be easily modified to incorporate LP gas heaters, which could be used by farmers, where no electricity is available. In the new design, the commercial HWT plants could be manufactured at a low cost and could be made available with competitive prices than the imported ones because most of the materials used are locally available.

Figure 5 Hot water treatment plant

Patent - Patent No 14391 – Hybrid Hot Water Treatment Plant to control seed bone pest and diseases of seed-cane

6.2.5 Combine steam generator (CSG) for sugarcane hot-water treatment plant

This research was focused on designing and evaluating a bagasse-powered pre-heating device (Figure 6) for the seed cane hot water treatment plant for saving energy and time. The total pre-heating process was divided into 3 stages; the generation of heat energy, transferring the produced heat to the plant, and heating the product. The pre-heating device was fabricated using locally available materials at the workshop of SRI, Uda Walawe, Sri Lanka.

The flue gas generated by the burning of bagasse was used as the energy source for the steam generation inside the pre-heating device. The pre-heating device was designed by combining the concepts of water tube boiler and shell boiler so that the device is named the combined steam generator. Specifications of the preheating device were calculated according to the heat energy requirement of feed-water, steam, and fuel energy. Conceptual design for the new pre-heating device was developed considering the system requirements. Based on the concept, a detailed design of each part of the pre-heating device was developed with properly defined dimensions, using a parametric 3D modeling software and simulation process carried out using finite element analysis (FEA). The operating pressure of the system is 1 bar pressure according to the design consideration. The heat exchanging unit was tested under 5 bar pressure. Then the preheating device was completely assembled with fabricated parts. According to the evaluation results, the efficiency of the combined steam generator was 80.14%. So the time and the electric energy consumption are reduced by 37% and 99.17% respectively.

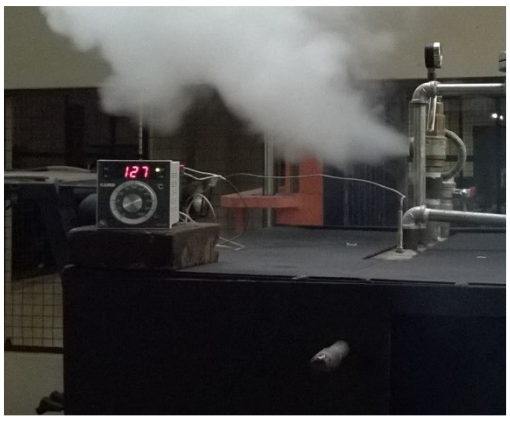


Figure 6 Steam generator

6.2.6 Design and development of blow pollinator for sugarcane

The field lantern method is one of the most effective methods for sugarcane hybridization practiced by SRI. But there are some drawbacks, such as difficulty in the application of pollens, time-consuming and intensive labor requirements in this method. The main objective of this project was to the development of an instrument to mechanize the lantern method. The developed instrument is named blow pollinator (

Figure 7) and it consists of four components: pollen applicator assembly, retractable lever assembly, lever, and cable unit, and air storage and releasing unit. The height of the instrument can be adjusted from 150 cm up to 300 cm. Pollen applicator was made up of stainless steel and plastic whereas the rest component is made up of stainless steel. The movements are controlled through a cable system. In this method, pollens are sprayed to the sugarcane inflorescences within around one minute at any height by using an airflow. The evaluation was done by comparing the time duration that blow pollinator was consumed and the time duration that the lantern method consumed for the artificial pollination. After practicing the lantern method and blow pollinator method for 20 plants separately, the meantime duration taken for one application was 343.2 second and 59.05 second respectively. The conclusion was that there is a significant reduction in time consumption when blow pollinator was used for artificial pollination.

Figure 7 Blow pollinator

6.2.7 Cane and dry leaves harvesting (CDLH) concept

Sugarcane harvesting requires a significant amount of energy and time to manage dry leaves after the harvesting process. Therefore, the objective of this study was to minimize the energy required to process the cane and dry leaves' harvesting (CDLH) for sugarcane while, at the same time, maximizing sugar production from cane and energy from dry leaves in Sri Lanka. The CDLH was conceptualized using a novel approach to optimize sugarcane harvesting to maximize biomass supply for energy production while reducing supply chain sugar loss. The CDLH was investigated for manual harvesting capacity, energy consumption, sugar loss, and biomass energy potential. It was observed that CDLH consumed higher energy compared to the present practices of harvesting. However, the energy used for fieldwork was reduced because of the shifting of cane chopping and cleaning from the field to the factory. The low bulk density of the harvested cane of the CDLH system had a higher energy requirement in transportation. Comparatively, CDLH showed higher biomass energy potential and less sugar loss. High energy potential increases the energy potential to consumption ratio compared to the existing method. Therefore, the theoretical evaluation showed that the CDLH system can produce more than 20 kg of sugar and 879 MJ of electricity when processing 1 t of sugarcane (Figure 8).

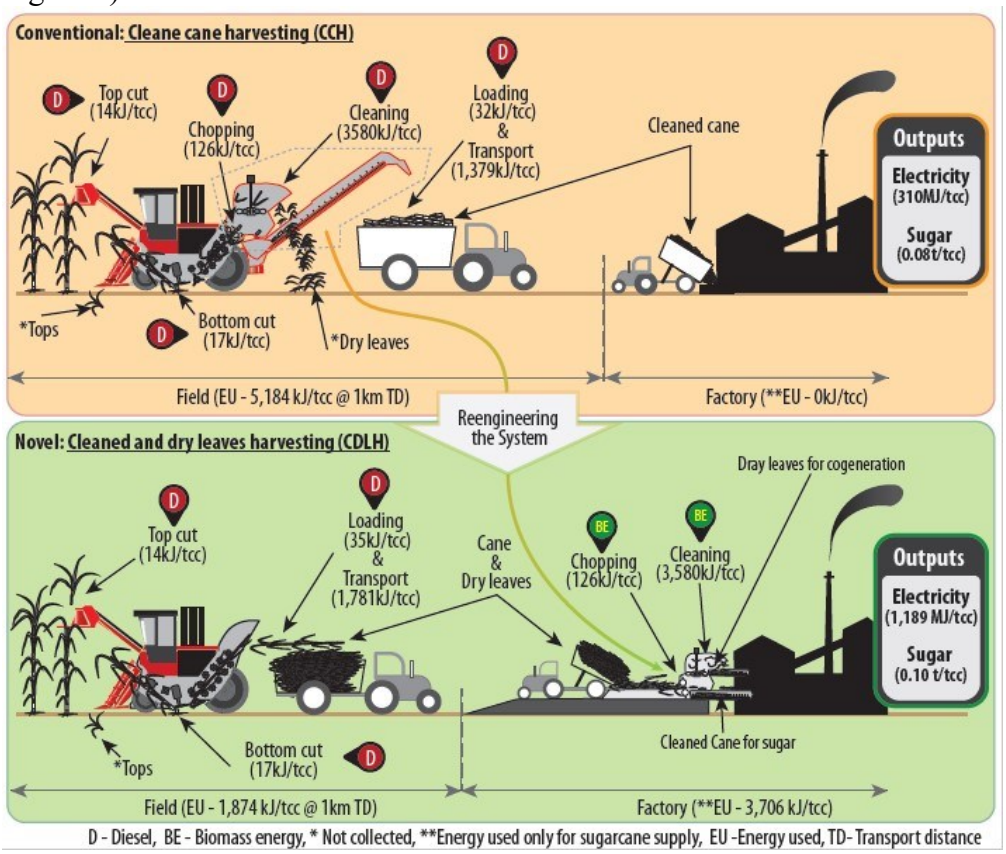


Figure 8 Comparison of CCH and CDLH

6.2.8 Integrated bagasse utilization system based on hydrothermal liquefaction in sugarcane mills

Sugarcane bagasse is used to produce bioenergy in sugar mills and export excess energy as electricity to the community. Researchers have investigated the production of high-energy bio-oil and hydrochar from bagasse using hydrothermal liquefaction (HTL) on a laboratory scale. However, the energy efficiency of the HTL integrated bagasse utilization system at the industrial level is unknown, especially compared with present practices of baggage utilization. Therefore, the objective of this study was to analyze the theoretical energy utilization of an HTL integrated bagasse utilization system compared with conventional bagasse utilization systems. A new bagasse utilization system was modeled and combined with HTL. We used data from published articles and experiments to analyze the model. We simulated the model with different bio-oil and hydrochar yields and four levels of heat recovery from the HTL final products. The results show that the novel process could exceed the electricity export rate compared with the conventional system, with a high bio-oil and hydrochar yield at 23% heat recovery level. Further results show that the HTL integrated system with high bio-oil and hydrochar yields and 75% heat recovery presented an electricity export benefit, which was above 170% higher than that of the existing method in ideal conditions when using high-moisture bagasse. Finally, further research should develop high-efficiency heat recovery systems, environmentally friendly HTL product separation techniques, and direct combustion of bio-oil and hydrochar to realize this concept for improving the energy utilization of sugarcane mills (Figure 9).

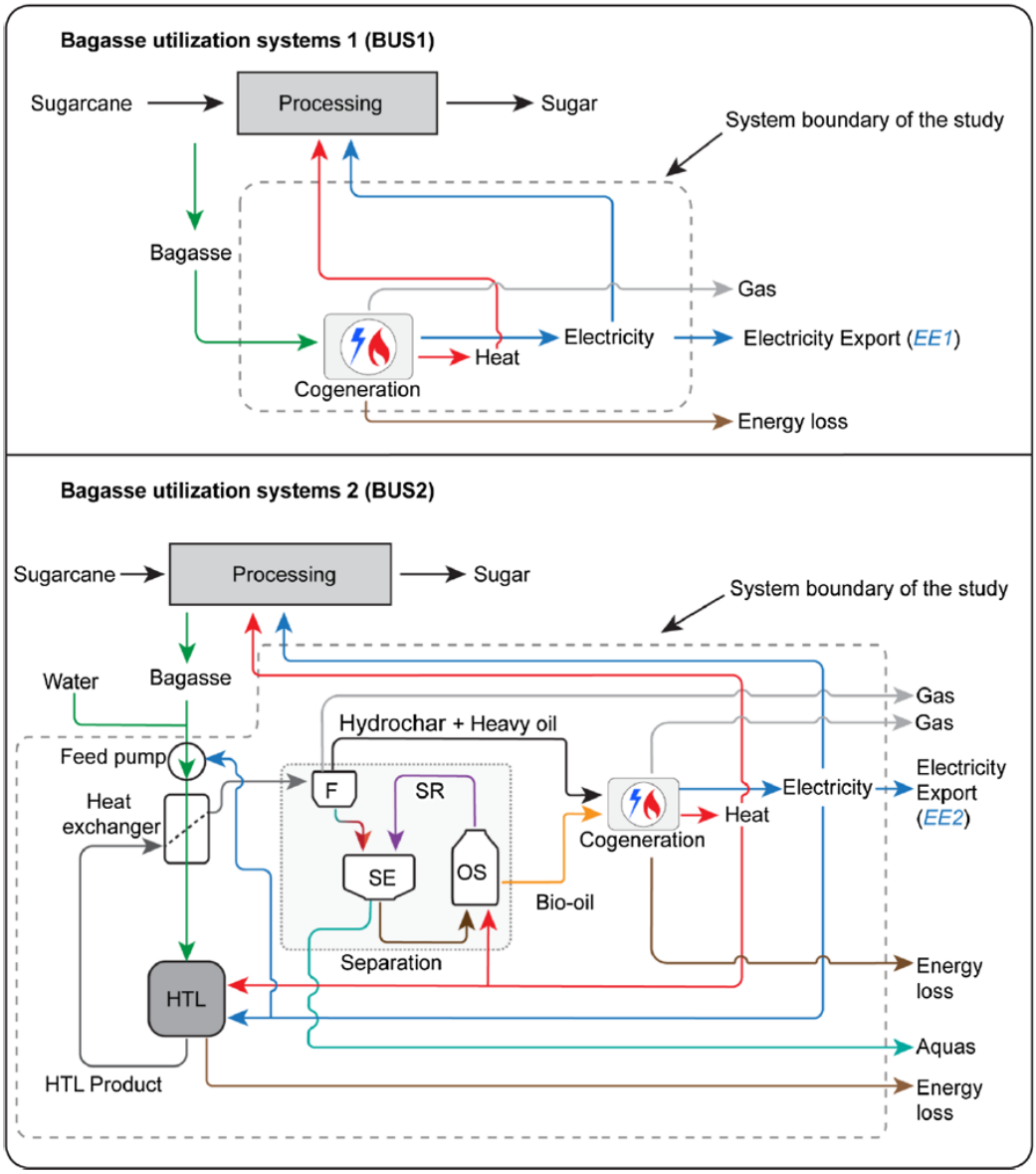


Figure 9 Integrated bagasse utilization system

6.2.9 Design and fabrication of sugarcane trash cutting machine

Inter-row cultivation practices of sugarcane fields in Sri Lanka are done with two-wheel tractor-mounted implements, such as tyne cultivator, furrow opener, fertilizer applicator, disc ratooner etc. Trash and sugarcane tops left on the ground after harvesting considerably hampers the inter-row cultivation practices of the subsequent ratoon crop. Burning trash is a common practice among farmers. This causes harmful effects on the ratoon crops due to degradation of soil fertility by volatilization of nitrogenic and phosphoric compounds, increasing soil erosion, etc.

The sugarcane trash, after value addition, can be used for different purposes to improve the economic status of farmers. Several such uses are chopping or cutting and mixing with soil to improve soil conditions, collecting and burning for energy production, and for several industrial applications. Burning trash in the field, either before or after harvesting is followed to facilitate other cultural practices but is not an agronomically and environmentally appropriate management practice. Chopping trash into small pieces is one of the best solutions

for controlling trash burning and it prepares a good mulching material evenly distributed in the field. Therefore, the introduction of a sugarcane trash-cutting machine (STCM) will facilitate the improvement of sustainable sugarcane farming in Sri Lanka.

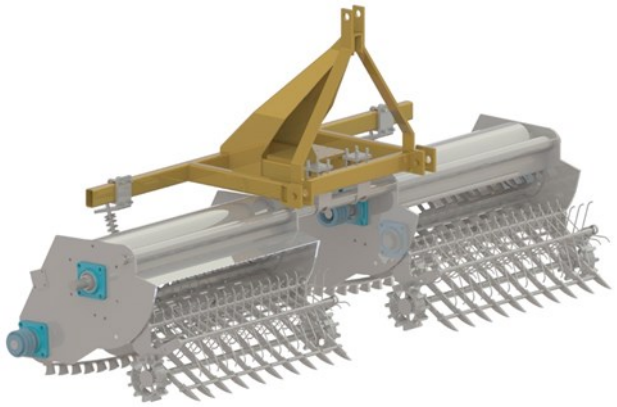


Figure 10 - STCM (Early-stage concept)

Figure 11 - STCM Prototype testing

6.2.10 Design and construction of two-wheel tractor-mounted fertilizer applicator

Fertilizer application is an essential but costly management practice in sugarcane farming due to the labor scarcity for manual applications. A smallholder, accurate, easy to operate sugarcane fertilizer applicator will be suitable for overcoming such labor shortages. Therefore, the main objective of this research was to develop a tractive wheel-driven fertilizer metering mechanism for a two-wheel tractor-mounted fertilizer applicator for evenly applying fertilizer in any field and at different speeds. The specific objective of this study was to evaluate the cost of fertilizer applications compared to manual applications. A metering mechanism was designed based on the sugarcane fertilizer recommendation of Sri Lanka. All the parts in contact with the fertilizer were fabricated using stainless steel to avoid the corrosive effect of fertilizer. Roller chains and sprockets were used as power transmission elements. Fertilizer dropping rates at different speeds of the tractor and the uniformity of fertilizer application (UFA) of developed fertilizer applicator were tested and compared to the manual application. Results concluded that the UFA of the new fertilizer applicator is 99.4% which is 13% higher than the manual broadcasting method (86.3%). Though the fertilizer dropping rate reduced slightly with the increasing speed,

the speed of the fertilizer applicator did not significantly affect the fertilizer dropping rate. The cost of fertilizer application can be reduced by 55% using the newly developed fertilizer metering mechanisms attached fertilizer applicator.

6.3 Recommendations

- Hot-water treatment plant operations
- Mechanical harvesting of sugarcane

7. Economics Biometry and IT Division

The Economic Biometry and Information Technology (EBIT) division has two research sections viz. economics and biometry. The main focus of the economic unit is to ensure that the technologies introduced by SRI are economically feasible, while the aim of the biometry unit is to guide other divisions of SRI for improving the quality of research conducted by them. Further IT related services are provided within the institute.

7.1 Goal of the division

The goal of the division is to sustainable increase of productivity and profitability of the sugar industry by improving its economic aspects and efficiency of sugarcane research.

7.2 Priority areas of the division

Economics:
- Economic assessment of new technologies developed by the institute.
- Assessment of productivity and profitability of sugarcane cultivation and processing of sugarcane and its co-products.
- Economic assessment of policies related to sugar industry and provision of policy guidelines for the development of the sugar industry.

7.3 Thematic areas

The Economics Biometry and IT divisional program was conducted under the following themes.

i. Economic assessment of new technologies developed by SRI.
ii. Economic assessment of sugarcane cultivation and processing.
iii. Analysis of the impact of macro-economic policies on the sugar sector of Sri Lanka and provision of guidelines for sugar sector development policy formulation.
iv. Conducting research falling into the discipline of biometry and involved in collaborative research in the sugar sector.
v. Provide necessary research support to the research divisions in designing experiments and data analysis for improving the capacity for undertaking advanced research.
vi. Providing IT-related services.

7.4 Summary of achievements in each thematic area

The summary of the studies conducted, progress and achievements during the last 10-year period are as follows based on each thematic area.

7.4.1. Economic assessment of new technologies developed by SRI

- Economic assessment of inter-cropping under sugarcane and published it in the brochure.
- Estimate cost of production of sugarcane top based silage as an animal feed and submit to CRM division.
- Economic assessment of meristem cultured sugarcane plant production and compare it with hot water treatment and prepare an economic publication report.
- Economic assessment of hot-water treatment of seed cane at Uda Walawe and Kantale hot-water treatment plants of SRI and submit reports to MT division.

- Cost and benefit analysis of using four-wheel tractor-mounted disc ratooner and submit the report to MT division.

7.4.2 Economic assessment of sugarcane cultivation and processing

- Economic assessment of the sugarcane cultivation in Sevanagala, Pelwatte and Hingurana – Annually conducting farmers surveys and prepare reports and published in the "Puwath Hasuna", the news-letter of SRI.
- Assessment of productivity and profitability of sugarcane cultivation, compared with other competitive crops in sugarcane-growing areas –Annually conducting farmers' surveys and prepare reports and published in the "Puwath Hasuna", the news-letter of SRI.
- Economic assessment of jaggery and syrup production in Moneragala and Badulla districts and economic publication report has been prepared including the comparison with cost and benefit of other crops of the areas.
- Identification of factors that caused shifting of sugarcane farmers from sugarcane to other crops at Sevanagala and prepared an economic publication report
- Estimate the commercial value of sugarcane – Annually collect data from all sugar industries and prepare estimations.

7.4.3. Analysis of the impact of macro-economic policies on the sugar sector of Sri Lanka and provision of guidelines for sugar sector development policy formulation

- Study on sugar industry of Sri Lanka: Major issues and future directions for development
- Development of a cane pricing formula for the local sugar industry
- Development of an ex-factory sugar pricing formula for Sri Lanka
- Development of an approach for determining the optimal replanting cycle for the Sri Lankan sugar industry
- Analysis of the impact of macro-economic policies on the sugar sector of Sri Lanka and provision of guidelines for sugar sector policy formulation
- Compiled and developed Sugar Sector Development Policy for Sri Lanka – 2014, 2016 and 2020 and presented 2020 one to stakeholders on 12/03/2021
- Analyse sugar import data – Annual
- Study on Indian and Thai production promoting sugar policies and their applicability to Sri Lanka – M.Phil. Thesis and Symposium paper
- Study on factors affecting quantity of sugar importation and sugar price in Sri Lanka – 2021 – Paper has been sent for publication

7.4.4 Conducting research falling into the discipline of Biometry

- Forecasting sugarcane production in Sri Lanka using an unobserved components model – published a paper.
- Analysing characteristics of rainfall in relation to sugarcane cultivation. Final report submitted to the Director.
- Analysing ratoon yield variation and determining optimum replanting cycles in sugarcane cultivation in Sevanagala, Sri Lanka. Final Report submitted to the Director.
- Assessing varietal adaptability of sugarcane in Sri Lanka. This information utilised in varietal release. Publish research papers.

- Selection of sugarcane genotypes based on genotype-environment interactions. This information are utilised for releasing varieties foe commercial cultivation. MPhil thesis and research papers.

7.4.5 Involved in collaborative researches with other divisions of SRI and contributed to the following research findings – These research works are already included in this report by other co-researchers in respective divisions.

- Actively involved in the development of new commercial and near commercial varieties by carrying out conventional varietal improvement programs and releasing of them to the sugar industry. Developing testing and selection of 20 new promising varieties by carrying out field experiments and statistical data analysis with the collaboration of the Division of Crop Improvement.
- Large mill tests and cane quality evaluation of varieties.
- Study on the post-harvest deterioration of sugarcane.
- Evaluation of some promising sugarcane varieties for quality jaggery production.
- Evaluation of the effect of hot water treatment and cold soak treatment on the production of smut and leaf scaled disease-free sugarcane planting materials.
- Evaluation of the effect of hot water treatment and cold soak treatment on the production of white leaf disease-free sugarcane planting materials.
- Preliminary investigation to identify the effect of $ZnSO_4$ on cane quality of the variety SL 96 128 at Uda Walawe, Sri Lanka.
- Optimising pre-liming pH for efficient juice clarification process in Sri Lankan Sugar factories.
- Production of organic fertilizers by using sugarcane industry by-products of Sri Lanka: A preliminary investigation.
- Performance of sugarcane varieties in a white leaf disease (WLD)-prone environment at Pelwatte.
- Evaluation of selected sugarcane varieties for smut disease reaction and its effect on cane and sugar yields.
- A Preliminary investigation on the response of sugarcane varieties SL 96 128 and SL 96 328 to Nitrogen, Phosphorous and Potassium under irrigation at Uda Walawe, Sri Lanka.
- Evaluation of some Brazilian sugarcane varieties for the resistance to sugarcane smut pathogen in Sri Lanka.
- Identification of different sugarcane smut strains in Sri Lanka.
- Evaluation of some Brazillian sugarcane varieties for resistance to leaf scaled disease pathogen in Sri Lanka.
- An assessment of the size of meristem explant for the elimination of sugarcane bacilliform virus.
- Estimation of heritability of sugarcane yield components through analysis of poly-cross families.
- Cross predictions for sugarcane breeding analysis of biparental families for estimation of heritability and cross prediction in sugarcane breeding.
- Relationship between the incidences of sugarcane white leaf disease and the population dynamics of its vector in Sri Lanka.
- Design and fabrication of a two-wheel tractor-mounted fertilizer applicator for sugarcane smallholders in Sri Lanka.
- Performance evaluation of power tiller mounted fertilizer applicator.
- Performance evaluation of four-wheel tractor-mounted disk ratooner.

- Effects of mulching on growth and yield in plant crop of sugarcane under rain-fed conditions in Sevanagala, Sri Lanka.
- The effects of high-grade Eppawala Rock Phosphate as a Phosphorous substitute on yield and quality of sugarcane in Sri Lanka.
- Study on distribution pattern of sugarcane woolly aphid on sugarcane plant based on leaf colour.
- Providing necessary research support to all research divisions in designing experiments and data analysis for improving the capacity for undertaking advanced research.
- Improving the capacity for undertaking advanced research through collaborative research. Receiving awards for collaborative research works- 05 occasions in plantation crop symposiums.

7.4.6 Providing IT-related services

- Development and promotion of information and communication technology (ICT) related activities within the institute.
- Development and maintenance of SRI web page.

8. Technology Transfer and Development Division

The main purposes of the Technology Transfer and Development (TTD) Division are to disseminate the knowledge/recommendations generated by the institute's research program for commercial application aiming the sustainable development of local sugar industry, and to initiate and implement development programs especially in non-traditional sugarcane growing areas as the cottage-level industries. The division implements programs to transfer new sugarcane technologies in collaboration with research divisions through farmer/field visits, group discussions/trainings/workshops/exhibitions, field trips/days, telephone calls, method and results demonstrations (field and in-house), seminars etc. Advisory pamphlets, videos, posters, newspaper articles, and newly-introduced SRI web page, SRI e-SMS service, SRI FB page, and SRI YouTube channel are used in knowledge dissemination/extension activities.

8.1 Goals/objectives of the division

The goal/s of the division is the development of local sugar industry through ensuring effective transfer of sugarcane technologies. In addition, the development of sugarcane-related cottage-level industries and the introduction of sugarcane cultivation into the non-traditional sugarcane growing areas, are emphasized.

8.2 Priority areas

1. Promotion of better sugarcane varieties
2. Promotion of improved planting techniques
3. Knowledge improvement on soil fertility management
4. Knowledge improvement on pest and disease management
5. Promotion of inter-cropping of short-duration crops with sugarcane
6. Improvement and adoption of good agronomic practices
7. Improvement of the entrepreneurial skills of the growers
8. Promotion of small-scale machinery for sugarcane cultivation and cottage-level processing
9. Improvement of jaggery and syrup production as a cottage-level sugarcane industry
10. Printing and publishing of institutional documents

8.3 Summary of achievements 2010 - 2021

Achievements -2010

- One-day Training on new sugarcane technologies for 30 farmers from Hingurana.
- Trained 312 farmers from Pelwatte, and 16 from Hingurana on weed management.
- Trained 364 school students on sugarcane cultivation.
- Two bulletins on pest and disease, a leaflet on nursery management were published.
- 12 varietal demonstrations at industry areas were established.
- Two programs on Tyne cultivators for 75 farmers at Kodayana were conducted and 12 Tyne cultivators were distributed among farmer at subsidised rates.
- Conducted awareness program on SWA for 28 officers at Pelwatte.
- Supplying required seed materials, established 16 demonstration plots on intercropping.
- Conducted farmer awareness programs, and supplied seedcane at Passara area to control SWA attack. In addition, with the CBSL, a subsidy scheme was launched.

- Two training on jaggery production for 35 farmers from Moneragala were conducted at SRI.
- Educational exhibition stalls were run at Deyata Kirula at Pallekele, and Jangama seva – Deyata Kirula at Badulla.

Achievements -2011

- Established demonstrations and conducted awareness programs to promote varieties, SL 83 06, SLI 121, SL 92 4918, SL 92 4997, and SL 92 5588.
- Conducted trainings on Tyne cultivator and furrow openers, and distribute 4 Tyne cultivator at Pelwatte.
- Supplying required seed materials, established 24demonstration plots on intercropping
- Conducted 4 training on soil fertility management at Hingurana.
- Conducted 17 training sessions for farmers on good agronomic practices.
- Conducted 3 training on jaggery production.
- Ran an exhibition stall at Deyata Kirula – Buttala.
- Printed SRI annual report 2009, revised SRI brochure, and Puwath Hasuna.

Achievements -2012

- Established, maintained and used to conducts 14 demonstration sites on the varieties of SL 96 128, SL 96 328, SL 92 5588 and SL 88 116 at Sevanagala, Siyamabalanduwa, and Hingurana.
- Produced 20 Tyne cultivators, and five furrow openers and distributed them among farmers. Conducted 8 awareness program on Tyne cultivator, and furrow opener for 112 farmers.
- Promoted the intercropping with sugarcane by conducting results demonstration for 283 farmers in industry areas.
- Conducted methods demonstrations on fertilizer application and soil fertility management for 202 farmers.
- Conducted training on good agricultural practices of sugarcane for 872 farmers in all industries.
- Conducted 11 trainings on pest and disease management for 655 farmers in all industries.
- Conducted five training on jaggery production for 131 farmers.
- Launched exhibition stalls at *Deyata Kirula* at Oyamaduwa, *Diri Udana* at Embilipitiya, *Siyawas Semaruma* of Dept. of agriculture at Gannnoruwa

Achievements -2013

- Established, maintained and used to conducts 20 demonstration sites on the varieties of SL 96 128, SL 96 328, SL 95 4033 SL 92 5588 and SL 88 116 at Sevanagala, Siyamabalanduwa, and Hingurana.
- Conducted 10 training sessions for 168 farmers on varieties.
- Conducted 9 awareness programs on Tyne cultivator and furrow openers and provided 7 implements for farmers.
- Established 46 demonstrations by providing seeds on intercropping.
- Conducted 10 demonstration on soil fertility management for 193 farmers.
- Conducted 15 demonstrations on spaced planting technique for 168 farmers.
- Conducted 17 awareness program on good agronomic practices for 470 farmers.

- Conducted 17 training sessions on pest and disease control for 380 farmers.
- Conducted 6 farmer training programs at Sevanagala, Pelwatte, and Siyambalnaduwa areas in collaboration with NIPM
- Conducted 5-day program on agric. Extension at Gannoruwa.
- Ran an exhibition stall at Deyata Kirula, Ampara.

Achievements – 2014

- Established, maintained and used to conducts 6 demonstration sites on the varieties of SL 96 128, SL 96 328, SL 95 4033 SL 92 5588 and SL 88 116 at Sevanagala, Siyamabalanduwa, and Hingurana.
- Established 18 demonstrations by providing seeds on intercropping.
- Running an exhibition stall at *Deyata Kirula* 2014 at Kuliyapitiya and National Agricultural Exhibition at Thelijjawila.
- Printing of SRI Annual Report 2012.
- Conducted five-days training program on Agricultural Extension for 12 Students from NIPM.
- Conducted 2-day training program for 8 officers from Sri Lanka Army.
- Printed the revised version of advisory leaflet on Jaggery production both in Sinhala and Tamil Languages.
- Conducted three-day training on sugarcane cultivation for 39 personnel from Kilinochchi.

Achievements - 2015

- Training a total of 2,866 farmers and 1,221 field officers on new sugarcane technologies by conducting 141 training programs/field demonstrations for farmers, and 55 training programs for field officers. A total of 147 visits were made to farmers' fields and 405 students of Universities, NIPM, AQUINAS, Agriculture Schools, National Youth Council and technical colleges were also trained on sugarcane technologies.
- Establishing maintaining 99 field demonstrations sites on varieties in sugar mill areas including the varieties SL 00 354 (06 nos), SL 00 603 (08 nos), SL 96 128 (02 nos), and SL 98 2524 (01 no).
- Published SI newsletter, Sugarcane Sri Lanka Journal.
- Conducted 3 trainings for university students.

Achievements - 2016

- Training a total of 1464 farmers and 617 field officers on new sugarcane technologies by conducting 39 training programs, 29 field demonstrations and two field trips. A total of 470 farm visits were made to farmers' field and 320 students from Universities, 49 students of NIPM and 113 students of schools were also trained on sugarcane technologies.
- Distribution of 18 Tyne Cultivators among farmers to promote its use.
- Establishment and maintenance of 71 filed demonstrations site in sugar mill areas.
- Distribution of 6900 copies of advisory publications among farmers/officers in sugar companies.
- Participating in the exhibition "Wasa Visa Nethi Hetak" at BMICH by running an exhibition stall jointly with Tea and Coconut Research Institutes.
- Published Sugarcane Sri Lanka journal Vol. 02
- Publishing SRI Newsletter and Annual Report 2015.

Achievements - 2017

- Training a total of 1,389 farmers and 411 field officers on new sugarcane technologies by conducting 53 training programs/field demonstrations and 01 field day for farmers, and 12 training programs for field officers. A total of 280 visits were made to farmers' fields and 260 students of universities and technical colleges, and 140 students of schools were also trained on sugarcane technologies.
- Establishing maintaining 80 field demonstration sites in sugar mill areas.
- Publishing 6 information sheets on new sugarcane varieties and SRI newsletter Puwath Hasuna, volume 07 No 01.□ Reprinting 5,500 copies of 05 leaflets (Leaf Scald Disease in Sugarcane, White Leaf Disease in Sugarcane, Sugarcane Shoot Borer, Ratoon Management in Sugarcane and Intercropping with Sugarcane) and printing 4000 copies of 02 revised information sheets (Cane Quality Improvement and Weed Management in Sugarcane).
- Distributing 6,650 copies of a farmer manual and advisory publications on agronomic practices, farm machinery and pest and disease control among farmers/officers in sugar companies.
- Coordinating the sugarcane industry section of the *Sara Prabha Gira* radio program.
- Preparing scripts and filming advisory videos on improvement of cane quality, ratoon management, planting techniques, intercropping and small-scale farm equipment.
- Drafting information sheets on the improvement of cane quality, weed management (revised) and nursery management.

Achievements - 2018

- Training a total of 1,139 farmers and 578 field officers on new sugarcane technologies by conducting 51 training programs/field demonstrations and 01 field trip for farmers and 11 training programs for field officers. A total of 325 visits were made to farmers' fields and 196 students of universities and technical colleges were trained on sugarcane technologies.
- Conducting a two-day training program on agricultural extension for 35 field staff members of sugar companies.
- Establishing and maintaining 67 field demonstration sites in sugar mill areas.
- Publishing 04 information sheets on new sugarcane varieties, nursery management and cane quality improvement.
- Producing advisory videos on improvement of cane quality (25min) and planting techniques (12 min) and filming and editing of advisory videos on ratoon management (12min) and intercropping (12min).
- Printing 6,000 copies of 02 leaflets and 03 information sheets (Cane quality improvement, nursery management, weed management and two sugarcane varieties).
- Distributing 2,650 copies of a farmer manual and advisory publications on agronomic practices, farm machinery and pest and disease control among farmers/officers in sugar companies.
- Preparing and distributing 1,000 copies of a poster on fall army warm among sugar companies to make the sugarcane farmers aware of the pest.
- Running exhibition stalls on sugarcane research and development at "V2020" Enterprise Sri Lanka at Moneragala and "Harvest 2018" at BMICH.
- Drafting information sheets on WLD control and soil fertility improvement.

Achievements - 2019

- Training a total of 1,130 farmers and 376 field officers on new sugarcane technologies by conducting 40 training programs/field demonstrations for farmers, and 13 training programs for field officers. A total of 240 visits were made to farmers' fields and 287 students of universities NIPM, National Youth Council and technical colleges were also trained on sugarcane technologies.
- Establishing and maintaining 88 field demonstration sites in sugar mill areas.
- Publishing an information sheet on seedcane production and SRI newsletter- "*Puwath Hasuna*", volume 09 No 01.
- Producing advisory videos on ratoon management (12min) and intercropping (12min) and filming and editing advisory video on seed cane production (15min) and uploading a video on cane quality improvement (24min) into SRI web page/YouTube.
- Printing 4000 copies of information sheets and newsletters (seedcane production and SRI newsletter- "*Puwath Hasuna*", volume 09 No 01.)
- Distributing 2,350 copies of a farmer manual and advisory publications on agronomic practices, farm machinery and pest and disease control among farmers/officers in sugar companies.
- Launching SRI TTD eSMS service for transfer extension messages between researchers, extension officers and farmers in the sugarcane sector.
- Running exhibition stalls on sugarcane research and development at Rajarata University – "Krushi Mela" 2019 at Anuradhapura and "Silpa Sena 2019" at BMICH.

Achievements - 2020

- Training a total of 555 farmers and 253 field officers on new sugarcane technologies by conducting 22 training programs/field demonstrations for farmers, and 09 training programs for field officers. A total of 645 visits were made to farmers' fields and 256 students of Universities, NIPM, AQUINAS, Agriculture Schools, National Youth Council and technical colleges were also trained on sugarcane technologies.
- Establishing maintaining 113 field demonstrations sites on varieties in sugar mill areas including the varieties SL 00 354 (06 nos), SL 00 603 (08 nos), SL 96 128 (02 nos), and SL 98 2524 (01 no).
- Distributing 1,200 copies of a farmer manual and advisory publications on agronomic practices, farm machinery and pest and disease control among farmers/officers in sugar companies.
- Continuing SRI TTD *eSMS* service for transfer extension messages between researchers, extension officers and farmers in the sugarcane sector.
- Running exhibition stalls on sugarcane research and development at Embilipitiya Maha Vidyalaya, February 2020.

Achievements - 2021

- Training a total of 195 farmers and 135 field officers on new sugarcane technologies by conducting 22 training programs/field demonstrations for farmers, and 2 training programs for field officers. A total of 56 visits were made to farmers' fields and 65 students of NIPM, Agriculture Schools, were also trained on sugarcane technologies and extension management.

- Establishing maintaining 87 field demonstration sites on SRI recommended varieties and intercropping with sugarcane in sugar mill areas.
- Three observational fields were established and being maintained on organic sugarcane farming at SRI research farm, Galoya, and Ethimale sugar companies in compliance with the revised research program of SRI on organic sugarcane farming. The observations are being obtained and awareness programs for agricultural staff of sugar companies and farmers have been planned to be conducted in 2022.
- Continuing SRI TTD *eSMS* service for transfer extension messages between researchers, extension officers and farmers in the sugarcane sector. Continuing the sharing of sugar industry information though the SRI FB page and updating SRI website. In addition, publishing two volumes of SRI Newsletter (*Puwath Hasuna* of SRI) and two annual reports for the years 2018 and 2019, and completing the report for 2020 were done.
- Initial steps have been made to establish "Uk Waga Gammana" in non-traditional sugarcane-growing areas in different parts of the country, i. e. Nagoda – Galle, Ketawala – Badulla , Welioya – Mulathew, and Poonewa, Medawachchiya. These projects is carryout under the purview of State Ministry. Based on the success of above programs, it was expected to expand the sugarcane cultivation in the areas where the cultivation and processing of sugarcane are possible.

9. List of publications (2011-2022)

9.1 In peer-reviewed indexed journals

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