Research

and

Technology Transfer and Development Programme

2023

Sugarcane Research Institute
Uda Walawe

Contents

Introduction

The 2023 program consists of three main components, namely, research, technology transfer and development.

The research program will be conducted under the following six main areas aiming at increasing the productivity, profitability and sustainability of the sugarcane industry of Sri Lanka to enhance its competitiveness:

i. Crop improvement
ii. Crop and resource management
iii. Crop nutrition
iv. Crop protection
v. Processing and product development
vi. Mechanization

The sugarcane crop improvement program aims at developing varieties superior to the existing ones, in terms of cane and sugar yields, resistance to diseases and pests, tolerance to drought, ratooning ability, maturing at different ages, adaptability to different sugarcane-growing environments, etc. It is a multi-disciplinary and multi-staged program conducted with the involvement of all technical divisions of the institute. The sugarcane crop and resource management program will be 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 and by diversified farming. The sugarcane crop nutrition program will be conducted mainly for recommending soil and fertility management practices for sugarcane by the Crop Nutrition Division. The crop protection program will be undertaken to recommend practices for disease and pest control and to provide crop protection services to prevent from and/or control of diseases and pests in sugarcane plantations. This will be carried out by the Crop Protection Division. The processing and sugarcane-based product development will be 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 leadership for this.

The technology transfer program will be undertaken to take the findings of the above-mentioned research programs to cane growers/millers/sugar companies and to promote adoption of new technologies and improved management practices for the development of the sugarcane industry of Sri Lanka. This program is carried out by the Technology Transfer and Development Division.

In addition, the development of sugarcane cultivation and small-scale processing industries in Kilinochchi and Badulla districts, production of seedcane at Uda Walawe, and Kantale, information and promotion center at SRI Colombo Office, introduction and evaluation of imported sugarcane varieties, large mill tests of 2000, 2002, 2003 and 2004 series varieties and the research programs started in 2022 to test the possibility of converting inorganic farming to organic farming of sugarcane will be continued in 2023.

Research, technology transfer and/or development projects that will be undertaken by each division are described in the following sections:

Divisional Programs

Crop Improvement Division

The following four research projects will be undertaken by the Crop Improvement Division (CI) in 2023:

Research

i. CI/23/01: Collection, conservation, evaluation and utilization of *Sacchurum* germplasm
ii. CI/23/02: Development and selection of new sugarcane varieties
iii. CI/23/03: Biotechnological applications for sugarcane variety improvement
iv. CI/23/04: Development and selection of sugarcane varieties for green economy

CI/23/01: Collection, conservation, evaluation and utilization of *Sacchurum* germplasm

Introduction

The richness of the genetic resource of sugarcane makes possible conducting crop improvement research with a greater success. The genetic diversity of the sugarcane germplasm collection is enriched for the development of new improved sugarcane varieties with better commercial attributes, such as high cane yield, high sucrose content, resistance to pest and diseases, adaptability to adverse environmental conditions and good morphological characteristics. The genetic diversity of sugarcane germplasm is required to be conserved *ex-situ* for further use, especially in crop improvement. The Sugarcane Research Institute conserves the *Saccharum* germplasm collection at the Sugarcane Breeding Station, Enselwatte, Deniyaya. It is comprised with 1,659 accessions assembled through foreign and local sources such as commercial and near-commercial sugarcane varieties, progenies of inter- and intra-specific crosses and locally collected accessions through local expedition. Among the basic *Sacchurum* species; accessions from *S. officinarum, S. spontaneum,* are available while the accessions belong to *S. barberi, S. sinense* and *S. robustem* are not available in this collection. The related wild genera; *Erianthus spp*. accessions and an accession of *Miscanthus japonica* are maintained. The related genera *Sclerostachya* and *Narenga* are not available in this collection.

Therefore, enrichment of the existing *Sacchurum* germplasm by adding accessions from the above-mentioned *Sacchurum* species, related genera, commercial and near-commercial sugarcane varieties and progenies of inter and intra-specific crosses makes possible conducting the sugarcane crop improvement program with a greater success.

Sugarcane crop improvement begins with hybridization using the selected parents to generate genetically-variable seedling population. Directional breeding is the key point to achieve the objectives of developing high-cane- and sugar-yielding progenies with resistance to biotic and abiotic stresses. Characterization of germplasm accessions phenotypically and genetically is important to identify the genetically diverse, potential parents and development of parental core-collection for directional breeding.

Objectives and targets

i. Improvement of genetic diversity of the *Saccharum* germplasm collection by adding new accessions and conservation of existing sugarcane genetic diversity.

ii. Assessment of parental worth in *Saccharum* germplasm for cane and sugar yields and their components.
iii. Development of core-collections for directional breeding for high yield, high sucrose content.
iv. Evaluation of imported varieties in different sugarcane growing areas in Sri Lanka.

Methods

Collection of germplasm

The *Saccharum* germplasm will be increased through introductions from other countries and local collections. Since, Sri Lanka covers under the agreement on plant genetic material protection of the World Trade Organization (WTO), preparation of Memorandum of Understanding (MoU) is a mandatory requirement for the exchange of genetic material with other countries. During the year 2023, it is expected to import promising varieties with desirable traits, such as, drought tolerance, white leaf disease (WLD) resistance, etc. from Fiji. Organized germplasm collection expeditions will be undertaken in northern dry-zone areas of Sri Lanka to collect *Saccharum* germplasm and to survey the presence of natural habitats and home gardens of *Saccharum* and related wild species. The Geographic Positioning System (GPS) available at SRI will be used in collaboration with the Crop and Resource Management Division for this purpose. The genetic material will be collected in accordance with the guidelines of the International Bureau of Plant Genetic Resources (IBPGR).

The varieties that are recorded as free of alien pests and diseases will be released from quarantine station with the approval of the Director General of the Department of Agriculture and will be established in the field for further evaluation and in sugarcane germplasm.

Conservation

The existing *ex-situ Saccharum* germplasm collection with 1659 accessions of imported, locally-collected, locally-bred and sub-clones developed through callus culture will be maintained as plant crop and ratoon 1 crop, respectively in duplicate blocks at the sugarcane breeding sub-station at Enselwatte, Deniyaya. To protect from wild boar damage and other damages, the same set of accessions are been establishing at Uda Walawe (Few clones at Uda Walawe). Each accession will be replanted in 5 m plot in replicate 1, and the accessions in replicate 2 will be ratooned during January - April 2023. These crops will be maintained throughout the year to facilitate sugarcane hybridization in 2023. Mericloning technique will be adopted to rescue the accessions infected with systemic pathogens.

The true hybrids developed through nobilization activities in 2016 will be established and maintained in a separate block of land for future utilization in back crossing (due to the non-availability of developed lands, unable to establish these true hybrids at germplasm, Enselwatte, Deniyaya). The progenies from recurrent breeding for the development of high-sucrose parental stock and population improvement of *Saccharum officinarum* and in-bred progenies will also be established and maintained in separate blocks reserved for them at the breeding sub-station.

Evaluation

Estimation of breeding values of the accessions for yield components

A field trial with 58 accessions collected through local expedition in 2018 was established in January 2022 using Randomized Completely Block Design (RCBD) with 2 replicates. One-metre-long furrow prepared in 1.37 m inter-row spacing was used as the plot size. One-metre gaps were given between two plots in the rows. Sugarcane yield components namely plot

weight, number of millable stalks per plot, stalk length, stalk diameter, field brix, laboratory brix, pol in juice, purity, pure obtainable cane sugar, sugar yield per plot and fibre percent fresh weight will be measured / estimated at harvesting the crop in January 2023.

ANOVA and mean separation will be used for finding superior accessions for each characteristic. The parent clones with more or less similar breeding values will be grouped using cluster analysis. Breeding values (BVs) of the accessions will be estimated using the equation; $BV = h^2_N (P-P^-)$ where, h^2_N = narrow sense heritability, P = phenotypic value of the accession and P^- = mean of the parental population. Based on the information gathered through the analyses, the parental core-collections for directional breeding of sugarcane for high cane and sugar yields will be formed by inclusion of candidate parental lines.

The selected sugarcane varieties, imported from Pakistan and Australia were multiplied in sugar industry areas and evaluation trials were established in 2021 using Randomized Complete Block Design (RCBD) with 2 replicates. The plot size of 5 m x 4 rows were and 1.2 m spacing was maintained. The trials were harvested in May-July 2022 in each industry area after 12 months of planting and data recording was done. The parameters related to the cane and sugar yields such as plot weight, stalk length, stalk diameter and number of millable stalks, laboratory brix, pol in juice, purity, POCS and fiber were measured and calculated. The ANOVA and mean separation on these characteristics were performed for selection of superior varieties. The 20 varieties selected from Lanka Sugar Company (Pvt) Ltd., Sevanagala and Pelwatte were multiplied in respective areas for further evaluation.

Location:

i. Northern dry zone areas of Sri Lanka for expeditions
ii. Sugarcane Quarantine Station, Hantane.
iii. Sugarcane Breeding Sub-station, Enselwatte, Deniyaya.
iv. Sugarcane Research Institute, Research farm, Uda Walawe
v. Lanka Sugar Company (Pvt) Ltd., Sevanagala and Pelwatte, Gal Oya Plantations (Pvt) Ltd. Ethimale plantations (Pvt) Ltd.

Officers responsible

Team Leaders: Ms. A.M.M.S. Perera (SRO- Crop Improvement)

Other Officers: Mr. K.P. Wickramasinghe (RO-Crop Improvement, on leave for fellowship program)
Ms. A.N.W.S. Thushari (RO - Crop Protection/Pathology)
Dr. K.M.G. Chanchala (RO - Crop Protection/Entomology)

Collaborating organization/s: Lanka Sugar Company (Pvt) Ltd., Sevanagala and Pelwatte, Gal Oya Plantation (Pvt) Ltd. Ethimale plantation (Pvt) Ltd.

Total estimated cost (Rs): 6,300,000

Funding agency: SRI

Duration: Continuation from 1984

Action plan for 2023

Month / Activity	J	F	M	A	M	J	J	A	S	O	N	D
1. Local expedition-Northern Province												
2. Importation from Fiji												

3. Replanting / ratooning of accessions												
4. Incorporation of locally collected and imported varieties to germplasm												
5. Maintenance of the accessions												

Benefit to the industry

Development and release of new improved sugarcane varieties and imported varieties adaptable for local conditions, for commercial cultivation in future by exploiting the enhanced genetic diversity and utilization of conserved genetic diversity in germplasm collection.

CI/23/02: Development and selection of new sugarcane varieties

Introduction

Hybridization of sugarcane is carried out in every year to develop new hybrids of sugarcane with superior commercial attributes. The majority of the crosses are performed between selected parents of *Saccharum* spp. hybrids (commercial crosses). Also, inter- and intra-specific crosses are performed to introgress wild genomes into *Saccharum officinarum* or commercial/near-commercial canes for developing hybrids which have the characteristics of high biomass production (e-cane), resistance to pests and diseases, tolerance to adverse environmental conditions, suitable for machine harvesting and etc.

In the selection process of new varieties, the true seeds of new hybrids are sown in the nurseries, and resulting genetically-varied seedlings are transplanted in the first-ground nursery. Different strategies in the selection of new sugarcane varieties are adopted in different sugarcane breeding stations around the world. Among them, individual selection, family selection and individual selection followed by family selection (combined selection) are well-known. Because of high degree of variation in the lands, individual selection followed by family selection is adopted at the first-ground nursery in Sri Lanka. At this stage, good morphology of cane and the levels of pest and disease infestations are considered in the selection of new varieties. Therefore, new varieties should be screened for resistance to major sugarcane diseases; smut disease, leaf scald disease and white leaf disease before the Preliminary Yield Trial (PYT) stage to ensure absence of disease susceptible varieties in the final stages of selection. Selection indices involving multiple trait selection criteria are used in selection of superior clones at stage 2 and 3. Promising varieties selected in stage 3 are tested at PYT stage. Varieties selected from PYTs are used for Replicated Yield Trials (RYTs). New varieties which are superior to standard varieties in RYTs up to second ratoon crop are chosen for further evaluation in maturity patterns and large block trials. Large-block trials for large mill tests and adaptability trials in different sugarcane growing areas are done at farmers' fields at different sugar industries before releasing them for commercial cultivations.

To make sure the superiority of varieties commercially, the clones are selected based on high cane yield, high sucrose content, moderate fibre content, maturity times, ratooning ability, tolerance to drought, wide and specific adaptability, good morphology and milling qualities using selection indices with multiple trait selection criteria in different stages of clonal selection. In addition, the response of new sugarcane varieties to fertiliser is tested after releasing them for commercial cultivation.

Objectives and targets

Objectives

i. Development of high yielding, early-, mid- and late maturing sugarcane varieties for different sugarcane-growing conditions in Sri Lanka with the characteristics of good ratooning ability, resistant to pest and diseases (WLD, smut and leaf scald), drought tolerance, and suitable for mechanization.
ii. Generating high-sucrose genetic stocks to be used as parental clones.
iii. Improvement of basic *Saccharum officinarum* population in breeding attributes and commercial attributes along the selection stages for commercial adoption.
iv. To collect information to adopt sequential selection (family selection).

Targets

To release one commercial sugarcane variety, from each breeding series for commercial cultivation.

Methods - Hybridization

Commercial crosses

Bi-parental crosses and poly-crosses from 750 – 1000 genetic combinations will be adopted at Enselwatte using the proven parents and proven crosses. Field lantern crossing technique and solution crossing technique will be adopted in the hybridization garden and in the crossing shed, respectively. Emphasis will be made to incorporate white leaf disease (WLD) resistance into the high-yielding progenies from the WLD resistant/tolerant parent's hybridization. High-yielding parents with good morphological traits, such as, self-trashing, non-lodging cane, and absence of spines on leaf sheaths, good ratooning ability and low propensity to flowering will be used with the parents resistant to WLD, to develop such progenies. The parental core-collections developed under the germplasm characterization projects will be used for performing directional crosses.

Nobilization and population improvement

Saccharum spontaneum and *Erianthus arundinaceus* will be nobilized through inter-specific and inter-generic crosses, respectively using *Saccharum officinarum* as the noble parent to broaden the genetic base. The first- and second-generation hybrids developed through above crosses in the past will be back-crossed with *Saccharum officinarum* in the introgression of wild genomes into the noble cane.

Intra-specific crosses will be made among the recurrent progenies of *Saccharum officinarum* clones in the respective core-collections to obtain improved sub populations of *Saccharum officinarum* for subsequent utilization in nobilization activities. The recurrent breeding program initiated in 2007 to generate high-sucrose parental stocks using a population of high-sucrose varieties will be continued.

In-breeding

The progenies that were obtained and planted in the arrowing site from the crosses involved in the selfing series initiated in 2007 using the selected parents for in-breeding in sugarcane improvement will be used to effect subsequent crosses. The in-breeding approach will be applied to develop varieties to be used in the following purposes in sugarcane breeding:

i. For direct cultivation as commercial varieties.
ii. To assess the parental worth of a variety.
iii. For use as parents in hybridization.

True seed processing
True seeds produced from the crosses will be dried, cleaned, packed and stored at -20 °C till they are sown for generation of seedling population.

Seed sowing and establishment of seedling nurseries
True seeds obtained from the crosses made in previous year will be sown separately in pans or flats containing seed germination medium made out of top soil and dried cow dung. Artificial NPK fertilizer mixture will be added when preparing the medium. The pans with sowing medium will be steamed for 4 hours to eradicate weed seeds and pathogens. The medium in pans will be carefully leveled prior to seed sowing. The fuzz will be spread as evenly as possible on the medium and sown in wind-free area. After spreading, the fuzz will be sprinkled lightly with water to flatten or press the fuzz to the soil surface. Then, the pans after final sprinkling of water to the sown fuzz, will be covered with plastic or thick opaque cover until germination. After germination, the cover will be removed completely to prevent etiolating young seedlings. The pans with the seeds sown will be labeled with the cross number.

Careful attention will be paid daily to watering, fertilizing, clipping, and pest and disease control during the first three to four weeks since young sugarcane seedlings are very delicate. Liquid fertilizer mixtures will be applied on to leaves if plants show nutrient deficiency. The above- mentioned activities will be carried out in the glass house. The sugarcane seedlings will be transferred to shade house for gradual hardening process.

After hardening in the shade house for 3 months, individual seedlings will be transplanted in polythene pots filled with soil so that the seedlings have sufficient space and resources to develop into plants capable of surviving and transplanting in the field. The transplanted plants in polythene pots will be arranged in nursery beds. Proper labeling system will be adopted and a plan of the nursery bed layout will be prepared. The required nursery operations will be undertaken till the plants are established in the field in the first selection stage.

Varietal evaluation – Stage 1
Individual seedlings will be transplanted in the field with 0.5 m spacing between plants in the rows after hardening them at the seedling nursery. The standard inter-row spacing of 1.37 m will be maintained in the entire field. The field will be separated into blocks in accordance with the age of the seedlings and the time of establishment of separate sections of the selection stage. The standard sugarcane variety Co 775 will be planted in every 10^{th} row of the block for comparison purpose during variety selection. When the crop reaches maturity (12 months of age), individual sugarcane plants in this selection stage will be assessed on highly heritable characteristics; field brix (an indirect measurement of sugar content in juice) and fibre content in cane (measured by rind hardness). Usually, varieties with high field brix and moderate fibre content will be selected. More emphasis will be paid to select the varieties with acceptable field brix (high sugar content) and high rind hardness for selection of energy cane. Good morphology and absence of pests and diseases will also be considered in the selection of varieties at this stage. Eight to ten percent of the progenies in selection stage 1 will be selected based on brix and rind hardness of the adjacent standard variety plots. The varieties with brix and rind hardness values higher than 2 points of the same parameters of the standard variety will be selected to be advanced into selection stage 2. Stem cuttings of the selected progenies will be used for the establishment of subsequent selection stage (selection stage 2).

Varietal evaluation – Stage 2
The land furrowed with 1.37 m inter-row spacing where the crop is going to be established will be separated into 5-metre wide blocks along the slope of the land leaving 1 m gap between two blocks. Blocking out will be done perpendicular to the furrow direction. It makes a grid where

blocks represent columns and furrows (the plots) represent rows. Each variety will be planted in a plot with 5 m length and the standard variety Co 775 is planted in the first and every 10^{th} row (plot) of the block to make a grid of standard. The test varieties will be planted in the furrows (plots) between the standard plots in the blocks. Hence, 9 test varieties are planted between two plots of standard in a block. Test varieties are not replicated at this selection stage.

Planting density of five three-budded setts per meter length of a plot will be adopted at this stage to ensure even growth and development of test varieties. The recommended cultural practices will be adopted to raise the crop of this selection stage. At the maturity of crop, 5-stalk weight, average 5-stalk field brix, average 5-stalk length and average 5-stalk rind hardness will be recorded in all standard plots and test varieties. The ANOVA will be performed for each variable of the standard plots using the following mathematical model to investigate the variations due to the existing land variations:

$Yij = \mu + \alpha i + \beta j + \alpha\beta ij$

Where;

Yij = individual value

μ = overall mean

αi = row effect

βj = column effect

$\alpha\beta ij$= interaction effect

The selection index:

I = 0.4 (rank HR brix) + 0.3 (rank stalk length) + 0.3 (absolute deviation of rind hardness from the optimum) will be calculated for each test variety to find the relative merit of the test variety compared with that of the standard variety in a particular block of the land in the selection stage. The test varieties will be selected using the average of two standard rows where test varieties exist if land variation is significantly different row-wise. If land variation exists column-wise, the average of two standard columns where test varieties exist will be used for comparison of the test verities for selection. If land variation exists in both directions, the average of four standard plots adjacent to the test varieties will be used to compare the values of the test varieties for selection. The weights for the characteristics in the selection index can be varied depending on the selection strategies (e.g., high cane yielding, high sugar yielding, moderate fiber, etc.) for selection of improved varieties in subsequent population. Cane weight will not be included in the selection index as response to selection is higher for cane yield through stalk length than direct selection for cane yield. The test varieties will be ranked based on 5-stalk weight to arrive at decisions during the selection of varieties in the field. Good morphology and free from pests and diseases will also be considered during the selection of the varieties.

Varietal evaluation – Stage 3

The land furrowed with 1.37 m inter-row spacing where the crop is to be established were separated into 10-metre-wide blocks along the slope of the land and perpendicular to the furrow direction, leaving 1 m gap between two blocks. It makes a grid where blocks represent columns and furrows (the plots) represent rows. The standard variety Co 775 were planted every 10^{th} plot (10 m-long 1 row) of the blocks to make a grid of the standard. The test varieties were planted in the furrows (10 m-long 2-row plots) between the standard plots in the blocks.

A planting density of five three-budded setts per metre length of a plot was adopted at this stage to ensure even growth and development of the test varieties. The recommended cultural practices were adopted to raise the crop. At the maturity of crop, 12-stalk weight and average

12-stalk length will be recorded for each test variety in the field. Cane samples of the test and the standard varieties will be taken for juice and fiber analyses at the laboratory. Laboratory brix and pol percent in juice and fiber percent in cane will be measured, and the purity and POCS in juice will be estimated based on those parameters.

Selection Index;
I = 0.2 rank purity + 0.2 rank brix + 0.3 rank stalk length + 0.3 rank absolute deviation of fiber from the optimum will be used to find out the relative merit of the test varieties for variety selection. The varieties will be ranked based POCS and 12-stalk weight to arrive at decisions during selection of varieties in the field. The varieties with high POCS and high fiber will be selected for the development of energy cane and erect cane will be selected for machine harvest. Good morphology and free from pests and diseases are considered during variety selection. The ANOVA will be performed for each variable of the standard plots using the following mathematical model to investigate the variations due to the existing land variations:

$Y_{ij} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij}$

Where;
Y_{ij} = individual value
μ = overall mean
α_i = row effect
β_j = column effect
$\alpha\beta_{ij}$= interaction effect

The test varieties will be selected using the average of two standard rows where the test varieties were planted if land variation is significantly different row-wise. If land variation exists column-wise, the average of two standard columns where test varieties were planted will be used for comparison of the test verities for selection. If land variation exists in both directions, the average of four standard plots adjacent to the test varieties will be used to compare the values of the test varieties for selection.

The weights for the characteristics in the selection index can be varied depending on the selection strategies (e.g. selection for high-cane yield, high-sugar yield and moderate/high fiber, etc.). Cane weight will not be included in the selection index as response to selection is higher for cane yield through stalk length than direct selection for cane yield. High-sugar varieties will be selected through pol rather than using POCS. The test varieties will be ranked for cane yield to arrive at decisions during the selection of varieties in the field. The varieties selected will be multiplied for obtaining planting material for the establishment of Preliminary Yield Trials. Materials from the selected varieties will be given to the Crop Protection Division for their screening for smut, leaf scald and white leaf disease resistance.

Preliminary evaluation of sugarcane varieties
The varieties selected based on disease reactions, and after multiplication, will be tested at this stage using the plots of 5 m X 4 rows in an appropriate statistical design with the standard varieties. Only the plant crop performance of the varieties will be assessed at the maturity of the crop. Plot cane yield, POCS and sugar yield will be considered as the main characteristics for varietal evaluation. ANOVA and mean separation on these characteristics will be performed for the selection of superior varieties. The selected varieties from PYTs will be multiplied using hot water-treated seedcane for RYTs.

Evaluation of sugarcane varieties at Uda Walawe

The promising varieties which are resistant or moderately-resistant to smut and leaf scald diseases will be evaluated for yield performance in plant and two ratoon crops in replicated yield trials. At the time of harvest of each crop, data on agronomically-important characteristics will be recorded for each variety. An appropriate statistical design will be used to lay out the RYTs determined according to the number of varieties selected testing and the type of land variation. The number of replicates will also be determined accordingly.

ANOVA and subsequent mean separation will be carried out for identifying significantly-high-cane- and sugar-yielding varieties compared to the standard/s. Apart from separate analyses for each crop (plant, ratoon 1 and ratoon 2), a combined analysis will be performed to select varieties on the basis of their performance in plant, ratoon 1 and ratoon 2 crops. DUNNET's procedure will be employed to compare the mean yields of the test varieties with that of the commercial standards to select the superior ones.

Evaluation of sugarcane varieties in different sugarcane-growing areas in Sri Lanka

Sugarcane is commercially-grown in different agro-ecological regions, namely DL1, IL1, (L1-L2), IM1, DL3 and DL4 of Sri Lanka. The differences in soil and climatic conditions in these regions make differences in performance of the sugarcane varieties due to the interactive effect of the two factors (variety and growing environment or genotype-environment interaction). Selection of varieties specifically- or generally-adapted to the above-mentioned environments is required for recommending sugarcane varieties for commercial cultivation in more diverse environmental conditions. This research will be undertaken to find out the suitable varieties specifically for Sevanagala, Pelwatte, Gal-oya, Ethimale, and Kantale sugar industry areas.

Methods

For each series, separate replicated field experiments with the same experimental design, plot size, number of varieties and replicates will be established in different environments representing sugar industry areas, namely, Sevanagala, Pelwatte, Hingurana, Ethimale and Kantale for estimation of varietal, environmental and GEI effects. The varieties will be tested under irrigated and/or rain-fed conditions depending on the cultivation regime in each location. At Hingurana, due to the existence of different soil groups, trials will be established in different locations representing those soil groups. Separate replicated yield trials for each series will be established at each site for estimating varietal (G), environmental (E) and G X E effects. Data on yield components will be recorded for each variety at the time of harvesting. Varietal multiplication plots were established at Uda Walawe using hot-water treated material for obtaining required quantity of planting material.

ANOVA will be conducted to identify the variations in yield due to differences in variety, environment and interaction of these two variables. Joint regression analysis (JR) and additive main effects and multiplicative interaction (AMMI) models will be used to further partitioning of GEI sums of squares. The yield stability of the varieties with respect to both cane and sugar yields will be evaluated by estimating the stability parameters, namely, the variance of a variety across environments (Si2), Shukla's stability variance (σ2i) and Wricke's ecovalance (Wi2). AMMI stability value (ASVi), Eberhart and Russel's stability statistics, regression coefficient (ßi) and the two stability statistics derived considering deviation from linear regression (8̸2di , ʎi) will also be used for this purpose. AMMI I and AMMI II biplots will be used to identify the response of varieties across environments.

Information on the structure and selection criteria pertaining to the various stages of the varietal selection scheme is given below.

Stage	Structure of the experiment	Selection criteria
1	Individual randomisation, No replication	H/R brix, fibre % approximated by penetrometer, visual estimations on plant architecture and free of diseases
2	5m row, no replication	5stalk weight, H/R brix, Av.5 stalk length, Selection Index (I); 0.6rank HR brix + 0.4 rank length
3	10 m x 2 rows per genotype, no replication (Select genotypes will be subjected to disease screening)	POCS, 10 stalk weight, Av. 10 stalk length, Selection index I = 0.2rank purity + 0.2rank brix + 0.3rank stalk length + 0.3rank absolute deviation of fibre
MULTIPLICATION STAGE –1 (Selected clones will be multiplied before PYT)		
4-PYT	5m x 4 rows plot, appropriate statistical design with standards. Plant crop only	Plot cane yield, POCS, sugar yield (ANOVA and mean separation)
MULTIPLCATION STAGE -2 (Selected clones will be multiplied before RYT)		
5-RYT	10mx 5rows plot, appropriate statistical design with standards. Plant + two ratoon crops	Plot cane yield, POCS, Sugar yield,(ANOVA and mean separation)
MULTIPLICATION STAGE – 3 Promising varieties selected from RYT will be multiplied and incorporated into breeder's seed nursery. Planting materials of these varieties will be given to the Agronomists for maturity testing. Large-scale trials will be established at each industry site to assess their performance at commercial scale in each location.		

A summary of the progeny testing activities to be undertaken during 2023 is given below:

i. Hybridization for 2023 series for commercial attributes and true seed processing (January 2023- December 2023)
ii. Seed sowing and establishment of seedling nursery SL 2022 series (May 2023-April 2024)
iii. Seed sowing and establishment of seedling nursery SL 2021 series (August 2022-May 2023)
iv. Establishment of seedling nursery SL 2020 series (June 2022-March 2023)
v. Varietal evaluation - stage 1 of SL 2019 series (January 2023- August 2023)
vi. Varietal evaluation - Stage 2 of SL 2018 series (August 2021- December 2023)
vii. Varietal evaluation - Stage III of SL 2017 series (June 2021- April 2023)
viii. Preliminary evaluation of sugarcane varieties – SL 2016 series (December 2022 – December 2024)
ix. Preliminary evaluation of sugarcane varieties – SL 2015 series (July 2022 – Oct 2024)
x. Preliminary evaluation of sugarcane varieties – SL 2014 series (July 2020 – December 2023)
xi. Evaluation of sugarcane varieties at Uda Walawe – SL 2013 series (November 2022-December 2026)
xii. Evaluation of sugarcane varieties at Uda Walawe – SL 2012 series (December 2021-December 2025)
xiii. Evaluation of sugarcane varieties at Uda Walawe – SL 2010 and SL 2011 series (October 2019 – December 2024)

xiv. Evaluation of sugarcane varieties at Uda Walawe – SL 2009 series (September 2019 – December 2023)
xv. Evaluation of sugarcane varieties at Uda Walawe – SL 2008 series (October 2019 – April 2023)
xvi. Evaluation of sugarcane varieties at Uda Walawe – SL 2007 series (July 2018 – December 2022, data analysis & multiplication- January 2023- December 2023)
xvii. Evaluation of sugarcane varieties in different sugarcane – growing areas in Sri Lanka – SL 2002 series (October 2017 – December 2023)
xviii. Evaluation of sugarcane varieties at Uda Walawe – SL 2005 and SL 2006 (January 2017 – April 2022, data analysis & multiplication- January 2023- December 2023)
xix. Evaluation of sugarcane varieties in different sugarcane-growing areas in Sri Lanka – 2005, 2006 and 2007 series (January 2016 – December 2023)

Location: Sugarcane Breeding Sub-station, Enselwatte, Deniyaya and Sugarcane Research Institute, Uda Walawe, Lanka Sugar Company (Pvt) Ltd., Sevanagala and Pelwatte, Gal Oya Plantation (Pvt) Ltd., Ethimale Plantation (Pvt) Ltd.

Officers responsible

Team Leader: Mr. K.P. Wickramasinghe (RO-Crop Improvement, on leave for fellowship program)

Other Officers: Ms. A.M.M.S. Perera (SRO- Crop Improvement)
Ms. B.D.S.K. Ariyawansha (SRO- Economics Biometry & Information Technology)
Ms. A.N.W.S. Thushari (RO - Crop Protection/Pathology)
Dr. K.M.G. Chanchala (RO - Crop Protection/Entomology)

Collaborating organization/s: Lanka Sugar Company (Pvt) Ltd., Sevanagala
Lanka Sugar Company (Pvt) Ltd., Pelwatte
Gal Oya Plantation (Pvt) Ltd.
Ethimale Plantation (Pvt) Ltd.

Total estimated cost (Rs): 26,000,000

Duration: Continuous from 1984

Action plan for 2023

` Month / Activity	J	F	M	A	M	J	J	A	S	O	N	D
1. Hybridization for 2023 series for commercial attributes and true seed processing (January 2023- December 2023)												
2. Seed sowing and establishment of seedling nursery SL 2022 series (May 2023-April 2024)												
3. Seed sowing and establishment of seedling nursery SL 2021 series (August 2022-May 2023)												
4. Establishment of seedling nursery SL 2020 series (June 2022-May 2023)												
5. Varietal evaluation - stage 1 of SL 2019 series (January 2023- August 2023)												

6. Varietal evaluation - Stage 2 of SL 2018 series (August 2021- December 2023)												
7. Varietal evaluation - Stage III of SL 2017 series (June 2021- April 2023)												
8. Preliminary evaluation of sugarcane varieties – SL 2016 series (December 2022 – December 2024)												
9. Preliminary evaluation of sugarcane varieties – SL 2015 series (July 2022 – Oct 2024) Varietal evaluation – Stage 3 of SL2016 series												
10. Preliminary evaluation of sugarcane varieties – SL 2014 series (July 2020 – December 2023)												
11. Evaluation of sugarcane varieties at Uda Walawe – SL 2013 series (November 2022- December 2026)												
12. Evaluation of sugarcane varieties at Uda Walawe – SL 2012 series (December 2021- December 2025)												
13. Evaluation of sugarcane varieties at Uda Walawe – SL 2010 and SL 2011 series (October 2019 – December 2024)												
14. Evaluation of sugarcane varieties at Uda Walawe – SL 2009 series (September 2019 – December 2023)												
15. Evaluation of sugarcane varieties at Uda Walawe – SL 2008 series (October 2019 – April 2023)												
16. Evaluation of sugarcane varieties at Uda Walawe – SL 2007 series (July 2018 – December 2022, data analysis & multiplication- January 2023- December 2023)												
17. Evaluation of sugarcane varieties in different sugarcane – growing areas in Sri Lanka – SL 2002 series (October 2017 – December 2023)												
18. Evaluation of sugarcane varieties at Uda Walawe – SL 2005 and SL 2006 (January 2017 – April 2022, data analysis & multiplication- January 2023- December 2023)												
19. Evaluation of sugarcane varieties in different sugarcane-growing areas in Sri Lanka – 2005, 2006 and 2007 series (January 2016 – December 2023)												

Benefits to the industry

Increase of productivity by introduction of new sugarcane varieties and minimising the risk of sugarcane crop losses due to biotic and abiotic stresses through diversifying varietal spectrum in commercial plantations in different sugarcane-growing areas.

CI/23/03: Biotechnological interventions for the improvement of sugarcane varieties

Biotechnological interventions hold great promise to address to enhance productivity of sugarcane, to improve sugarcane varieties with disease resistance and to improve quality of the crop. Biotechnological approaches for sugarcane improvement have been applied in Sugarcane Research Institute, Sri Lanka in the areas of tissue culture, molecular diagnostics of sugarcane pathogens, development of genetic maps using molecular markers, molecular testing of plants for variety identification and molecular characterisation of various traits.

Callus culture technique is being used in sugarcane tissue culture to create genetic variability in calli-clones. Some constraints in good varieties such as susceptibility to diseases, presence of spines on leaf sheath etc. could be rectified by using them as donor clones in callus culture. Further, attempts were made to induce genetic variability in sugarcane by *in-vitro* culture combined with radiation or chemical induced mutagenesis. The use of gamma radiation to induce mutation is a method that has been applied in plant breeding to increase genetic variability. It has been used as an effective method, which can greatly induce mutations and modify physiological characteristics to create new mutants with improved properties. Therefore, this research will be continued to generate genetic variability in some selected *Saccharum officinarum* cultivars, commercially cultivated sugarcane varieties; Co 775 and SL 96 128, and high-yielding promising varieties (SL 98 2087, SL 98 2549 and SL 98 2118) using gamma radiation as physical mutagen and Ethyl Methane Sulphonate (EMS) as chemical mutagen.

Meristem culture technique is used in sugarcane to produce disease-free planting materials. Commercial varieties could be propagated *in-vitro* by meristem culture to eliminate systemic diseases. Genes are responsible in all the activities in plants as well as animals. Sucrose synthase gene is responsible in sucrose metabolism. Gene expression studies in sugarcane are one of the key areas to identify the maturity of sugarcane stalks. Therefore, this research was designed to get an idea of maturity of stalks and the sugar retention period in stalks by molecular method.

The modern molecular biological techniques, such as, Simple Sequence Repeats (SSR), isozyme staining and chromosome counting could be applied in the identification of genetic relatedness among sugarcane varieties, development of molecular markers for high sugar and cane yields and disease resistance of varieties, identification of mechanism of meiosis and alien chromosome. Evaluation of the sugarcane germplasm to identify the parents for hybridization using morphological and molecular methods are important for improving the efficiency of the sugarcane crop improvement. Knowledge of genetic diversity and relationship among breeding genomes of *Saccharum* species and their related genera and chromosome number plays a significant role in deciding sugarcane crop improvement strategies. This knowledge can be used to plan the crosses to be performed to increase the genetic diversity and important traits of the resultant sugarcane progenies for subsequent selection.

Germplasm evaluation for identification of parental clones for disease resistance is an important step that determines the efficiency of a sugarcane crop improvement. Smut is a

major disease in sugarcane cultivation. It is caused by the Ustilago *scitamineum* which cause considerable yield loss and reduction in cane quality. There are no effective fungicides that affect after smut infection and the use of resistant varieties is the best control practice. It is necessary to develop a variety that has both smut disease resistance and high productivity. In the sugarcane breeding program of SRI, smut disease resistance is evaluated by the artificial inoculation test. It is laborer consuming and limited by the lands. Therefore, an effective method of evaluating smut disease resistance at earlier selection stages, such as marker-assisted selection (MAS), is necessary to accelerate the breeding of smut disease resistant varieties.

Reliable markers that are tightly bound to genes or genomic regions controlling target traits are necessary for MAS. However understanding the quantitative traits and mapping their loci in the sugarcane genome are challenging because of the highly polyploidy and heterozygous characteristics of the genome. Smut disease resistance is thought to involve internal and external disease resistance mechanisms controlled by several small-effect QTLs.

Objectives and targets

i. To produce disease-free planting materials from newly-released varieties.
ii. To produce *in-vitro*-cultured materials for varietal exportation and to expedite sugarcane quarantine process by meri-cloning of the imported varieties.
iii. To induce genetic variability in selected sugarcane varieties in germplasm and generate at least 10 mutants from each clone.
iv. To minimize the time and resources required for maturity testing by adopting the molecular method for testing maturity.
v. To characterize the sugarcane germplasm for directional breeding.
vi. Identification of QTLs for high sugar content in sugarcane.
vii. Development of marker-assisted selection protocols for smut disease resistance

Methods

The protocols developed by SRI for sugarcane meristem culture will be used to produce meri-clones from newly-released varieties, the varieties with disease infections under quarantine and varieties to be exported. The varieties needed rapid multiplication will be meri-cloned to produce disease-free mother stocks.

Evaluation of genetic variability of *Saccharum officinarum* through in-vitro mutagenesis in callus culture technique

The widely cultivated commercial sugarcane varieties (SL 96 128 and Co 775), pipeline varieties with some defects (SL 98 2087, SL 98 2549 and SL 98 2118), and locally collected *Saccharum officinarum* were used for this experiment. Callus were generated and maintained in tissue culture laboratory of SRI.

Proliferating callus (1-month-old callus) were subjected to gamma rays from ^{60}Co source using 5 doses of 0, 20, 30, 40 and 50 Gy. Each treatment was replicated four times. Post irradiated callus were cut in to 5 mm square pieces and each were placed at a spacing of 2 x 2 cm on freshly prepared MS medium for callus maintaining. Survival of the irradiated callus were determined using relative growth rate after four weeks of radiation treatment. Then, surviving callus were transferred to shoot initiation medium for at least four-five times on same medium until cali-clone formation.

EMS solution will be prepared as 1M Phosphate buffer at pH 7.0. Ten proliferating callus from each variety will be cut in to 3 mm pieces and treat with different concentrations of EMS solutions (0%, 0.05%, 0.1%, 0.2% and 0.25%) at different time intervals (15 min, 30 min, 45 min and 60 min) by immersion. Mutated callus will be cultured back on MS medium to induce somaclonal variability. Subcultures will be raised every 2weeks until the age of 2 months. Percentages of live callus and color of the callus will be observed. All the cultures will be transferred in to MS medium to induce plant regeneration. Well rooted plantlets will be transferred to poly bags and maintain for 45 days in the greenhouse condition. Percentage of survival plants will be determined after 45 days. Then selection of promising mutants will be subjected to selection process according to the standard procedures adopted in crop improvement program at SRI.

Fresh plant material of immature leaves will be collected from 6 months old field grown mutated plants. DNA will be extracted from fresh leaves of selected sugarcane varieties and extracted DNA will be subjected to the PCR amplification with selected primers. Gel electrophoresis will be done to analyzed coefficient of similarity between prior and after treated plants.

Gene expression studies related to the sugar content and maturity of variety SL 96 128

Stem cuttings (3-budded setts) of the varieties SL 96 128 collected from field and mericlones, Co 775, *Saccharum officinarum, Saccharum spontaneum* and *Erianthus* spp. were established in 10 m 2 rows to obtained leaf and stem samples for RNA extraction and to measure the field brix in juice. Plant crop will be harvested and ratoon one crop will be raised for sample collection. After seven months of ratooning, cane and RNA samples of the test varieties and the standard variety will be taken for juice analyses and molecular studies in one-month intervals. Specific primers were design and synthesized for sucrose synthase gene, actin gene and sucrose phosphate synthase genes. The RNA extraction kits and trizol method will be used for RNA extraction. Specific primers for sugar content will be used for PCR amplification. The PCR products of each primer will be measured by running 1.2% agarose gel with known ladders. The gene expression will be studied by using amplified amplicons.

Characterization of *S. officinarum* using molecular and cytological methods

The modified protocol of the CTAB method will be used for total genomic DNA extraction of 150 germplasm accessions. Highly polymorphic SSR primers will be used for PCR amplification. The PCR products of each primer will be confirmed by running 1.2% agarose gel and 6% PAGE with 50 bp DNA ladders. The genetic similarity among the varieties will be calculated by NTSYS-pc 2.2 software. A dendrogram will be constructed based on genetic distance. Chromosome staining will be done using root tips of sugarcane accessions 5-6 months after planting.

Detection of a QTL for smut disease resistance

The mapping population will be constructed using highly smut disease resistant variety with highly smut susceptible variety. DNA will be extracted from the F1 population and PCR will be done using smut specific primers. Highly resolve bands will be scored and data will be analyzed using an appropriate software for QTL mapping. Agronomic traits of the mapping population will be evaluated.

Location: Tissue culture and biotechnology laboratories in SRI, Uda Walawe,
Sugarcane Breeding Station, Enselwatte, Deniyaya

Officers responsible
Team Leader: Ms. A.M. M. S. Perera (SRO- Crop Improvement)
Other Officers: Ms. A.N.W.S. Thushari (RO - Crop Protection)
Mr. K.P. Wickramasinghe (RO-Crop Improvement, on leave for fellowship program)
Total estimated cost (Rs): 3,800,000
Duration: January 2020 to December 2024

Action plan for 2023

Activity \ Month	J	F	M	A	M	J	J	A	S	O	N	D
1. Evaluation of genetic variability of *Saccharum officinarum* through in-vitro mutagenesis in callus culture technique												
2. Gene expression studies related to the sugar content and maturity of variety SL 96 128												
3. Characterization of *S. officinarum* using molecular and cytological methods												
4. Construction of mapping popukation for QTL mapping												

Benefit to the industry

Identification and dissemination of disease free, new improved varieties for commercial cultivation in different sugar mill areas.

CI/23/04: Development and selection of sugarcane varieties for organic farming

Introduction

This project is initiated to prepare a road map for the conversion of inorganic farming to organic farming using organic fertilizers for sugarcane cultivation. This project consists with two activities; 1) Identification of sugarcane varieties for organic fertilizer and 2) Evaluation of commercial sugarcane varieties for organic farming.

1) Identification of sugarcane varieties for organic fertilizer

It is not possible to select sugarcane varieties for organic fertilizer with commercial qualities straight from thousands of seedling progenies produced through hybridisation. Therefore, varietal selection stage 1 (initial selection step) of field evaluation of seedlings will be proceeded without any fertilizer with the existing nutrients in the soil, because initial evaluation will be done based on brix in juice and fibre content. Then, selection stage 2 will be proceeded with organic fertilizer for yield parameters. Few steps under different disciplines have to be

conducted before recommending the sugarcane varieties for commercial cultivation under organic farming.

The individual plants from different families in the seedling populations are selected for the desired commercial attributes. These seedling populations are developed through seed sowing and subsequent nursery establishment. After hardening, 5-6 months age seedlings in nurseries are transplanted in the field for evaluation (selection stage 1). After 12 months of planting, the stem cuttings of sugarcane varieties selected for commercial attributes from stage 1, will be established at the selection stage 2. This selection stage will be evaluated under organic and inorganic fertilizer. The selected varieties from selection stage 2 will be established for selection stage 3 and maintain under organic and inorganic fertilizer as previously. After 12 months of establishment, selected clones for commercial attributes will be multiplied in appropriate conditions. Simultaneously, selected varieties from stage 3 will be given for screening of diseases reactions. The selected varieties based on the commercial attributes and disease reactions under organic and inorganic farming will be evaluated further in PYT and RYT in irrigated and rain-fed conditions separately.

Objectives and targets

Selection of suitable sugarcane varieties for organic farming

Methods

Individual seedlings will be transplanted in the field with 0.5 m spacing between plants in the rows after hardening them at the seedling nursery. The standard inter-row spacing of 1.37 m will be maintained in the entire field. The field will be separated into blocks in accordance with the age of the seedlings and the time of establishment of separate sections of the selection stage. The standard sugarcane variety Co 775 will be planted in every 10^{th} row of the block for comparison purpose during variety selection. All the plants evaluated without fertilizer. When the crop reaches maturity (12 months of age), individual sugarcane plants in this selection stage will be assessed on highly heritable characteristics; field brix (an indirect measurement of sugar content in juice) and fibre content in cane (measured by rind hardness). Usually, varieties with high field brix and moderate fibre content will be selected. More emphasis will be paid to select the varieties with acceptable field brix (high sugar content) and high rind hardness for selection of energy cane. Good morphology and absence of pests and diseases will also be considered in the selection of varieties at this stage. Eight to ten percent of the progenies in selection stage 1 will be selected based on brix and rind hardness of the adjacent standard variety plots. The varieties with brix and rind hardness values higher than 2 points of the same parameters of the standard variety will be selected to be advanced into selection stage 2. Stem cuttings of the selected progenies will be used for the establishment of subsequent selection stage (selection stage 2).

The selected varieties from each cross divided into two sets and it will be established in furrows (5 m-long 1-row) between the standard plots in the blocks. The recommended cultural practices will be adopted to raise the crop. It will be evaluated under organic and inorganic fertilizer recommendations given by the Crop Nutrition division. After 12 months of planting cane and yield parameters will be measured and promising clones will be selected as varietal evaluation stage 2 described as in CI/23/02. The selected varieties after varietal evaluation stage 2 will be planted in the furrows (10 m-long 2-row plots) between the standard plots in the blocks and evaluated under organic and inorganic fertilizer separately. After 12 months of planting cane and yield parameters will be measured and promising clones will be selected as varietal evaluation stage 3 described as in CI/23/02. Selected varieties will be multiplied in

appropriate conditions in organic and inorganic fertilizer. Selection and future evaluation will be done described as in CI/23/02.

Location: Sugarcane Research Institute, Uda Walawe. Lanka Sugar Company (Pvt) Ltd., Sevanagala and Pelwatte, Gal Oya Plantations (Pvt) Ltd., Ethimale Plantation (Pvt) Ltd.

2) Evaluation of commercial sugarcane varieties for organic farming

Introduction

The commercial varieties in breeders seed garden are tested for their yield performance of plant crop and two ratoon crops in replicated yield trials (RYTs) using bigger plots with organic fertilizer. At this stage, the average cane and sugar yields of each variety will be estimated. The varieties with higher cane and sugar yields will be released for organic farming.

Objectives and targets

Identification of sugarcane varieties for commercial cultivation under organic farming.

Methods

The commercial sugarcane varieties which are resistant or moderately-resistant to smut and leaf scald diseases evaluated under inorganic farming was evaluated under organic farming (irrigated conditions) for yield performance. Replicated yield trials was established for evaluation. At the time of harvest of each crop, data on agronomically-important characteristics will be recorded for each variety. An appropriate statistical design will be used to lay out the RYTs determined according to the number of varieties selected testing and the type of land variation. The number of replicates will also be determined accordingly.

ANOVA and subsequent mean separation will be carried out for identifying significantly- high-cane- and sugar-yielding varieties compared to the standard/s. Apart from separate analyses for each crop (plant, ratoon 1 and ratoon 2), a combined analysis will be performed to select varieties on the basis of their performance in plant, ratoon 1 and ratoon 2 crops.

Location: Sugarcane Research Institute, Uda Walawe.

Officers responsible for both activities

Team Leader: Mr. K.P. Wickramasinghe (RO-Crop Improvement, on leave for fellowship program)

Other Officers: Ms. A.M.M.S. Perera (SRO/ Crop Improvement)
Ms. B.D.S.K. Ariyawansha (SRO- Economics Biometry & Information Technology)
Ms. A.N.W.S. Thushari (RO- Crop Protection/Pathology)
Ms. V.K.A.S.M. Wanasinghe (RO- Crop Protection/Entomology)
Dr. K.M.G. Chanchala (RO - Crop Protection/ Entomology)

Total estimated cost (Rs): 2,400,000

Duration: September 2021 – December 2025

Action plan for 2023

Activity \ Month	J	F	M	A	M	J	J	A	S	O	N	D
1. Maintenance of stage 3 under organic and inorganic farming conditions and data collection, analysis												
2. Multiplication for PYT												
3. Maintenance of field trials with recommended varieties under organic farming.												
4. Harvesting, data collection and analysis												
5. Raised ratoon 1 crop and ratoon management												

Benefit to the industry

Identification of suitable varieties for organic farming system, multiplication and to be released for commercial cultivation.

Crop and Resource Management Division

The crop and resource management divisional program will be conducted under the following three major thrust areas in 2023.

1. CRM/01/23: Assessment of climate variability and water management for enhancing the productivity of sugarcane
2. CRM/02/23: Development of package of crop management practices for increasing the productivity of sugarcane
3. D/01/18-III : Sugarcane development project

Under the each thrust area, different research projects will be conducted as follows.

CRM/01/23: Assessment of climate variability and soil water management for enhancing the productivity of sugarcane

CRM/01/23-I: Analysis of agro-meteorological conditions of major sugarcane-growing areas in Sri Lanka in 2023

Introduction

Understanding on variations in climatic parameters is essential for proper crop management and to keep pest and disease incidences below the economic threshold limit. To investigate the atmospheric influences on crop yields, long-term observations of meteorological parameters are necessary. Thus, recording agro-meteorological data in both spatially and temporally helps in making decision in planning sugarcane cultivation as well as in designing and planning irrigation, drainage systems, etc.

Objectives and targets

i. To provide agro-meteorological information for sugarcane research and sugar industry development purposes.
ii. To study prevailing climatic conditions in sugarcane-growing areas in the year 2023.

Methods

Agro-meteorological data in Uda Walawe, Sevanagala, Pelwatte, Siyambalanduwa, Hingurana, Kantale, Hantane and Enselwatte will be collected daily during 2023. The data will be summarized on weekly and monthly basis and will be distributed among all research divisions. These data will also be made available to the other interested parties.

The collected agro-meteorological data will be used to prepare annual agro-climatic report for the year 2023.

Officers responsible

Team Leader:	L.M.J.R. Wijayawardhana RO (CRM)
Other Officers:	A.L.C. De Silva (SRO/HEAD-CRM)
	G.A.A. Chathuranga (RO/CRM)
	M.K.P.C. Gunawardhana (DO/Kantale)
	Agronomist-Pelwatte Sugar Industry Ltd,
	Agronomist-Sevanagala Sugar Industry Ltd
	Agronomist –Hingurana sugar Industries Ltd

Collaborating organization: Sevanagala, Pelwatte, Hingurana and Kantale Sugar Industries
Total estimated cost for CRM/01/23 I and II (Rs.): 3,415,000
Funding agency: SRI
Duration: January-December 2023

Action plan for 2023

Month / Activity	J	F	M	A	M	J	J	A	S	O	N	D
Meteorological data collection												
Data computerization												
Data analysis and annual report writing												

Benefits to the industry

The results could be used for planning sugarcane cropping to increase productivity and income from rain-fed sugarcane lands in addition to interpretation of research results.

CRM/01/23-II: Irrigation scheduling for Kantale

Introduction

Although the Kantale sugarcane project is not currently functioning, various parties, especially the new sugarcane project proposal preparation agencies have been requesting technical data on irrigation and water management subject area. Therefore, it is timely important to prepare a complete irrigation scheduling report by collecting the data available and by collecting field level data related to soil hydrological properties which are important for preparation of irrigation and water management plans. The proposed research will mainly address the gaps in the Kantale climate database, soil hydrological properties database while developing an irrigation schedule with revised recommendations.

Objectives and targets

i. To collect and compile all the climatic data available in Kantale area.
ii. To prepare irrigation schedule.

Methods

Agrometeorological data available in Kantale area will be collected for past decades. The soil hydrological properties will be measured by site visiting and collecting soil samples up to 90 cm depth (15- 25 cm, 45 – 55 cm and 85-95 cm). Soil bulk density, permanent wilting point, field capacity, saturation hydraulic conductivity, texture and porosity will be assessed. The infiltration capacity of soils will be measured using bauble ring infiltrometer test. Topographical elevation maps will be collected from survey department of Sri Lanka or using remote sensed technology.

Location: Kantale sugarcane project area

Officers responsible
Team Leader: L.M.J.R. Wijayawardhana (RO/CRM)
Other Officers: A.L.C. De Silva (SRO/CRM)

G.A.A. Chathuranga (RO/CRM)
M.K.P.C. Gunawardhana (DO/Kantale)

Funding agency: SRI
Duration: 2023- (January-December)

Action plan for 2023

Month / Activity	J	F	M	A	M	J	J	A	S	O	N	D
Agrometeorological data collection												
Soil infiltration test												
Soil sampling for physical property testing												
Soil sample laboratory testing												
Data analyzing and terminal report writing												

Benefit to the industry

Currently, direct benefit to the sugar industry will not be generated by the proposed research work as no sugarcane industry functioning. However various outsider agencies will be indirectly benefited when their project proposal preparation stages, particularly most upcoming sugarcane projects in the same area or surrounding other districts such as, Anuradhapura and Mulathiw.

CRM/02/23: Development of package of crop management practices for increasing the productivity of sugarcane

CRM/02/23-I: Evaluation of new sugarcane varieties of 2004 series for maturity patterns

Introduction

Information about the maturity of new sugarcane varieties is required before releasing them for commercial cultivation to schedule planting for maximizing cane and sugar yield. Varieties differ in their agronomic characteristics and pattern of maturity. Knowledge on pattern of maturity of a variety is a prerequisite to decide harvesting age to get maximum yield. Therefore, the information generated from this study is useful to identify planting program and organize harvesting operation to get highest cane and sugar yield. Studies are therefore conducted with new varieties ready to be released for commercial cultivation to find out their pattern of maturity.

Objective

To find out the maturity pattern of 2004 series varieties with age and planting time.

Methods

Planting material of superior varieties selected from replicated yield trials were multiplied at the SRI research farm in 2022. After the multiplication of seedcane, each variety will be planted

in plots with 9 m 6 rows and 3 replicates in two-month intervals during a calendar year at the research farm Uda Walawe starting from *Yala* 2023. Crop management will be done in line with SRI recommendations. Cane will be sampled and analyzed for testing of juice quality (Brix %, Pol %, Fiber %, Purity% and POCS %) from 8 to 16 months age at monthly intervals. Top-Bottom ratio (TB) of brix for each variety at monthly intervals from 8 to 16 months age will be recorded.

Location: Uda Walawe.

Officers responsible
Team Leader: G.A.A. Chathuranga (RO/CRM)
Other Officers: A.L.C. De Silva (SRO/CRM)
L.M.J.R. Wijayawardhana (RO/CRM)
Total estimated cost for CRM/02/23 I-IV (Rs.): 8,623,500
Funding agency: SRI
Duration: 2022-2024(Three years)

Action plan for 2023

Month / **Activity**	J	F	M	A	M	J	J	A	S	O	N	D
Research trial establishment and maintenance												
Data collection on crop maturity												

Benefit to the industry

Information helps to organize planting and harvesting to obtain maximum cane and sugar yields from new varieties.

CRM/02/23-II: Investigation of the effect of agronomic practices on soil improvement in organic sugarcane cultivation

Introduction

In Sri Lanka a large extent of lands, especially in Sevanagala, Pelwatte and Hingurana areas, have been allocated to sugarcane cultivation and are mostly grown as a mono crop under rain-fed and irrigated conditions. Usually, sugarcane crop takes minimum of twelve months to mature and harvest. Since, the land availability is limited, growing sugarcane continuously in the same land for a long period is a common practice adopted by many farmers. Generally, soil erosion takes place with each land preparation. Also, a substantial amount of nutrients are removed from soil while removing millable stalks with each harvest. So far, the common practice was applying synthetic fertilizer to replenish nutrient requirement of the crop. These practices may adversely affect soil chemical, physical and biological properties of the soil. Therefore, application of organic fertilizer is suggested in the national level. Therefore effect of agronomic practices on soil improvement in sugarcane crop have to be investigated under organic scenario.

Objective

To investigate the effect of possible agronomic practices that can be used to improve soil in organic sugarcane cultivation

Methods

Experiment 1

Evaluation of fallow management/crop rotation practices:

The experiment will be conducted at the research farm, SRI. In this experiment, different green manure species will be established and incorporated into the soil before planting sugarcane. For measuring the changes in soil parameters, soil sampling will be done before the establishment of green manure crops and after incorporating them into the soil. The biomass production, nutrient content of the green manure crop samples will be measured at monthly intervals after establishing green manure crops. After incorporating green manure crops in to the soil sugarcane will be planted and managed under organic cultivation conditions. Sugarcane crop growth and yield parameters will be measured to assess the impact of rotation practices on sugarcane crop.

Experiment 2

Investigation of intercropping practices:

This experiment was started in 2022 and will be continued in 2023 also. Sugarcane crop was intercropped with legume crop species (Mung bean, ground nut, soy bean, and cowpea). The conventional cultivation was used as the control experiment. During the early sugarcane crop growth period, legume crop species were established as intercrop and after the intercrop period legume species were incorporated in to the soil. Soil sampling was done before the establishment of intercrops and after incorporating them into the soil. Biomass production and nutrient composition of legume crop samples at the time of soil incorporation was measured. Also sugarcane growth (Crop biomass) was measured and finally yield parameters will be measured to estimate the impact of intercrop species on sugarcane crop growth.

Location: Sugarcane Research Institute, Uda Walawe

Officers responsible

Team Leader:	G.A.A. Chathuranga (RO/CRM)
Other Officers:	L.M.J.R. Wijayawardhana (RO-CRM)
	A.L.C. De Silva – (SRO/HEAD-CRM)
	B.R. Kulasekara (RO/CN)
	S.M.T.A. Maralanda (RO/PT)
Funding agency:	SRI
Duration:	2021 -2025

Action plan for 2021 – 2025

Activity	Year				
	2021	2022	2023	2024	2025
Literature reviewing					
Activities of experiment 2					

Activities of experiment 1					
Data analysis and report writing					

Benefit to the industry

Finding of this study will be useful for better crop management in organic sugarcane cultivations

CRM/2/23-III: Investigation of non-chemical weed management techniques in organic sugarcane

Introduction

Weed controlling in sugarcane plantations is necessary because weeds account for 10% -70% yield losses and sometimes even up to 100%. Integrated weed management is a widely accepted method in sustainable agriculture. Nowadays, weed management in the sugarcane sector mainly depends on the application of weedicides. However long-term use of weedicide may contribute to environmental pollution and health issues of people. Therefore, when it comes to synthetic-chemical free cultivation, practicing integrated weed management except using the chemical methods will be the possible solution for sugarcane weed control. However the efficacy and applicability of these non-chemical weed management techniques have to be tested for the sugarcane crop also under local field situations. Therefor an experiment will be conducted to investigate the non-chemical weed management approaches for sugarcane crop.

Objectives

1. To study the applicability and efficacy of non-chemical weed management techniques under local conditions
2. To investigate the effect of non-chemical weed management techniques on sugarcane crop growth

Methods

The experiments were started at the Sugarcane Research Institute (SRI), research farm in 2022 and will be continued up to 2025. Several experiments will be conducted to study the different aspects.

Experiment 1

Land preparation and planting methods for reducing weed emergence:

An experiment will be establish at the research farm of SRI according to the RCBD method with 6 treatments and three replicates. Treatments will be established according to the table 1. Sugarcane crop will be planted and manage (Irrigation and other crop management practices) based on SRI recommendations. After establishment of treatments weed counts in 2 week intervals will be recorded before practice each weed control event. Sugarcane germination up to one month at weekly intervals, tiller counts up to 4 months in monthly intervals, and plant biomass at 3 and 6 month will be recorded. Finally cane yield and sugar yield data will be collected at the harvesting.

Treatments for experiment 1

Treatment No	Details
1	Conventional land preparation, 1.37 m row spacing (control)
2	Minimum land preparation, 1.37 m row spacing
3	Conventional land preparation, 1.2 m row spacing
4	Minimum land preparation, 1.2 m row spacing
5	Conventional land preparation, 1.0 m row spacing
6	Minimum land preparation, 1.0 m row spacing

Experiment 2

Evaluation of mini-weeder machines and cultivators to control inter-row weeds:

An experiment will be establish at the research farm of SRI according to the RCBD method with 6 treatments and three replicates. Treatments will be established according to the table 1. Sugarcane crop will be planted and manage (Irrigation and other crop management practices) based on SRI recommendations. Weed counts will be recorded before applying each treatment to estimate weed density before treatment application and after 2 weeks period of treatment application. Soil samples will be collected before practice weeder machines or cultivators to record the soil moisture condition. Number of sugarcane plants damaged after using weeder machine will be recorded for each treatment. The cost related information (Fuel, labor) will be collected to estimate the cost effectiveness of the methods. Sugarcane germination up to one month at weekly intervals, tiller counts up to 4 months in monthly intervals, and plant biomass at 6 month will be recorded. Finally cane yield and sugar yield data will be collected at the harvesting.

Treatments for experiment 2

Treatment No	Details
1	Manual weeding (Control)
2	Tine cultivator
3	Mini scraper machine (Brush cutter type)
4	Brush cutter weeding
5	Inter-row cultivator 1
6	Inter-row cultivator 2

Experiment 3

Application of different mulches for plant and ratoon sugarcane

Two separate experiments, one for the plant crop and the other for the ratoon crop will be established at the research farm of SRI according to the RCBD method with 6 treatments and three replicates. Treatments will be established according to the table 1. Sugarcane crop will be planted and manage (Irrigation and other crop management practices) based on SRI recommendations. After applying treatments, weed counts will be taken at 2 weeks interval to measure the weed emergence. Sugarcane germination up to one month at weekly intervals, tiller counts up to 4 months in monthly intervals, and plant biomass at 3 and 6 month age will be recorded. Finally cane yield and sugar yield data will be collected at the harvesting.

Treatments for experiment 3

Treatment No	Details
For plant crop	
1	Manual weeding (Control)
2	Mulching with *Gliricidia* leaves
3	Mulching with *Tithonia* leaves
4	Mulching with polythene
5	Mulching with sugarcane trash
For Ratoon crop	
1	Manual weeding (Control)
2	Mulching with sugarcane trash
3	Sugarcane trash + *Gliricidia* mulch
4	Sugarcane trash + *Tithonia* mulch

Location: Sugarcane Research Institute, Uda Walawe

Officers responsible
Team Leader: G.A.A. Chathuranga (RO/CRM)
Other Officers: L.M.J.R. Wijayawardhana (RO-CRM)
A.L.C. De Silva – (SRO/HEAD-CRM)
K.A.D. Kodithuwakku (SRO/ EBIT)
K.H.D. Abeyrathna (RO/MT)
K.T. Ariyawansha (RO/MT)
Funding agency: SRI
Duration: 2021 -2025

Action plan for 2021 - 2025

Activity	Year				
	2021	2022	2023	2024	2025
Literature reviewing					
Activities of experiment 2					
Activities of experiment 1					
Activities of experiment 3					
Data analysis and report writing					

Benefit to the industry

Findings will be useful to develop non-chemical weed management package for organic sugarcane cultivations

CRM/2/23-IV: Screening of new herbicides identified for testing weed control in sugarcane in 2023

Introduction

Yield loss due to weed competition in sugarcane plantations varies from 6% to 75%, and sometimes goes up to 100% depending on the type of weed, degree and duration of competition. Usually, the critical period of weed/crop competition extends from 3 to 12 weeks

after planting, and control measures have to be adopted before weed competition begins. Adoption of integrated weed management is the best solution for sugarcane plantation. However use of herbicide is a common practice in sugarcane sector due to its efficacy. However, use of same herbicides for long period may leads to develop herbicide resistance and finally reduce the effectiveness of existing herbicides. Therefore, finding alternative herbicides for more economical control of weeds in sugarcane, has become necessary. Therefore, SRI screens new herbicides, in each year to find out the efficient and economical new weedicides for sugarcane weed management.

Objective

The objective of the study is to evaluate the effects new weedicides for controlling weeds in preliminary stage and in replicated experiments.

Methods

New weedicides will be selected based on the recommendation of Registrar of Pesticide (ROP). As first stage preliminary experiments are conducted and in the second stage the weedicides identified as effective in preliminary experiment are tested in replicated-experiment since observations made in the preliminary experiment have to be confirmed by conducting detailed investigations.

In 2023, the new weedicides recommended by ROP for the testing during 2023 will be used for the experiments in SRI research farm. The preliminary experiments will be carried out in 100 m^2 plots without replications. The treatments will be decide based on the manufacture recommendation and the literature. Land preparation, planting and crop management will be done as per SRI recommendations (SRI, 1991). New herbicides identified as effective will be tested in a replicated-experiment as Randomised Complete Block Design (RCBD) with three replicates. The treatments will be decided based on the observations made at the preliminary experiments. Each treatment plot will consist of 9 m-long 6 cane rows.

Sugarcane stem cuttings or “setts” will be planted in furrows prepared at the recommended spacing of ridge and furrow system. The herbicide will be applied by hand-operated knapsack sprayer. The sprayer and the nozzle with the operator used to apply herbicide will be calibrated before spraying. The experimental plots will be managed under irrigated condition, and the irrigation interval will be 7 – 10 consecutive dry days. If there were not rains, sprinkler irrigation will be provided to maintain uniform wetness in all treatment plots during the early crop growth stages of initial five months of planting.

Assessments

Both weed control and crop damage will be assessed. Weeds appeared in each treatment plot at 1, 2, and 3 months after planting (MAP) will be identified, counted and recorded by placing 50 X 50 cm quadrant in minimum of 10 places selected randomly in each treatment plot. After identification and recording the weeds, their dry weight of each sample will be measured at 1, 2 and 3 MAP only for replicated-experiments. Crop damage will be assessed based on the dry/yellow color leaf count in randomly selected sugarcane plants. For replicated-experiments, Sugarcane germination at 1 MAP and tiller production at monthly intervals up to 3 months will be recorded. Height of 30 tillers selected randomly from inner four cane rows in each treatment plot will be recorded at 3 and 6 MAP. The number of millable stalks and cane yield in the inner four cane rows will be recorded at harvesting. Pure Obtainable Cane Sugar (POCS %) will be estimated by analyzing juice extracted from a representative cane sample obtained from each treatment plot at harvesting when the crop is 12 months age.

Data analysis
The data will be summarized and subjected to ANOVA procedure to examine the treatment effects. The count data on weed control and crop damage will be summarized and analyzed using Kruskal-Wallis test. Finally, most effective dosage will be identified for controlling weeds in sugarcane fields.

Location: Research farm, Sugarcane Research Institute, Uda Walawe.

Officers responsible
Team Leader: G.A.A. Chathuranga (RO/CRM)
Other Officers: L.M.J.R. Wijayawardhana (RO-CRM)
A.L.C. De Silva - (SRO/HEAD-CRM)
Funding agency: SRI
Duration: January-December 2023

Action plan for 2023

Month / Activity	J	F	M	A	M	J	J	A	S	O	N	D
Planting & spraying for preliminary studies												
Planting & spraying for detail studies												
Data collection												
Trial maintenance												

Benefits to the industry

Recommendations of new herbicides to control of weeds in sugarcane lands.

D/01/18-III: Sugarcane development project

D/01/18-III: Production of seedcane and expansion of sugarcane cultivation for small-scale processing industries in Kilinochchi

Introduction

The Sugarcane Research Institute (SRI) has started a development program in 2010 and continues up to now for the improvement of livelihood of the war-affected people in the Northern Province aiming to introduce sugarcane cultivation and jaggery processing industry. Before the civil war, sugarcane had been cultivated successfully in commercial scale to produce jaggery at Scandapuram in Akkaraikulam in the Kilinochchi district. Accordingly, sugarcane industry has been restarted at pilot scale in privet farmers' fields at Skandapuram, Anavilundhan, Akkarayan and Vannerikulum area. At present there are farmers in Kilinochchi area who are willing to cultivate sugarcane and join the sugarcane processing for jaggery and syrup production. Already a jaggery and syrup processing unit has been established at Anavillunthan with contribution of SRI and Kilinochchi district secretariat. Therefore continues supply of healthy seed cane and cultivation and processing technology for farmers are essential. Based on this SRI will maintain a sugarcane nursery in Vannerikulam area.

Objective

To supplying of healthy seed cane for sugarcane farmers/planters in Kilinochchi district.

Methods

In 2023, seedcane nursery at Vannerikulum will be further maintained to provide healthy seedcane to farmers. Newly introduced sugarcane variety especially for jaggery production (SL 04 624), will be further multiplied at Vannerikulam seedcane nursery and will be distributed among farmers in Kilinochchi area. Also, the projects started with sugarcane farmer organization and the CSD will be continued in 2023. For the farmer organization project, processing activities will be continued in 2023 and relevant technical support on jaggery processing will be provided by SRI. The processing unit operation and marketing of jaggery and syrup will be done by the Farmer organization. For the CSD project, all the technical support for sugarcane cultivation and jaggery processing will be provided by SRI.

Location: Vannerikulum, Kilinochchi.

Officers responsible
Team Leader: A.L.C. De Silva – (SRO/HEAD-CRM)
Other Officers: G.A.A. Chathuranga– RO/CRM
L.M.J.R. Wijayawardhana - RO/CRM
M. Sivapalan- FA/CRM
Total estimated cost (Rs.): 4,550,000
Funding agency: SRI
Duration: January-December 2023

Action plan for 2023

Months / Activities	J	F	M	A	M	J	J	A	S	O	N	D
Nursery management(Crop and electric fence maintenance)												
Providing technical support on jaggery and syrup processing												
Sugarcane planting in Vannerikulum Nursery												
Providing technical support to CSD and farmers												

Benefits to the industry

Supplying healthy seedcane and technical knowledge on sugarcane industry to sugarcane farmers will improve the profitability and sustainability of sugarcane cultivation in Kilinochchi district.

Crop Nutrition Division

Projects that will be undertaken during 2023 include the following:

Research

i. CN/01/19: Development of organo-mixed fertilizer pellets for sugarcane by using low-cost sugarcane industry by-products
ii. CN/01/20: Evaluation of response of the sugarcane variety SL 96 128 for N, K and Zn on its cane yield and quality parameters (continuation)
iii. CN/02/22: Management zone based site-specific fertilizer management for sugarcane cultivation in Sri Lanka
iv. CN/03/22: Appropriate organic-based plant nutrition study for commercial sugarcane cultivation
v. CN/04/22: Development and testing improved organic amendments for sugarcane cultivation.

Research services

i. CN/01/23: Analyses of soil, plant and sugar samples for other divisional research needs and industry needs

The details of each project are given below:

CN/01/19: Development of organo-mixed fertilizer pellets for sugarcane by using low-cost sugarcane industry by-products

Introduction

In Sri Lankan sugarcane cultivation, fertilizer management primarily depends on synthetic mineral nutrient sources namely Urea, Triple Super Phosphate and Muriate of Potash with an annual usage around 6100, 3800 and 4800 tons respectively. Mineral nutrient usage seems to be a good option in short terms as nutrients are in a readily available form and easiness of fertilizer management practices. However, losses due to volatilization, leaching (nitrogen) fixation and creating unfavorable soil conditions are key failures of mineral fertilizers in long term sustainable agriculture. The organic matter percentages of Sri Lankan sugarcane cultivated lands are under 2% which is far below the optimum required value of fertile soils considered as 5%. To reduce the losses and increase the nutrient absorption efficiency, split application of nitrogen and potassium fertilizers is recommended for sugarcane cultivation. But the incorporation of organic fertilizers along with mineral and synthetic fertilizer application during the crop production manages to overcome the weaknesses raised from both single uses of mineral fertilizers or organic fertilizers. Organic matter acts as a fertilizer reservoir when applied along with inorganic fertilizers. Excess nutrients can be absorbed by the organic matter complexes and gradually releases nutrients whenever the nutrient concentration depleted in the soil solution as cation exchange sites exist in the soil. Sugarcane industries generate by-products during the production processes of sugar and alcohol, namely filtermud and vinasse. Filtermud on average; OM - 22.3%, N – 2.0%, P – 1.1%, K – 0.3%, Ca – 2.1%, Mg – 0.6%, S – 0.25%. Vinasse on average; N – 485 ppm, P – 175 ppm, K – 1644 ppm, Ca – 500 ppm, Mg – 129 ppm, pH – 4.8, EC – 9.72 dS m^{-1}. Filtermud-vinasse compost recognized as a good source of organic fertilizer for sugarcane cultivation which requires low-cost materials generate within the sugarcane industry. Several studies concluded that incorporation of filtermud – vinasse compost along with mineral fertilizers significantly improve the quality and the quantity final

sugarcane harvest. At present, there is a huge concern about the over-application of mineral fertilizers with high losses. Apart from the high cost of production, environmental and livelihood effect due to contamination by excess nutrients created government bodies to restrict mineral fertilizer consumption and promote organic-base cultivations.

An effective way to mitigate these problems is to develop an organo-mixed fertilizer, which involves a combination of synthetic or natural nutrient sources with organic compost mixture made out of sugarcane industry by-products. The organic mixture consists of vinasse and filtermud produced in sugar production. Combination of nutrient sources and organic compost mixture during the production of organo-mixed fertilizer increases nutrient concentrations requiring lower field application rates. Hence, Crop Nutrition Division established a field trial in 2021 using organo-mineral combinations of fertilizer pellets. In 2023, the ratoon crop will be maintained and harvested.

Objectives and targets

1. Development of organo-mixed (OMF) fertilizer pellets using vinasse - filter mud compost and mineral fertilizers
2. Evaluation of the ability of OMF to;
   a. Reduce mineral fertilizer usage on sugarcane cultivation
   b. Control release of nutrients to the soil solution
   c. Reduce the fertilizer application cost
   d. Improve the yield quality of sugarcane cultivation

Methods

This study consists of three main stages;

Stage I: Development of compost from vinasse and filtermud
The compost development will be carried out according to the results of studies conducted by the Crop Nutrition Division of the Sugarcane Research Institute, Sri Lanka, and literature information regarding the filtermud composting process using filtermud and vinasse collected from Lanka sugar factory Sevanagala, Sri Lanka. Fresh filtermud and vinasse will be collected and subjected to test the chemical parameters. (N%, P%, K%, OM%, pH, EC)

Filtermud and vinasse will be mixed according to the following ratio during the composting process.

- Filtermud : Vinasse ration; 15 kg : 2L

Several preliminary composting batches will be prepared with above ratio to analyze the suitability of filtermud – vinasse compost for the production of organomineral fertilizers. Then compost batch will be prepared for organomixed fertilizer production. Open windrow method will be used as the composting method. Mixing and turnover of the compost pile will be done in every two weeks interval to facilitate the aeration and uniform distribution of vinasse and filtermud within the composting pile. The moisture content of the compost will be maintained within 40 -60% range to encourage microbial activities at an optimum level. Temperature measurement will be obtained daily. The composting process will be continuing up to 45 days. After composting process complete, basic chemical parameters (N, P, K, Organic carbon, CN ratio) and physical parameters (Colour, Odder, Final moisture content, bulk density, pH and EC) will be evaluated. Sieving of compost will be carrying out with 2 mm mesh size sieve to obtain uniform particles for the pelleting process.

To determine the optimum levels of compost and synthetic fertilizer ratio preliminary pelleting process will be conducted and chemical and physical parameters of the pellets will be analyzed. Final mineral and compost ratios were determined based on the preliminary pelleting tests, possible application rates and amount of organic matter provided as organomineral fertilizers.

Stage II: Evaluate the effectiveness of organo-synthetic fertilizers on sugarcane cultivation

A field trial will be conducted with following treatments

Synthetic fertilizers: compost ratio

- 1:4

Three types of mineral fertilizer combinations

- MF1 - Urea + TSP + MOP
- MF2 - Urea + MOP + YARA
- MF3 - SRI recommendation
- MF4 - SRI recommendation + compound fertilizer
- MF5 - Zero fertilizer

Three levels of application rates based on nutrient the availability

- 80% from the total nutrient requirement
- 65% from the total nutrient requirement
- 50% from the total nutrient requirement

General plant crop trial maintenance will be continued for the research trial and maturity testing, plant crop harvesting and yield data collection, after harvest soil sampling and laboratory analysis will be carried out in 2022. Ratooning will be done to continue to research trial and fertilizers will be applied according to the treatment combinations after initial soil sampling. OMF pellets will be produce using the pelleting machine in the Crop Nutrition Division of SRI. Initial soil samples will be analyzed to determine following chemical composition.

- Total Nitrogen
- Available Phosphorous
- Exchangeable Potassium
- pH & EC
- Organic carbon

Germination count will be collected 2 weeks after ratooning to calculate the germination percentage. According to that results gap filling will be done if necessary. After 45 days and 90 days of planting fertilizer application will be done by following the fertilizer recommendation guidelines gives by the SRI according to the treatment combinations. At 4 ½ month after ratooning leaf sampling will be done and laboratory analysis will be carried out to determine the sugarcane crop nutrient uptake. This data will be statistically analyzed to determine the effect of pellets on crop nutrient uptake of the sugarcane plant under different application rates. At the same time tiller count, plant height, cane girth measurements will be taken to investigate the effects of treatments on sugarcane general growth parameters. General ratoon trial maintenance will be carried out during the year 2022.

New OMF fertilizer pelleting

With the objectives of introducing alternative nutrient sources and evaluating their effects on OMF pelleting processes, OMF pelleting study will be carried out in the year 2022. Following alternative nutrient sources will be used to produce different types of OMF pellets using the pelleting machine of the Crop Nutrition Division of SRI.

- Sea weed extract (Nitrogen and calcium source)
- Micronutrients (Zinc sulphate, Compound micronutrient mixture)
- Compound fertilizers (N,P,K sources)
- Natural fertilizers (Compost tea, fish tonic, HGRP, ERP)

Laboratory chemical analysis will be carried out to evaluate the nutrient composition, stability of nutrient retention. Physical property analysis will be done to evaluate the effect of different nutrient sources on the physical stability of the different types of pellets. Chemical analysis of different pellets (Stewart, 2005)Total N,P,K .

- pH
- Organic Carbon
- Nutrient partitioning

Physical analysis of different pellets (Pare et al., 2009; Romano et al., 2014)

- Untapped bulk density
- Granule density
- Crushing strength
- Abrasion fragility
- Moisture Content
- Water sorption from atmosphere

Data collection and analysis

Soil analysis
Total nitrogen, available phosphorous and exchangeable potassium will be measured using Kjeldahl digestion method, Olsen's bicarbonate extraction method, the Ammonium acetate method respectively. Soil pH will be measured by 1:2.5 soils to distilled water ratio, using pH meter with glass electrodes. Soil moisture will be measured by the oven-dry method described in the Manual of Soil Science Society of Sri Lanka, 2007.

Agronomic parameters
Data on germination, tillering, crop growth and yield will be collected from middle 3 rows leaving outer two as guard rows. Germination, number of tillers/clump, girth, plant height, number of internodes, number of water shoots, will be measured at field level. The number of plants emerged in inner three rows will be counted 1 month after plating to estimate germination percentage in each experimental plots. The total number of tillers in inner three rows will be counted 3 months after planting to take tiller count. Visual observations on incidences of pests and diseases will be recorded in each treatment plot over the experimental period. Leaf sampling will be done at 4½ month stage and wet digestion method will be followed to analyze leaf N, P, K by UV spectrophotometer and Atomic absorption spectrophotometer. Cane weight of middle three rows will be measured after the harvest to estimate cane yield.

Sugarcane juice quality (brix, polarity, purity, fiber) will be measured in the laboratory. Brix and pol value will be measured using digital refractometer and polarimeter respectively. Purity and POCS values will be calculated using brix, pol and fiber readings.

Data analysis
The effects of treatments will be compared by analysis of variance. The treatment means will be separated by Turkey`s procedures against the control at the 5% probability level.

Location: Uda Walawe

Officers responsible
Team Leader: Mr. U.W.L.M. Kumarasiri (RO-Crop Nutrition)
Other Officers: Mr. H.A.S. Weerasinghe (ROIC-Crop Nutrition)
Mr. B. Kulasekara (RO-Crop Nutrition)
Collaborating organization/s: Regional Agriculture research center - Makandura
Total estimated cost (Rs): 1,946,563.00
Funding agency: SRI
Duration of the project: January 2019 - December 2023

Action plan for 2023

Month / Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
OMF new pellets laboratory analysis												
OMF trial ratoon 01 harvest, data collection												
Laboratory analysis												
Dnata analysis and report writing												

Benefits to the industry

Increase productivity and profitability of sugarcane land by increasing efficiency of fertilizer usage, reduced wastage and environmental pollution.

CN/01/20: Evaluation of response of the sugarcane variety SL 96 128 for N, K and Zn on its cane yield and quality parameters

Introduction

The crop improvement program of the Sugarcane Research Institute (SRI) develops high-cane- and sugar-yielding sugarcane varieties adaptable to various sugarcane-growing conditions in Sri Lanka aiming at sustainable increase of the productivity and profitability of the industry. Selection of the varieties for high cane and sugar yields is done under recommended management conditions at the initial and intermediate selection stages in the varietal development program. According to that, SL 96 128 was released officially, in 2015 which was more preferable variety among the farmers and industry personals. Presently, the majority of

the sugarcane extent in Sri Lanka is occupied by this variety SL 96 128 and it is around 60% of the total extent. However, even though the variety gives good yield, with the low level of sugar recovery in recent past milling seasons, there are some arguments regarding this variety and the industry personal have requested to conduct detail evaluations on the aspect of cane quality and recovery of this variety. Emergence of higher number of water shoots, less stability in maturity and higher rate of post-harvest deterioration are coming as the issuing factors in the dialogue. When addressing poor recovery, Sucrose losses after the harvest of sugarcane and luring subsequent milling operation are one of the most serious problems in many sugar processing countries. Literature evident that pre-harvest soil and foliar application of various chemicals such as; sodium metasilicate, sodium lauryl sulphate, sodium malonate, mercuric chloride, zinc sulphate, Manganese sulphate, Polaris, Ethrel and etc. have been used to inhibit the invertase activity for increasing sugar recovery. Especially, application of Zn^{2+} can be identified as most practically applied manner in literature and in Brazil and India, there are existing recommendations of 5-10 kg ha^{-1} for zinc fertilizers. According to Brazilian studies, they believe that the current recommendation may not be high enough to help sugarcane crops reach their full growth potential. It is likely that the recommendation will increase to 10 kg ha^{-1} based on the success of recent and ongoing studies. However, achieving maximum cane and sugar yields, application of correct levels of fertilizer is important for cost of production and environmental aspects.

The field trial was established and the ratoon 1 was harvested in 2022. The ratoon 2 will be maintained during 2023 and the final evaluation will be carried with the received data.

Objectives and targets

The main objective is to formulate a specified fertilizer recommendation for variety SL 96 128 along with the better cane quality

Specific objectives;

i. To identify the most appropriate N and K combination affected to the yield and cane quality enhancement of SL 96 128
ii. To investigate the influence of micro nutrient, Zn on cane quality enhancement

Methods

A field experiment was consisted with 11 treatment combinations followed by randomized complete block (RCBD) design with three replications (Table CN 01). Each plot was 7 m long with 5 rows planted 1.3 m apart. The middle 3 rows were used for taking observations and the 2 outer rows were considered as guard rows. Apart from that, an observational experiment was conducted to evaluate the response of Zn on cane yield and quality. A ratoon crop was evaluated for the observational experiment under with and without ZnSO4 (7.5kg/ha) under RCBD design with 4 replicates.

Location and crop establishment

The field experiment was established at the Research farm (6° 21' N, 80° 48' E) of the Sugarcane Research Institute in October 2020, *maha* rainy season. The locational soil represented the general topography of the Walawe basin.

Soil and climate

The soil of the selected site was classified as Reddish Brown Earths (Soil taxonomy Order - Alfisols, Suborder - Ustalfs, Great group – Rhodustalfs). The average annual rainfall is about

1450 mm and 900 mm. The average annual minimum and maximum temperatures are 22 ± 1.4 °C and 33 ± 1.4 °C, respectively.

Table CN 01: Treatment combinations

Treatment	N kg/ha	K2O kg/ha	ZnSO4 kg/ha
1	75	100	7.5
2	75	100	0
3	100	125	7.5
4	100	125	0
5	125	150	7.5
6	125	150	0
7	150	175	7.5
8	150	175	0
9	SRI Recommended level(138)	SRI Recommended level(135)	7.5
10	SRI Recommended level(138)	SRI Recommended level(135)	0
11	Zero Fertilizer		

The recommended amount of P fertilizers (90kg/ha of P2O5) will be applied to all treatments except zero fertilizer level.

Field operations

The land was prepared according to the recommendations for commercial sugarcane planting. Three-budded stem cuttings (setts) obtained from ten months old sugarcane plants of the variety SL 96 128 was planted. The plots were fertilized according to the treatment levels up to the first top. The sources of fertilizer are Urea (N), Triple Super Phosphate (P) and Muriate of Potash (K) and Zinc Sulphate (Zn) and at the planting, $^{1}/_{6}$ of N, total P and ½ K will be applied. One third of N was be applied 45 days after planting and ½ of N, ½ of K. The total amount of Zn was applied 90 days after planting in January 2021. During the year 2021 plant crop was maintained and crop was harvested. The ratoon 1 crop was maintained and harvested in the year 2022. At the harvesting, growth, yield and cane quality parameter data were recorded. After harvest, ratooning operation and fertilizer application were completed as per the predetermined treatment combinations. The ratoon 2 crop will be maintained for the year 2023 and ratoon crop will be harvested.

Soil and plant parameters

Soil sampling and analysis

Soil chemical properties in two soil depths (0-15cm and 15-30cm), pH, Electrical conductivity (EC), Total Nitrogen (N), exchangeable potassium (K), exchangeable zinc (Zn), Cation Exchange Capacity (CEC) are in progress in both trials (samples collected that before treatment application, six months after establishment and after harvesting). As it is to the plant and ratoon 1 crop, soil sampling and analysis will be carried out in the ratoon 2 crop further.

The following analytical procedures were followed to analyze the above mentioned soil properties:

Soil pH: 1:2.5 soils to distilled water ratio, using pH meter with glass electrodes

Soil EC: Suspension method

Soil total Nitrogen: Kjeldhal method

Soil exchangeable Potassium: Ammonium acetate method using the Atomic Absorption Spectrophotometer (AA 6300)

Available Zinc: DTPA extraction method using the Atomic Absorption Spectrophotometer (AA 6300)
Cation Exchange Capacity: Ammonium Saturation Method

Leaf sampling and analysis
The leaf nutrients will be compared with the critical leaf nutrient levels to determine the excess or deficient nutrient levels in the soil. Therefore, the leaf (3rd leaf of plant at $4^1/_2$ months after planting) sampling of the plant and ratoon 1crops were completed and analysis of the samples are in progress according to the standard analytical methods. Wet digestion method was followed and N, K and Zn will be analyzed by UV spectrophotometer and Atomic absorption spectrophotometer respectively. At the age of $4^1/_2$ months of the ratoon 2 crop, leaf sampling will be carried out further for necessary analysis.

Plant growth parameters and quality parameters
Germination, tiller count, girth and height at the age of 6 months after planting were measured as follows:
Germination: The number of germinated plants in a 7 m row will be counted 1 month after plating.
Tiller count: The number of plants in a 7 m rows will be counted 2 months and 3 months after planting
Height: The sugarcane crop height of each sample plot is defined as the average stem distance from the soil to the insertion of the top-visible dewlap leaf (TVD) on the stem (Figure CN 01).

At harvesting of the plant and ratoon 1 crops, girth, height, internodes, cane weight, no. of millable stalks, water shoots of each treatment plot were recorded. Representative samples of 12 stalks taken from each treatment plots were used to estimate Brix%, Pol%, fibre% and POCS% contents. Further, these data will be collected in the ratoon 2 crop same as to the plant crop.

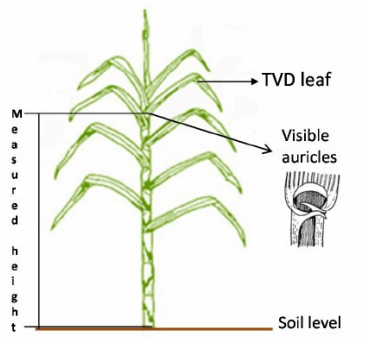


Figure CN 01. Sugarcane plant height measurement

Statistical analysis

Analysis of soil, plant, cane and sugar yield data
The effects of treatments will be compared by analysis of variance. The treatment means will be separated by Dunnett procedures against the control at 5% probability level. Data will be analysed using SAS statistical software followed by PROC GLM procedure of SAS in the data analysis.

Economic analysis
Further, information on cost of labor, fertilizer, chemicals and data relevant to the yield and POCS% are recorded for economic analysis.

Location: SRI Research farm at Uda Walawe

Officers responsible
Team Leader: Mr. B.R. Kulasekara (RO-Crop Nutrition)
Other Officers: Mr. H.A.S. Weerasinghe (ROIC-Crop Nutrition)
Mr. U.W.L.M. Kumarasiri (RO-Crop Nutrition)
Mrs. B.D.S.K. Ariyawansha (SRO-Economic Biometry & IT)
Mr. K.A.D. Koddithuwakku (SRO-Economics)
Mr. G.A.A. Chathuranga (RO-Crop and Resource Management)
Total estimated cost (Rs): 1,931,563.00 (for the year 2023)
Funding agency: SRI
Duration of the project: January 2020 - December 2023

Action plan for 2023

Month / Activity	J	F	M	A	M	J	J	A	S	O	N	D
Laboratory level sample preparation and analysis												
Application of Zn treatments with the 2nd top												
Maintenance of the ratoon 2 crop, recording plant height at 6 months age and maturity testing												
Leaf and soil sampling at $4^1/_2$ months and 6 months age (ratoon 2 crop)												
Maturity testing and harvesting of the field trail (ratoon 2 crop)												
Soil sampling after harvest, ratooning and fertilization for ratoon 2 as per the results												

Benefits to the industry

The variety SL 96 128 has become as most popular among the farmers and around 70% of the total extent of Sri Lanka is occupied by this variety. However, some inherent characters of this variety are coming as the issuing factor in the dialogue of poor cane quality. Hence, any recommendation coming out from this study will be affected to the productivity and profitability of Sri Lankan sugarcane industry.

CN/02/22 Management zone based site-specific fertilizer management for sugarcane cultivation in Sri Lanka

Introduction

Site-specific fertilizer management requires optimizing nutrient inputs by considering both temporal and spatial variability of the sugarcane field. Variability mapping and crop reflectance sensor-based techniques are prominent for implementing site-specific management of crop inputs. But traditional soil and plant sampling methods are not economical when considering the level of accuracy needed in larger sugarcane cultivation areas where the level of spatial nitrogen variability can exist over short distances in fields. The sensors used to identify and

collect spectral and spatial information, equipped to satellite or airborne vehicles and their uses depend on the scale of the level of expected details. Satellite images have been used to derive spectral and spatial information, yet in the case of high-level detail scales monitoring, the use of Unmanned Aerial Vehicles (UAVs) is becoming great equipment for this task. Multiple vegetation indices derived from the visible and infrared spectrum of conventional, multispectral and hyper-spectral sensors have been created to assess different agronomic parameters such as leaf area index (LAI). Chlorophyll content, sugarcane crop biomass and leaf nitrogen concentration throughout the world.

Therefore, sensor-based methods by light reflectance measurements have been used for sugarcane cultivation to estimate the real time crop status of the plants. Multispectral drones, real time soil status measurement technologies, digital mapping opens up new pathways to monitor and support decision making processes in a more precise way. With that intention this research project will design and carry out the following objectives.

Objectives and targets

- To evaluate the potential of delineating site-specific management zones using precision agriculture techniques for sugarcane cultivation
- To develop site-specific nutrient management zones using precision agriculture techniques for sugarcane cultivation
- To evaluate the effectiveness of nutrient management zones for sugarcane cultivating areas in Sri Lanka

Methods

Entire study will be divided into three stages based on specific objectives.

- **Stage I**

During the 2021/2022 sugarcane growing season a study will be conducted to evaluate the potential of delineating site-specific management zones using precision agriculture techniques for sugarcane cultivation. Several commercial sugarcane cultivation areas will be demarcated that are located at the Lanka Sugar Company – Sevanagala Unit. Area demarcation will be based on the information in previous yield and soil maps which are generated during recent research studies and industry information.

Each demarcated field will be scanned using a multispectral unmanned aerial vehicle (agricultural drone) to capture sugarcane leaf and plant reflection. Each sugarcane field will be scanned three times during the growing period. Scanning time was selected based on the optimum sugarcane growth stage for canopy reflectance sensor measurements. UAVs images will be processed to georeferenced images and Normalized Difference Vegetative Index (NDVI) maps will be generated using Ag Multispectral processing options in Pix4D software. Field boundaries will be drawn using the regions tools to generate NDVI values for only filed within the interested area of the study. All of these image processing tools will be utilized for all the drone surveys. Generated NDVI maps will be imported to ArcGIS software and process to delineate nitrogen management zones. During each drone survey, NDVI maps will be generated. NDVI values of each geo referenced point in all three layers will be summed and averaged to produce averaged NDVI map. Then average NDVI layer values are subsequently arranged into 5 x 5m blocks with their averaged NDVI values. These bocks will be reclassified to possible groups based on Jenks, a natural break function. Based on the different groups that

will be created in average NDVI values, following data will be taken on field covering all the NDVI groups at 4 ½ months after ratooning

- Leaf sampling - Laboratory chemical analysis (Total N)
- Soil sampling (0-15 cm) - Laboratory chemical analysis (Total Nitrogen, pH, EC)
- Leaf SPAD value (first dewlap leaf)

PROC Glimixx Lsmeans will be carried out in SAS software for each soil parameter and leaf nitrogen values to calculate least square mean values for each nitrogen management zone. Pearson correlation analysis will be carried out using SAS, to determine significant relationships between average NDVI values of each management zone and soil properties, leaf nitrogen values. A coefficient of variance (CV) will be also calculated separately for each field to identify variation of properties within a field.

- **Stage II and Stage III**

Based on the results of stage I, stage II of the research study will be initiated and carried out to develop site-specific nutrient management zones for sugarcane cultivation in sugarcane cultivation areas. Based on the results of studies conducted by the crop nutrition division of sugarcane research institute Sri Lanka, industry yield maps and other related information available, possible management area will be identified. As methodology described in stage I, drone surveys reflectance data will be collected within all the selected sugarcane areas and NDVI maps will be generated. According to the different classes of variable NDVI values possible management zones will be delineated and representative georeferenced soil samples, 4 ½ stage leaf samples, SPAD values will be taken and laboratory analysis will be carried out to determine following parameters.

Soil
- Total Nitrogen
- Available Phosphorus
- Exchangeable Potassium
- pH, EC
- Organic carbon
- Micronutrients
- Soil texture
- Soil bulk density

Leaf
- Total Nitrogen
- Total Phosphorus
- Total Potassium

Sugarcane yield samples will be collected during the harvesting stage in each delineated management zones as a representative samples 5 x 5 m sampling area will be demarcated at the center of each management zone to avoid possible border effects. Coordinates of the sampling areas will be recorded and entered into a GPS unit to locate the geo-referenced sampling points in the field. Cane sample weight and number of canes per plant will be determined during yield sampling period. At laboratory conditions, brix value, polarization value and fiber value will be determined to calculate Pure Obtainable Cane Sugar content which is representing each delineated management zone.

Statistical analysis will be carried out to determine the significance of the relationship between soil parameters, yield as well as the NDVI values obtained inside the delineated management zones. Stage III studies will be carried out based on the results generated during the stage I and stage II studies and considering soil chemical, physical parameters and water management conditions adjusted fertilizer requirements will be delineated and applied to evaluate the effectiveness of delineated management zone-based fertilizer applications. During stage III crop cultivation, drone surveys will be carried out to determine the nitrogen response of sugarcane plants with adjusted fertilizer applications. Final yield will be calculated and quality assessment will be carried out to evaluate the effectiveness of delineated nutrient management zone

Soil sampling and analysis

Soil chemical properties (pH), Electrical conductivity (EC), Total Nitrogen (N), available phosphorus (P), and exchangeable potassium (K) will be analyzed, before ratooning of the crop. The following analytical procedures will be adopted to analyze the above-mentioned soil properties:

- Soil pH – 1: 2.5 soils to distilled water ratio, using pH meter with glass electrodes
- Soil EC - 1: 5 soils to distilled water ratio, using EC meter
- Soil total nitrogen - Kjeldhal method
- Soil available Phosphorus - Olsen P method
- Soil exchangeable Potassium - Ammonium acetate method using the Atomic Absorption Spectrophotometer (AA 6300)

Leaf sampling and analysis

The leaf nutrients will be compared with the critical leaf nutrient levels to determine the excess or deficient nutrient levels in the soil. Therefore, the leaf (3rd leaf of a plant at 4 ½ months after ratooning) will be analyzed according to the following standard methods. Wet digestion method will be used and N, P and K will be analyzed by UV Spectrophotometer and Atomic Absorption Spectrophotometer, respectively.

Location: Sugarcane Research Institute, Uda Walawe

Officers responsible

Team Leader:	Mr. H.A.S. Weerasinghe (ROIC-Crop Nutrition)
Other Officers:	Mr. U.W.L.M. Kumarasiri (RO-Crop Nutrition)
	Mr. B.R. Kulasekara (RO-Crop Nutrition)
	Dr. T. Ariyawansha (RO-Mechanization Technology)
	Mrs. B.D.S.K. Ariyawansha (SRO-Biometry)
	Prof. Udaya Vitharana (University of Peradeniya)

Collaborating organization/s: The technical support of Dr Senani Karunaratne (CSIRO, Australia) will be received where necessary on advance technology.

Consultants: Subject specialists will be joined according to the requirements.

Annual total estimated cost (Rs): 2,031,563.00

Funding agency: SRI

Duration of the project: Three years (2022 – 2024)

Action plan for 2023

Month / Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Site selection and soil, yield data												
Drone survey and soil survey												
Map development and data analysis												
Management zone development												
Report writing												

Benefits to the industry

Improving the fertilizer recommendation up to site-specific level using advanced precision agriculture techniques.

CN/03/22: Appropriate organic-based plant nutrition study for commercial sugarcane cultivation

Introduction

Organic sugarcane cultivation avoids the use of synthetic fertilizer and emphasizes the use of organic inputs to provide nutrients to the plant. In organic sugarcane cultivation the main inputs used are agro-industrial residues, such as filter-mud, vinasse and natural phosphates. Mineral fertilizers are supplied to maximize the productivity of organic sugarcane cultivation. In Brazil it has been found sugarcane plants respond positively to fertilization with filter-mud which has raised the accumulation of P, K and Cu in aerial parts of the plants. The Crop Nutrition Division of the Sugarcane Research Institute has developed a compost using industry by-products i.e. filter mud and vinasse of the Sugar and Ethanol Industry. On average 200-300 L of vinasse can be applied for a 1 ton of filter-mud to maintain the optimum moisture level of the heap which is important for the composting process. As per the conditions of the heap, vinasse can be applied again in, timely intervals without disturbing the process and quality of the end compost product.

The four consecutive stages of the decomposing process namely, warming-up phase, heating phase, cooling down phase and maturation phase would be completed within 50 to 60 days' time period. The average nutrient status and chemical characteristics of sugarcane by-products based organic compost are as follows (Table CN 02).

Table CN 02. Average chemical characteristics of compost prepared with filter-mud and vinasse

pH	EC (mS/cm)	N %	P%	K%	Mg%	Ca%	Mn ppm	Zn ppm	Cu ppm
8.12	1.92	1.09	0.44	0.53	0.37	1.80	612.8	148.8	36.2

The prepared compost by the Crop Nutrition Division falls within the range of the national standards of organic compost given by Sri Lanka Standard Institution (SLSI) (Table CN 03),

Table CN 03. The SLSI standards of organic compost

Parameter	Threshold values
Physical Requirement	
Moisture (%)	<25 (dry weight)
Colour	Brown/grey to dark black
Keeping quality	Store in prescribed package under room temperature for 12 months
Odour	Without any unpleasant odours
Sand content (%)	<10 (dry weight)
Chemical Requirement	
pH	6.5-8.5
Organic carbon (%)	>20
Nirogen (%)	>1.0
Phosphorus as P_2O_5 (%)	>0.5
Potassium as K_2O (%)	>1.0
C:N ratio	10-25
Cadmium (ppm)	<10
Chromium (ppm)	<1000
Copper (ppm)	<400
Lead (ppm)	<250
Mercury (ppm)	<2
Nickel (ppm)	<100
Biological requirements	
Viable weed seeds	< 16 viable weed seeds/m^3
Faecal coliforms per g	Free
Salmonella per 25 g	Free

Source: Sri Lanka Standard Institution (2003)

The prepared compost will be used as the baseline to initiate organic compost/fertilizer research by the Crop Nutrition Division which will be carried out to expose the actual situation of organic cultivation compared with application of inorganic fertilizer.

Objectives and targets

1. To investigate the performance of cane and sugar parameters of sugarcane with the usage of different quantities of the prepared organic compost mixture.
2. To investigate the possibility of reducing the amount and cost of organic compost mixture for sugarcane cultivation without an economic loss.

Methods

Study 01

Experimental methodology

A field experiment was established using the randomized complete block design (RCBD) having 8 treatment combinations of nitrogen (Table CN 04) with four replicates under irrigated (Two varieties; SL 96 128 and Co 775) and rain-fed (One variety; SL 96 128) conditions. Each plot was 7 m-long 5 rows planted 1.21 m apart. The middle 3 rows were used for taking observations and data.

Table CN 04. Proposed treatment combinations of organic compost

Treatment	Organic compost mixture (t /ha)	SRI chemical fertilizer recommendation (%)
T1	0.5	-
T2	1	-
T3	2	-
T4	4	-
T5	14	-
T6	55	-
T7	0	100
T8	0	-

Location and crop establishment

The field experiment was established at the Research Farm (6° 21' N, 80° 48' E) of the Sugarcane Research Institute, which represents the general topography of the *Walawe* soil series with the commencement of *Maha* rains in September/October 2021.

Soil and climate

The soil of the selected sites for the field experiments used for both irrigated and rain-fed conditions is classified as Reddish Brown Earths (Soil taxonomy order - Alfisols, Suborder - Ustalfs, Great soil group - Rhodustalfs) and texture ranges from sandy loam to sandy clay loam. The area receives an annual rainfall of about 1450 mm and 900 mm of 75 % expectancy with a distinct bimodal distribution. The average annual minimum and maximum temperatures are 22 ± 1.4 °C and 33 ± 1.4 °C, respectively.

Field operations

The land was prepared according to the recommendations for commercial sugarcane planting. Three-budded stem cuttings (setts) obtained from ten-month old sugarcane plants of the variety, SL 96 128 and Co 775 were used for planting. The plots were fertilized according to the treatment levels (Table CN 04). Filter-mud and vinasse based organic compost was applied at the planting along the rows after laying the seed setts. Field maintenances and other trial activities were done according to the SRI recommendations. Maintenance of the ratoon crop will be performed in the year 2023 same as the plant crop.

Data collection and analysis

Soil and plant parameters

Soil sampling and analysis

Soil chemical properties (pH), Electrical conductivity (EC), Total Nitrogen (N), available phosphorus (P), and exchangeable potassium (K) will be analyzed, before application of the treatments, four and half-month age and after harvesting the crop. The following analytical procedures will be adopted to analyze the above-mentioned soil properties:

Soil pH – 1: 2.5 soils to distilled water ratio, using pH meter with glass electrodes
Soil EC - 1: 5 soils to distilled water ratio, using EC meter
Soil total nitrogen - Kjeldhal method
Soil available Phosphorus - Olsen P method
Soil exchangeable Potassium - Ammonium acetate method using the Atomic Absorption Spectrophotometer (AA 6300)

Leaf sampling and analysis
The leaf nutrients will be compared with the critical leaf nutrient levels to determine the excess or deficient nutrient levels in the soil. Therefore, the leaf (3^{rd} leaf of a plant at $4^1/_2$ months after planting) will be analyzed according to the following standard methods. Wet digestion method will be used and N, P and K will be analyzed by UV Spectrophotometer and Atomic Absorption Spectrophotometer, respectively.

Other growth and quality parameters
Germination count at one month after planting, tiller count at 3 months after planting were recorded. At harvest, average values of stalk diameter, stalk height and number of internodes per stalk were estimated from randomly-selected 12-stalked samples. Number of millable stalks and water shoots in each plot were recorded at harvesting of the plant crop. The same samples of 12-stalked samples were used to measure or estimate laboratory brix, Pol percent in juice, fibre percent fresh weight and pure obtainable cane sugar (POCS). Same analytical procedures will be followed in the ratoon crop further.

Statistical analysis
Analysis of cane and sugar yield data
Data will be analyzed using SAS statistical software.
Initial soil nutrient levels of the individual plots will be recorded prior to application of the treatments. The effect of treatments on yield and quality parameters will be tested using Analysis of Covariance (ANCOVA) by considering initial soil nutrient levels as covariates. Precision of the experiment will be improved by using adjusting relevant variables with the covariance of initial fertility levels of each plot.

PROC MIXED procedure of SAS software will be used in analysis of data assuming block effect is random. Mean separation will be performed using the adjusted treatment means. Best performing fertilizer treatment will be selected by considering the yield performance and economic gains relative to the cost of fertilizer.

The economic viability of the different fertilizer mixtures will be analyzed by using Benefit-cost ratio and Net Present Value (NPV) calculation methods.

Location: Sugarcane Research Institute, Uda Walawe

Officers responsible

Team Leader:	Mr. H.A.S. Weerasinghe (ROIC-Crop Nutrition)
Other Officers:	Mr. B.R. Kulasekara (RO-Crop Nutrition)
	Mr. U.W.L.M. Kumarasiri (RO-Crop Nutrition)
	Mrs. B.D.S.K. Ariyawansha (SRO - Biometry)
	Mr. K.A.D. Koddithuwakku (SRO - Economics)
	Mrs. S.M.T.A. Maralanda (ROIC-Processing Technology)

Collaborating organization/s: Lanka Sugar Company (Pvt) Ltd will supply filtermud-vinasse

based compost for the trial (this was prepared under the guidance of the Crop Nutrition Division, SRI).
Consultants: Subject specialists will be joined according to the requirements.
Annual estimated cost (Rs): 2,221,563.00
Funding agency: SRI
Duration of the project: October 2021 - December 2024

Action plan for 2021-2024

For three-year time duration (Including plant and two ratoon crops)

Activity	Oct-Dec 2021	Jan-Dec 2022	Jan-Dec 2023	Jan-Dec 2024
Organising and establishment				
Maintenance of Plant crop, harvesting and rationing				
Maintenance of ratoon-I crop, harvesting and rationing				
Maintenance of ratoon-II crop, harvesting and rationing				
Laboratory analysis & statistical analysis				
Report writing& termination				

Action plan for 2023

Month / Activity	OCT	NOV	DEC	JAN 2022	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT
Soil sampling after harvesting plant crop													
Ratooning and fertilization of ratoon crop													
Laboratory preparation of soil samples and analysis													
Irrigation, weeding and													

maintenance of trials													
Data collection and analysis of germination, tillering and other growth parameters													
Collection and analysis of soil and plant samples at $4^1/_2$ months after ratooning													
Maturity testing from 9 months after planting up to harvesting													
Statistical analysis and report writing													

Benefits to the industry

Identify the most economic amount of organic compost to increase the productivity, profitability and maintain sustainability of sugarcane lands.

CN/04/22: Development and testing improved organic amendments for sugarcane cultivation.

Introduction

There are different products of organic compost and organic fertilizers available in the market to be used in crop cultivation. Suitable products should be identified for sugarcane cultivation where those should be tested at laboratory and field level. In addition organic related material that enhances the soil could be developed and one such is biochar which could be used to improve the soil. Biochar is a carbon rich substance and it is produced during the thermal decomposition of organic wastes under a limited supply of oxygen and at relatively low temperatures (<700 ^{0}C). Biochar is characterized by its high content of organic carbon and the low susceptibility to degradation. When compare to the biomass materials, biochar has a higher surface area and porosity, catalytic activity and physicochemical activity. Biochar has applications in the areas of soil improvement, mitigation of climate change, energy production and waste management. Biochar improves soil physical and chemical properties. Raising soil pH, increasing water holding capacity, increasing cation exchange capacity and nutrient

retention are few soil benefits from the biochar. Also biochar creates an environment with higher aeration which causes to improve the soil microbial activity and thereby helps to improve plant growth and crop yield. For selectively improve the physicochemical properties of soil, different types of biochars can be produced by selecting specific biomass and production conditions.

The characteristics of biochar vary depending on the type of biomass and the production conditions like treatment temperature, heating rate and holding time. Various types of biomass like coconut husk, coconut shell, rice husk, rice straw, sugarcane bagasse, sugarcane waste straw, palm shell, corn straw, wheat straw and coffee husk have explored for the potential to produce biochar through pyrolysis. For efficient and economical production of biochar the availability and the composition of biomass is very important. The cellulose, hemicellulose, lignin, fixed carbon content and volatile matter content of the biomass is significantly affecting for the biochar properties and its morphology. The biochar production could be carried out by two methods namely, traditional and using modern techniques. As the traditional approaches there are ancient methods and conventional pyrolysis techniques like slow pyrolysis and fast pyrolysis. Gasification, hydrothermal carbonization, electro modification and modified traditional methods like flash pyrolysis, vacuum pyrolysis and microwave pyrolysis are modern approaches.

Objectives and targets

1. To identify commercially available organic amendments suitable for sugarcane cultivation in Sri Lanka
2. To compare the characteristics of various sugarcane biomass; bagasse, sugarcane waste from mini mill and sugarcane trash derived biochars from laboratory and barrel techniques.
3. To determine the effect of biochar on improvement of soil fertility of long-term sugarcane growing soils.
4. To identify the best amounts of boiler-ash as a soil amendment.

Methods

Experimental methodology

Objective 1

The available organic compost products will be submitted to the Sugarcane Research Institute, Uda Walawe will be selected according to the following guidelines;

a. First come first basis
b. Quality of the product and suitability for the crop
c. Sugarcane experience – local and worldwide
d. Environment-friendly considerations.

At the CN Laboratory, products will be tested along with the SLSI quality standards and suitable products will be identified.

According to the quality of the products pot experiments, observational field trials and replicated field trials will be carried out to identify the effectiveness on sugarcane cultivation.

Objective 2

Collection of raw materials:

- Sugarcane bagasse after the juice extraction of sugarcane stalks, sugarcane waste from the mini mill and sugarcane trash were collected at Sugarcane Research Institute, Uda Walawe, Sri Lanka.

Preparation of biochar:

- The sugarcane bagasses were air dried and ground to pass a 2mm sieve.
- The sugarcane waste from the mini mill and sugarcane trash were cut into small pieces (less than 4-5cm) will be used separately.

Muffle furnace method

- Raw material were fully packed in a metal container and tightly closed.
- The metal container was placed inside a muffle furnace with an exhaust pipe and heated at three different temperatures (300^0C, 450^0C, 600^0C)
- After allowing to cool to the room temperature, it was ground to pass a 2mm sieve for use in characterization.
- The procedure was triplicated for all four biomasses at three different temperatures.

Low cost pyrolysis barrel method

Designed low cost biochar production unit was used for this method.

This consist 5 main components as outer barrel, inner barrel, fire grate, hinged top lid and chimney. As outer barrel 200-liter empty oil barrel is used. Lower part of the barrel is perforated for secondary air supply. At the lower part there is also three square shaped openings made with equally spacing for primary air supply and initial firing. Inner barrel with the lid is used to pack biochar making biomass. Fire grate to stack fire wood is in between outer barrel and inner barrel in a height of 4 inch from the bottom of the large barrel. A chimney of 5 feet height and 4" x 4" cross section is fixed on the top of the hinged top lid.

- Biomass were packed in the inner barrel and after tightly closing it was placed inside the outer barrel.
- In the space between two barrels suitable quantity of fire woods were packed.
- Then hinged top lid with the chimney was fixed to the outer barrel.
- Firing was started through the three square openings.
- After finishing the heating process, it was allowed to cool.
- The resulting biochar were ground to pass a 2mm sieve for use in characterization.
- The procedure was triplicated for the four types of biomass.

Biochar yield:

As the yield of biochar is expressed as the ratio of the mass of the biochar to the initial mass of the biochar subjected to the pyrolysis process, the biochar weight and the subjected biomass weight were measured.

Characterization of biochar samples:

- The proximate analysis of biochar was performed based on ASTM standards

1. Moisture content: ASTM E871-82
2. Ash: ASTM D1102-84
3. Volatile matter: ASTM E872-82
4. Fixed carbon: 100- (Moisture content + Ash + Volatile matter)

- The ultimate analysis of biochar for C, H, N and S contents were carried out using an elemental analyzer. O content will be calculated by the difference.
- Bulk density of the biochar was measured based on the methodology adopted by Mary et al. (2016).
- pH of the biochar was measured based on the methodology adopted by Sahoo et al. (2021).

1g of biochar sample was mixed with 60ml distilled water. After shaking the solution in a shaker for 1 hour and letting to cool to the room temperature and the pH was measured with a portable digital pH meter.

- Electrical conductivity (EC) of biochar was measured in 1:20 w/v biochar water extract using electrical EC meters.
- BET surface area and the total pore volume was measured with BET surface area and pore size distribution analyzer. Average pore diameter was calculated using the obtained results.
- The morphological characterization of biochar was investigated by using Scanning Electron Microscopy.
- The FTIR characterization was conducted using spectrometer.

Objective 3

- **Initial Biochar preparation**
  Sugarcane bagasse from Lanka Sugar Company Sevanagala was used for this study. After air drying, the biochar was prepared from two methods; using muffle furnace pyrolysis temperature at 450 ˚C for 2h and barrel method. Biochar was grounded to pass through a 2 mm sieve.

Pot experiment to study the effectiveness of biochar

- **Collection of soil samples**
  Soil will be collected from Uda Walawe sugarcane growing fields. Surface soil samples at the depth of 0-30cm will be collected. Soil samples will be stored in closed plastic bags until bring to Sugarcane Research Institute.
- **Soil characterization**
  Soil samples will be separately homogenized, air dried and crushed to pass through a 2mm sieve. Then analyzed for electrical conductivity (EC), Cation exchange capacity (CEC) pH, total organic carbon, total N, P, K and Ca^{2+},Mg^{2+},Zn^{2+} ion contents using standard methods.
- **Treatment with biochar**
  Biochar will be mixed with soil at the rate of 2.5 % the soil weight. Pots will be filled with biochar amended soil; each pot will be equipped with an outlet to collect leachates. Controls will be filled only with soil samples without amending with biochar. Soil biochar mixtures will be moistened at 65% of their water holding capacity.
- **Experimental setup and crops**
  The experiment was conducted with plants and without plants. Pots with plant were planted with a single budded sett. Triplicate of each sample were prepared. (36 of total samples) All the pots were arranged in Randomized Completely Block Design (RCBD) and supplied with basal fertilizer according to the standard fertilization rate. When start the leaching event, leachates were collected in to 250ml polythene bottles for 24h.
- **Sample Analysis**
  Leachates collected from each pot once every week were analyzed for N, P, K and Ca^{2+}, Mg^{2+}, Zn^{2+} ion contents using standard methods.

30 days after fertilization

Whole plant was harvested from each pot and washed with distilled water. The shoot system and root system were separated and dried at 80◦C to a constant weight. Dried plant tissues were ground into 0.25 mm size.

Shoot and root samples were analyzed for total N, P, K and Ca^{2+},Mg^{2+},Zn^{2+} ion contents using standard methods.

Immediately after harvesting soil samples were collected from each pot and analyzed for electrical conductivity (EC), Cation exchange capacity (CEC) pH, total organic carbon, total N, P, K, Ca^{2+} ,Mg^{2+},Zn^{2+} ion content using standard methods.

Objective 4

In the year 2023, this study will be carried out with three experiments. The first experiment will be a pot culture, planted with sugarcane to compare the effect of boiler-ash and biochar on soil physical and chemical properties and the initial growth of sugarcane in plant nutritional aspects. The second experiment will be laboratory-level testing on Soil pH buffering capacity along with the different levels of soil incorporated biochar and boiler-ashes. The third experiment will be a field level study based on the results of first two experiments.

The sugarcane bagasse and boiler-ash will be collected from the Lanka Sugar Company (PVT) Limited, *Pelwatte*. Biochar will be prepared from the sugarcane bagasse through pyrolysis at 450 ^{0}C in a muffle furnace (Model-OSK 6352-MHA-14). Biochar and boiler-ash will be analyzed for their physical and chemical properties at the Crop Nutrition laboratory of SRI.

Experiment 1 - Pot culture

Soils used for the pot experiment will be collected from the research farm of SRI and soils will be analyzed to determine initial nutrient levels before applying treatments. Single budded sets of sugarcane (*Saccharum* hybrid spp.) variety SL 96 128 will be grown in pots under shade house conditions at SRI Uda |Walawe. Ten treatment combinations, including 4 levels of biochar and 4 levels of boiler-ash will be tested in the pot experiment with four replicates in an RCBD (Table CN5).

Table CN5: Treatment combination of the pot experiment

Treatment number	Treatment combinations
T1	1.0 t/ha Biochar + N:P:K recommendation of SRI
T2	2.0 t/ha Biochar + N:P:K recommendation of SRI
T3	4.0 t/ha Biochar + N:P:K recommendation of SRI
T4	6.0 t/ha Biochar + N:P:K recommendation of SRI
T5	1.0 t/ha Boiler-ash + N:P:K recommendation of SRI
T6	2.0 t/ha Boiler-ash + N:P:K recommendation of SRI
T7	4.0 t/ha Boiler-ash + N:P:K recommendation of SRI
T8	6.0 t/ha Boiler-ash + N:P:K recommendation of SRI
T9	N:P:K recommendation of SRI
T10	Zero Fertilizer/ amendments (Control)

The incorporation of biochar and boiler-ash with pot soils will be practiced before one week of sugarcane bud planting.

The recommended amounts of fertilizers (Urea-325 kg/ha, Triple Super Phosphate-50 kg/ha, Muriate of Potash-225 kg/ha) will be applied in the pot experiment as per the established treatment combinations. The maintenance of soil moisture in potting soil will be simulated by pouring 100 ml of distilled water into each pot daily. The leachates will be separately collected and quantified daily. The microbial activities in the leachate will be arrested by adding a drop

of 2% mercuric chloride to each and every collecting bottle. The collected samples will be stored in a freezer until analysis. The pooled leachate samples will be analyzed for pH and EC (pH/EC meter Model HQ40d) at weekly intervals and total N, Available P, Zn, Cu, Fe exchangeable K, Ca and Mg contents in the leachate samples will be tested at monthly intervals.

At the completion of 3 months after planting, plant height, the number of tillers and leaves of sugarcane plants will be recorded. Plants will be uprooted and oven-dried at 70 ℃ until getting a constant weight to determine total dry weight (TDW) of plants. Prepared shoot and root biomass samples will be analyzed for chemical properties in plant nutrition. At the end of the pot experiment, soil samples will be collected from each pot to analyze soil for their physical and chemical parameters *ie.* Soil texture, bulk density, moisture, pH, EC, Total N, Available P, Zn, Cu, Fe exchangeable K, Ca, Mg and cation exchange capacity (CEC).

Experiment 2 - Testing of Soil pH buffering capacities

The same treatment combinations which are practiced in the first experiment will be tested for their soil pH buffering abilities under laboratory condition at SRI with three replicates in a CRD.

A freshly prepared 0.22 M $Ca(OH)_2$ liming solution will be introduced to each treated soil at the rates of 0, 1 ml and 2 ml of Ca(OH)2) to 10g of air-dried soil (Weavera *et al*., 2004). The resulting pH will be measured after 0, 20, 40 minutes and, 1hour, 1 hour and 20 minutes, 2, 4, and 6 hours to ascertain the equilibrium time required for maximum neutralization using the similar Soil: Solution. Measurement of pH in the suspensions will be done potentiometrically using a pH meter (pH/EC Model HQ40d). Two drops of chloroform will be added to each suspension to curtail microbial activities and the containers will be covered with parafilm to arrest evaporation as well as the interaction with the laboratory atmosphere. Using the time duration gained for equilibrium from the above pre-test, the pH buffer curves for all treated soils will be plotted by adopting the same procedure.

Experiment 3 – Field-level investigations on the effect of boiler-ash on soil and sugarcane yield and quality parameters

The field-level experiments will be started based on the results of experiments 1 and 2. Further, field-level experiences and existing soil information on sugarcane-growing soils will be utilized at the time of planting and establishing field trials at SRI or industry premises. Suitable treatment levels of boiler-ash as a soil amendment at the industry level will be determined after a critical evaluation of the relevant primary and secondary information.

Laboratory level Biochar, boiler-ash, soil, plant and leachate sample Analysis
The chemical parameters, pH and electrical conductivity (EC) will be measured by 1:2.5 and 1: 5 sample to distilled water ratio methods respectively by using a pH and conductivity meter (Model HQ40d). The analysis of organic carbon contents in the samples will be followed by loss on ignition method by using a muffle furnace (OSK 6352-MHA-14). The dry bulk density of the samples will be measured by oven method.

Sulphuric Selenium mixture and hydrogen peroxide method will be used to digest biochar and boiler-ash samples, then samples will be analyzed to determine their concentrations of P, K, Ca, Mg, Zn, Cu and Fe contents.

In soil sample analysis, standard Kjeldhal procedure will be followed for total soil N analysis with a modified colourimetric method. The soil available P content will be analyzed through

the standard Olsen method followed by 0.5 M $NaHCO_3$ extraction with Ammonium Molybdate and Ascorbic by modified colourimetric method. The exchangeable K, Ca, Mg will be analyzed through the ammonium acetate extraction method and available Zn, Cu and Fe will be analysed through the diethylenetriaminepentaacetic acid (DTPA) extraction method and CEC will be analyzed through 95 % ethanol and standard Na stock solution method.

Plant samples will be digested by following Sulphuric Selenium mixture and hydrogen peroxide method and digested plant samples will be analyzed for total N, Available P, Zn, Cu, Fe exchangeable K, Ca and Mg contents.

The non-metallic elemental analysis will be followed by using UV-VIS - spectrophotometer (UV-2600-Shimadzu) and metallic elemental analysis will be followed by using Atomic Absorption Spectrophotometer (AA 6300).

Statistical analysis
Suitable statistical procedures will be followed where data will be analyzed using SAS statistical software package. The economic viability of the different fertilizer mixtures will be analyzed by using Benefit-cost ratio and Net Present Value (NPV) calculation methods.

Location: SRI, Crop Nutrition Laboratory Uda Walawe

Officers responsible
Team Leader: Mr. H.A.S. Weerasinghe (ROIC-Crop Nutrition)
Other Officers: Mr. B.R. Kulasekara (RO-Crop Nutrition)
Mr. U.W.L.M. Kumarasiri (RO-Crop Nutrition)
Ms. B.D.S.K. Ariyawansha (SRO-Economics Biometry & IT)
Mr. K.A.D. Koddithuwakku (SRO-Economics Biometry & IT)
Collaborating organization/s: Prof Meththika Vithanage,
Consultants: Subject specialists will be joined according to the requirements.
Annual estimated cost (Rs): 2,181,563.00
Funding agency: SRI
Duration of the project: Two years (2022- 2023)

Action plan for 2023

Month / Activity	J	F	M	A	M	J	J	A	S	O	N	D
Laboratory testing and sample analysis												
Literature review												
Development of research methodology, work plan and proposal preparation												
Establishment of the pot experiment and maintenance												
Sample preparation and laboratory analysis												
pH buffering capacity experimentation												
Data collection, tabulation, analysis and reporting												

Determination of suitable treatment levels and preparation for field level experiments												

Benefits to the industry

Identify suitable organic products available in the market for sugarcane cultivation in Sri Lanka. Further to identify the characteristics of sugarcane bagasse-based biochar and compare the quality with different preparation techniques, and also its contribution to soil fertility improvement.

CN/03/20: Evaluation of the suitability of compound fertilizers for sugarcane cultivation in Sri Lanka

Introduction

Sugar is an important sub-sector of the economy of Sri Lanka. The current domestic requirement of sugar (at per capita consumption of 32 kg and population of 21.67 million in 2018) is estimated at about 693,000 tones. The domestic sugar production in 2018 was nearly 51,000 tones which was sufficient to meet less than eight percent of the total requirement. In the year 2018, 645,000 tons of sugar have been imported costing nearly Rs 40 billion, which was nearly 1.2% of the outlay on the total imports. Thus, the sugar sector of Sri Lanka makes a significant contribution to the national balance of payments in addition to its contributions to income and employment generation, development of under-developed rural areas in the dry and intermediate zones, green development, etc. The three sugar mills currently operating in Sri Lanka namely, Pelwatte, Hingurana and Sevanagala have a total sugarcane crushing capacity of 6,550 TCD. If they operate for 200 days during a year at full capacity, the total requirement of sugarcane would be 1.3 million tones. As against it, total amount of sugarcane crushed was only about 0.72 million tons during 2018. Inadequate supply of sugarcane is a major constraint for the underperformance of sugar mills. Such under-utilization of the crushing capacity has led to higher unit costs of production of sugar. One plausible solution to the problem is to increase sugarcane availability to sustain the use of the crushing capacity. Sugarcane availability to the mills can be increased either by increasing the sugarcane area or increasing average yields. Since agriculture lands are limited, the non-cane grower farmers should be encouraged to cultivate sugarcane. Such a shift in crop pattern would depend on the profitability of sugarcane crop relative to the competing crops. Profitability is again related to cost of inputs, price of yield and the yields. Fertilizer is one of the major input and a contributor to the yield of sugarcane cultivation. Even with the subsidized fertilizer price, the cost for fertilizer accounts for 10% to 12% of the total cost of sugarcane cultivation. Hence, researches for identification of low cost and high yielding fertilizer mixtures are a prerequisite for the development of the sugar industry in Sri Lanka.

Application of fertilizer mainly, Nitrogen (N) is required to achieve a successful harvest of high cane and sugar yields in sugarcane cultivation. Nitrogen deficiencies could decrease cane yields whereas excess N would also affect the quality of cane juice. Nitrogenous fertilizer in the absence of Potassium (K) steadily decreases the sucrose percentage in cane and addition of K counteracted this trend, producing a favorable response. The best N:K ratio lie between 1:1 and 1:1.5. Besides achieving maximum cane and sugar yields, application of correct levels of fertilizer is important for minimizing the cost of cultivation and environmental pollution. The profitability levels can also be considerably improved with the use of N, P and K fertilizers in balanced quantities. The sugarcane is commercially cultivated in Sri Lanka from South-eastern

to North-eastern dry and intermediate region, primarily on *Alfisol* soils (Reddish Brown Earth, Low Humic Gley soils) under rain-fed and irrigated conditions depending on water availability. Total commercial sugarcane cultivation area of about 18,000 ha in Sri Lanka entirely depends on chemical straight fertilizers where the current recommendation includes N in the form of Urea, P in the form of Triple Superphosphate and K in the form of Muriate of Potash. The tentative annual usage of Urea, Triple Super Phosphate and Muriate of Potash for sugarcane accounts to around 6100, 3800 and 4800 tons respectively.

Fertilizer application consists of three doses, namely, basal, 1st and 2nd top dressings applied at planting, after 45 days and after 90 days respectively. The main challenges are to apply fertilizer on time, at the right quantities and minimize losses. Among the straight fertilizers, Urea has recorded, volatilization losses around 60 %. This creates another challenge in long-term agriculture where most of the fertilizers are lost to the environment.

With the objective of increasing the yield per hectare of sugarcane in Sri Lanka, more attention is required to identify advance fertilizer technologies with low nutrient losses. Further, this was highlighted in meetings at the National Fertilizer Secretariat (NFS) to bring about research findings of advance and efficient fertilizer for particular crops which can be considered on decisions taken at the national level.

At present world is promoting and executing many projects to increase the efficiency of fertilizer technologies. One of the major aspect of those experiments is to make fertilizers more plant-available while reducing the environmental losses thereby reducing the overall fertilizer usage and cost of production. Compound fertilizers are developed with such advance technologies to making those more plant available, reducing losses and more environmentally friendly.

Objectives and targets

1. To investigate the performance of growth and yield (cane and sugar) parameters of sugarcane with the usage of compound fertilizers as a substitute
2. To investigate the possibility of reducing the amount and cost of fertilizers application for sugarcane cultivation without an economic loss.

Methods

A field experiment was conducted using the randomized complete block design (RCBD) having 6 treatment combinations of nitrogen (Table CN6) with five replicates under irrigated and rain-fed conditions. Each plot will be 7 m-long 5 rows planted 1.34 m apart. The middle 3 rows were used for taking observations and data.

Table CN6: Proposed treatment combinations of YARA and straight fertilizer

Treatment	N % from Straight fertilizer*	N % from Yara Winner*
1	100	0
2	75	25
3	50	50
4	25	75
5	0	100
6	0	0

* Percentages are based on current SRI recommendation

Location and crop establishment
The field experiment was established at the Research Farm (6° 21' N, 80° 48' E) of the Sugarcane Research Institute, which represents the general topography of the Walawe soil series. The plant crop was established in the field in January 2020.

Soil and climate
The soil of the selected sites for the field experiments used for both irrigated and rain-fed conditions is classified as Reddish Brown Earths (Soil taxonomy order - Alfisols, Suborder - Ustalfs, Great soil group - Rhodustalfs) and texture ranges from sandy loam to sandy clay loam. The area receives an annual rainfall of about 1450 mm and 900 mm of 75 % expectancy with a distinct bimodal distribution. The average annual minimum and maximum temperatures are 22 ± 1.4 °C and 33 ± 1.4 °C, respectively.

Field operations
The land was prepared according to the recommendations for commercial sugarcane planting. Three-budded stem cuttings (setts) obtained from ten-month old sugarcane plants of the variety Co 775 was used for planting. The plots were fertilized according to the treatment levels of compound ('Yara') and straight (Urea, Triple Super Phosphate and Muriate of Potash) fertilizers. At planting, $^1/_6$ of N, total P and ½ K will be applied. At 45 days after planting $^1/_3$ of N and after 90 days of planting ½ of N and remaining K were applied. In the field trail, Plant and ratoon 1 crops were harvested and ratoon 2 crop will be maintained and harvested in the year 2023.

Soil and plant parameters

Soil sampling and analysis
Soil chemical properties (pH), Electrical conductivity (EC), Total Nitrogen (N), available phosphorus (P), and exchangeable potassium (K) will be analyzed, before application of the treatments, four and half-month age and after harvesting the crop. The following analytical procedures will be adopted to analyze the above-mentioned soil properties:

Soil pH – 1: 2.5 soils to distilled water ratio, using pH meter with glass electrodes
Soil EC - 1: 5 soils to distilled water ratio, using EC meter
Soil total nitrogen - Kjeldhal method
Soil available Phosphorus - Olsen P method
Soil exchangeable Potassium - Ammonium acetate method using the Atomic Absorption Spectrophotometer (AA 6300)

Leaf sampling and analysis
The leaf nutrients will be compared with the critical leaf nutrient levels to determine the excess or deficient nutrient levels in the soil. Therefore, the leaf (3rd leaf of a plant at $4^1/_2$ months after planting) will be analyzed according to the following standard methods. Wet digestion method will be used and N, P and K will be analyzed by UV Spectrophotometer and Atomic Absorption Spectrophotometer, respectively.

Other growth and quality parameters
Germination count at one month after planting/ratooning, tiller count at 3 months after will be recorded. At harvest, average values of stalk diameter, stalk height and number of internodes

per stalk will be estimated from randomly-selected 12-stalked samples. Number of millable stalks and water shoots in each plot will also be recorded. The same samples of 12-stalked samples will be used to measure or estimate laboratory brix, Pol percent in juice, fiber percent fresh weight and pure obtainable cane sugar (POCS).

Statistical analysis

Analysis of cane and sugar yield data

Data will be analyzed using SAS statistical software. Initial soil nutrient levels of the individual plots will be recorded prior to application of the treatments. The effect of treatments on yield and quality parameters will be tested using Analysis of Covariance (ANCOVA) by considering initial soil nutrient levels as covariates. Precision of the experiment will be improved by using adjusting relevant variables with the covariance of initial fertility levels of each plot.

The appropriate mathematical model applicable to test the effects of treatments and blocks is given by:

$$Y_{ij} = \mu + \alpha_i + \rho_j + \beta_i\left(X_{ij} - \ddot{X}_{..}\right) + \varepsilon_{ij} \qquad \text{Eq. (1)}$$

Where;

Y_{ij} is the value of the ith treatment in the jth block and X_{ij} is the covariate in the relevant plot, μ is the overall mean yield, α_i is the effect of the ith treatment, ρ_j is the effect of the jth block, β_i is the slope of the ith treatment, $\ddot{X}_{..}$ is the overall mean of all X_{ij}s, and ε_{ij} is the experimental error.

PROC MIXED procedure of SAS software will be used in analysis of data assuming block effect is random. Mean separation will be performed using the adjusted treatment means. Best performing fertilizer treatment will be selected by considering the yield performance and economic gains relative to the cost of fertilizer.

The economic viability of the different fertilizer mixtures will be analyzed by using Benefit-cost ratio and Net Present Value (NPV) calculation methods.

Location: SRI, Crop Nutrition Laboratory Uda Walawe

Officers responsible

Team Leader: Mr. H.A.S. Weerasinghe (ROIC-Crop Nutrition)

Other Officers: Mr. B.R. Kulasekara (RO-Crop Nutrition)
Mr. U.W.L.M. Kumarasiri (RO-Crop Nutrition)
Mrs. B.D.S.K. Ariyawansha (SRO-Economics Biometry & IT)
Mr. K.A.D. Koddithuwakku (SRO-Economics Biometry & IT)

Funding agent: CIC Agri Businesses (Pvt) Ltd

Total estimated cost of the project: Rs. 2,916,000/= (for 3 years)

Estimated cost for 2022: Rs. 972,000/=)

Duration of the project: Three years (2020 – 2023)

Action plan for 2020-2023

For three-year time duration (Including plant and two ratoon crops)

Activity	Jan – 2020	Jan - 2021	Jan- 2022	Dec - 2023
Organizing and establishment				

Maintenance of Plant crop				
Maintenance of ratoon-I crop				
Maintenance of ratoon-II crop				
Laboratory analysis & statistical analysis				
Report writing& termination				

Action plan for 2023

Month / Activity	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Data collection and analysis of growth parameters												
Collection and analysis of soil and plant samples at $4^1/_2$ months after planting												
Maturity testing from 9 months after planting up to harvesting												
Statistical analysis and report writing												

Benefit to the industry

The results of this experiment will provide valuable research information on the growth and yield performance of sugarcane related to advanced compound fertilizers and their mixtures. In addition, they will provide useful information regarding the possibility of using compound fertilizer while reducing the amount and cost of fertilizers application without an economic loss to the farmers.

Services

CN/01/23: Analyses of soil, plant and sugar samples for other divisions of SRI and sugar companies

Introduction

At present, about 2000-3000 cane samples, leaf samples and soil samples are analyzed annually at the crop nutrition laboratory. Most of the samples come from the experiments conducted by other divisions of SRI. Providing required analytical facilities is one of the prime objectives of SRI.

Objectives and targets

To analyze the samples of other divisions at SRI and improve the laboratory methods according to acceptable standards and for the requirements of sugar companies.

Methods

Samples will be analyzed according to the standard analytical procedures available in the division after necessary preparation of samples.

Location: Crop Nutrition laboratory at SRI, Uda Walawe

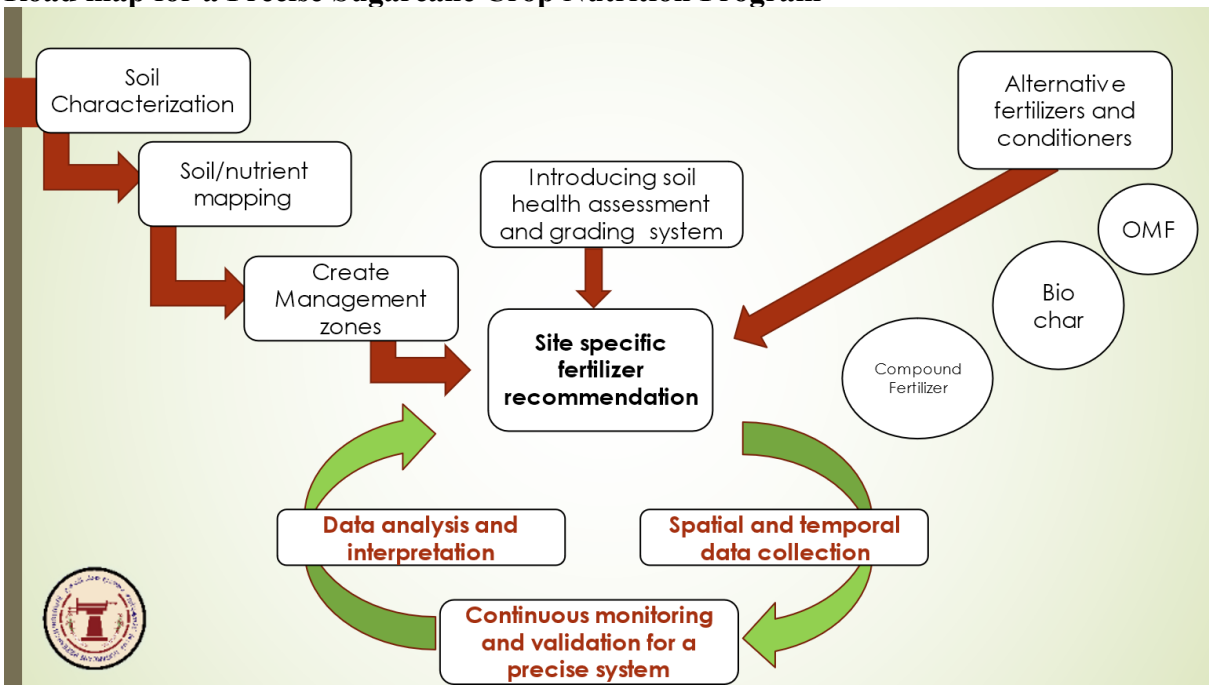
Officers responsible
Team Leader: Mr. H.A.S. Weerasinghe (ROIC-Crop Nutrition)
Other Officers: Mr. B.R. Kulasekara (RO-Crop Nutrition)
Mr. U.W.L.M. Kumarasiri (RO-Crop Nutrition)
Collaborating organization/s:
Total estimated cost (Rs): Rs. 1,956,563.00
Funding agency: SRI
Duration of the project: One year (2023)

Action plan for 2023: Analytical services are carried out throughout the year as per the pre plan requests of other research divisions

Benefits to the industry
Provide necessary analytical facilities for the research divisions of SRI and the sugar industry.

Future Directions

Road map for a Precise Sugarcane Crop Nutrition Program



The crop nutrition division intends to implement an integrated approach in combining organic and inorganic fertilizer to maximise cane and sugar yield while maintaining the soil health. Further, new technology will be used develop recommendations at site-specific level where future directions would be as follows,

- Soil characterization and converting to digital maps
- Creating management zones based on the nutrient maps
- Introduction of a soil health assessment and grading system
- Practising site-specific fertilizer recommendations
- Introducing alternative fertilizer and soil conditioners
- Improving the quality of factory by-product based organic compost and biochar
- Development of Organomineral pelletized fertilizer
- Spatial and temporal data collection for continuous monitoring and validation of a precise system
- Develop expert systems to facilitate crop nutrient management

Crop Protection Division

Research and services projects planned to be undertaken during the year 2023 are:

Research projects

1. CP/01/2023: Development of IPM package to manage sugarcane pest in Sri Lanka
2. CP/02/2023: Development of IDM package to manage sugarcane diseases in Sri Lanka

Service project

1. CP/03/2023: Provision of crop protection services to industries, farmers and other divisions in SRI on their request

CP/01/2023: Development of IPM package to manage sugarcane pests in Sri Lanka

i. Incorporation of sex pheromones, insecticides, miticides, biological control agents and tolerant varieties for IPM package
ii. Evaluation of germplasm for selected pests to find out potential parents to produce tolerant hybrids

CP/02/2023: Development of IDM package to manage sugarcane diseases in Sri Lanka

i. Incorporation of resistant/tolerant varieties for major diseases and chemicals and non-chemicals to manage diseases
ii. Introduction of molecular- based disease screening methods to screen varieties for smut disease to find out resistant varieties

CP/03/2023: Provision of crop protection services to industries, farmers and other divisions in SRI on their request

Under this project regular inspection of sugarcane nurseries and plantations in all sugarcane-growing areas will be conducted

01. CP/01/2023: Development of IPM packages to manage sugarcane pests in Sri Lanka

Integrated Pest Control is a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury.

Use of agronomic, biological, cultural, physical methods and resistant plants to suppress pest populations in sugarcane have contributed to maximization of production. Applying of small amounts of selective pesticides according to the pest forecasting schedules also contributed to lowering the pest damages. Integrated Pest Management (IPM) packages have been developed for the important sugarcane pests of Sri Lanka in order to limit the excess use of insecticides. These packages should be timely reinforced by incorporating novel and sustainable pest management strategies.

Therefore, a six-year research project was initiated in year 2020 to incorporate novel strategies to the IPM packages of moth borers and spider mite of sugarcane. Relevant studies were planned to incorporate synthetic sex pheromones of moth borers, insecticides, miticides for

spider mite, identification of potential biological control agents and tolerant varieties. Evaluation of the sugarcane germplasm will be commenced for selected pests to find out potential parents to produce tolerant hybrids.

I. Incorporation of sex pheromones, insecticides, biological control agents and tolerant varieties for IPM package

a. Reinforcing IPM package for sugarcane borers

Damage incidences of sugarcane moth borers have been increased in most of sugarcane plantations in Sri Lanka with high yielding sugarcane varieties. There is a requirement to reduce the crop losses due to moth borers on the newly bred high yielding varieties using green management methods. The studies on synthetic sex pheromones of moth borers in Sri Lanka have been completed in year 2020 and other research activities will be carried out in year from 2021 to achieve following objectives.

Objectives and targets

Following activities will be conducted during year 2023 to reinforce IPM package

i. Plant volatiles responsible for the interaction between female moth of *Chilo sacchariphagus* (Lepidoptera: Crambidae) and *Erianthus arundinaceus* - Continuation
ii. Resistant and susceptible accessions of *Erianthus arundinaceous* (Retz.) Jeswiet (Poales: Poaceae) for moth borers in Sri Lanka – Continuation
iii. Studying the potential of laboratory rearing , releasing and augmentation of the *Cotesia flavipes* ; natural enemy of sugarcane borers- New activity
iv. Evaluation of the efficacy of a granular insecticide; Dinotefuran 1% GR and Emamaectin benzoate 5%+ Lufenuron 40% WG for the management of borer pests of sugarcane in Sri Lanka- New PPP project

Methods

i. Plant volatiles responsible for the interaction between female moth of *Chilo sacchariphagus* (Lepidoptera: Crambidae) and *Erianthus arundinaceus*

Plant volatiles were collected from leaves of *Erianthus arundinaceous* and other test varieties using recommended extraction methods. Volatiles of samples were chemically identified using Gas Chromatography coupled Mass Spectrometry (GC-MS) at the University of South Eastern Sri Lanka during year 2021 and 2022. The moth attraction for the collected volatiles will be tested at the entomology laboratory, Uda Walawe using Y-tube olfactometer during 2023.

Oviposition preference assay will be conducted to make sure the female of *Chilo sacchariphagus* used host volatiles for oviposition site selection. It will be conducted using identified synthetic electro-physiologically active volatile compounds. The dual choice oviposition chamber will be prepared using transparent polystyrene cylinders. Both sides of the cylinder will be covered with two layer of muslin cloth to facilitate aeration, oviposition substrate and odour placement. Cylinder will be provided with moisture and honey solution (10%) by placing the soaked folded tissue paper at middle of the cylinder. Odour source will be placed on the cloth in one side and other side will be used as control (or blank). Each compound, 1 µl volume with concentration 10^{-4} will be used separately and compound will be diluted in DCM. Odour source will be renewed daily until the death of female. Number of eggs laid on each side will be counted and removed daily. Number of eggs will be compared by paired t test using IBM SPSS version 21.

Electroantennogram (EAG) studies will be carried out to determine the electrophysiological response for the identified individual compounds. Pure synthetic volatile compounds (>99% purity) will be purchased and used for the study. EAG responses of adult females and males will be made using an electroantennographic system (consisting of a dual electrode probe for antenna fixation, a CS-05 stimulus controller and an IDAC 232 box for data acquisition system) available in the entomology laboratory in the Coconut Research Institute, Lunuwila, Sri Lanka. The procedures described by Kumara *et al*, 2016 will be followed for the study. Behavioural studies will be conducted to determine the behavioral responses of EAG active volatiles according to methods described by Kumara *et al*, (2016).

ii. Resistant and susceptible accessions of *Erianthus arundinaceous* (Retz.) Jeswiet (Poales: Poaceae) for moth borers in Sri Lanka

Three field trials have been established at the research farm of the Sugarcane Research Institute, Uda Walawe (6^0 27'N, 80^0 52'E), research farm at Siyambalanduwa and at a field in the Galmaduwa zone of the Gal-Oya plantations (Pvt) Ltd., Hingurana (7^0 13'N, 81^0 39'E) with twenty-one (21) accessions of *E. arundinaceous* (Table 01) and 05 commercially-released sugarcane varieties (Co 775, SL 83 06, SL 90 6237, SL 92 5588, SL 96 128). The field trials are in Randomized Complete Block Design (RCBD) with four replicates. Plot size is 2 x 2 m rows and 3-budded four seed setts were used for planting one-meter row length. The inter-row spacing and distance between two plots are maintained as 1.37 m and 2m, respectively. Standard sugarcane cultural practices are being adopted for managing the crop except the use of insecticides.

Ratoon crop will be and damage incidences and intensities will be determined at the time of harvest and following assessment will be continued for 2nd ratoon crop.

Assessment of shoot damage

The total number of shoots/tillers and number of "Dead Hearts" due to *Chilo sacchariphagus* will be counted in each row at fortnight intervals up to 120 DAPs (Days After Planting) and percentage damage incidence will be calculated as mentioned below;

$$\text{Percentage damage incidence} = \frac{\text{Number of damaged shoots with "Dead Hearts"}}{\text{Total number of shoots inspected}} \times 100$$

Assessment of stalk damage

The assessment of stalk damage will be undertaken monthly from 120 DAPs using two methods i.e, percentage damage intensity and a damage rating system.

The total number of internodes and number of infested internodes will be counted on randomly selected 15 plants from each plot and percentage damage intensity will be calculated as mentioned below;

$$\text{Percentage damage intensity} = \frac{\text{Number of damaged internodes}}{\text{Total number of internodes inspected}} \times 100$$

The ratings will be given by considering the production of lateral buds and broken or dead tops in addition to the percentage of the leaf sheaths showing feeding sign prior to the larvae entering the stalk. Accumulation of frass at the leaf-sheath and reddening of the sheath are indications

of larval feeding activity (White *et al*, 2001). Damage response ratings will be based on a 1 to 9 scale, where 1 indicates little borer damage and 9 indicates heavy borer damage (Table CP).

Table CP1. Rating system to evaluate sugarcane borer damage

Rating score	Description
	Resistant
1	<30% of stalks with leaf-sheath feeding
2	30 to 60% of stalks with leaf-sheath feeding
3	>60% of stalks with leaf-sheath feeding and isolated lateral shoots may be present
	Intermediate
4	<30% of stalks with lateral shoots and with or without leaf sheath feeding
5	30 to 60% of stalks with lateral shoots and wide spread leaf sheath feeding
6	>60% of stalks with lateral shoots and wide spread leaf sheath feeding
	Susceptible
7	Same as 6, and with <30% of stalks with dead or broken tops
8	Same as 6 and with 30 to 60% of stalks with dead or broken tops
9	Same as 6, and with >60% of stalks with dead or broken tops

Officers involved in the project

Team Leader: Ms. V.K.A.S.M. Wanasinghe (RO- Crop Protection)

Other Officers: Dr. K.M.G. Chanchala (RO - Crop Protection)
Ms. A.M.M.S. Perera (SRO-Crop Improvement)
Ms. B.D.S.K. Ariyawansha (SRO - Biometry)
Mr. K.A.D. Kodituwakku (SRO - Economics)

External Supervisors:

i. Dr. L. Nugaliyadde (Retired Entomologist of Rice Research and Development Institute, Sri Lanka and Professor in Agricultural Biology, University of Ruhuna, Sri Lanka and Currently General Secretary, Sri Lanka Institute of Agriculture)
ii. Dr. A.D.N.T. Kumara (Senior Lecturer, Department of Biosystems Technology, Faculty of Technology, South Eastern University of Sri Lanka)
iii. Prof K.S. Hemachandra (Professor in Agricultural Biology, Faculty of Agriculture, University of Peradeniya, Sri Lanka)

Collaborating organizations: Coconut Research Institute, Lunuwila and South Eastern University of Sri Lanka

Funding agency: SRI

iii. Laboratory rearing, releasing and augmentation of the *Cotesia flavipes*; natural enemy of sugarcane borers- New activity

Cotesia flavipes is an effective natural enemy of sugarcane moth borers *Chilo sacchariphagus*, and *Sesamia inferans.* Several studies on laboratory rearing of *Cotesia* using rice grain moth; *Cosira* as alternative host and borer larvae reared on artificial diet was conducted. Due to high cost and labour requirement, requirement of new technique has been arisen recently. This activity will be conducted with the objective of developing new techniques for laboratory rearing, releasing and augmentation of the *Cotesia.* Strategies for Rearing *Cotesia* will be studied and optimised during year 2023.

Methods

Larvae of Shoot borer and INB will be collected from the borer infested fields of the research farm; SRI, sugarcane fields in Sevanagala, Pelwatte, and Siyambalanduwa. Collected larvae will be reared in insect rearing laboratory to obtain adult borer moths and *Cotesia* adults.

Adult moths will be released to the field cage with two month old sugarcane plants to obtain borer eggs.

Plants with eggs will be separately maintained until egg hatch taken place and larvae bore in to the plants. Borer larvae infested plants will be introduced to the rearing cage with *Cotesia* adults. Plants with deferent larval stages (L1 to L3) will be introduced to study the optimum larval stage to parasitize by *Cotesia*.

Artificial illumination will be provided to induce mating of the *Cotesia* adults and sugar solution will be provided for *Cotesia* adults as feeding medium. Deferent number of female *Cotesia* adults per borer larvae will be introduced to determine optimum host: parasitoids ratio. Larvae around 45 days old will be collected and reared on sugarcane stalk pieces (3/4cm long) in insect rearing laboratory to obtain *Cotesia* cocoons.

Deferent strategies on rearing will be practiced in deferent ways according to the requirement and required conditions will be optimised for efficient rearing of *Cotesia.*

iv. Evaluation of the efficacy of a granular insecticide; Dinotefuran 1% GR and Emamaectin benzoate 5%+ Lufenuron 40% WG for the management of borer pests of sugarcane in Sri Lanka- New PPP project

Laboratory experiment will be conducted to determine the lethal concentrations (LD_{50} and LC_{90}) and selected concentrations will be used for the field experiment. The field experiment is being conducted in the research farm at the Siyambalanduwa substation since March 2023 with variety SL 96 128 (The plot size is 10 m x 5 rows, Randomized Complete Block Design with 4 replicates. The recommended management practices are followed except for the application of herbicides. The effects of the treatments are tested according to the schedule with 55-days interval up to 5 1/2 months. The effect of the existing recommended insecticide for *Chilo sacchariphagus*; Fipronil 0.3% (w/w) GR (18 kg/ ha) is being tested for assessing its effectiveness against the new insecticide for management of sugarcane borers.

The percentage damage incidences and damage intensity of stalk borers will be calculated according to the following formulae:

$$\textit{Percentage incidence of stalk borers} = \frac{\textit{Number of damaged plants by stalk borers}}{\textit{Total number of plants inspected}} \times 100$$

$$\textit{Percentage intensity of stalk borers} = \frac{\textit{Number of damaged internodes by stalk borers}}{\textit{Total number of internodes inspected}} \times 100$$

Having achieved the normal distribution by transforming the values through appropriate data transforming method, analysis of variance will be carried out to test the significance of the effects of treatments on the efficacy of proposed treatments of insecticide. The means will be compared with LSD test at 0.05 probability level using the Statistical Analysis System software (for Windows 9.0).

Duration of the project: Two years (2023– 2025)

Action plan for 2023 - 2025

For two-year time duration (including plant crop and 1st ratoon crop)

Activity	March -2023	March - 2024	March - 2025
Organizing and establishment			
Maintenance of Plant crop			
Maintenance of ratoon-I crop			
Report writing & termination			

Benefits to the industry

The study will be useful in developing environmentally friendly, clean and green pest management methods against this severe pest in Sri Lanka and it will provide an additional control supplanting insecticide in the IPM program

b. Studying non chemical strategies to minimize the pest population

Justification

Integrated Pest Management (IPM) is a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury.

Use of agronomic, biological, cultural, physical methods, resistant plants and chemical control to suppress pest populations in sugarcane have contributed to maximization of production. With less availability of synthetic chemicals for local agriculture, it has to be focused more in other pest management strategies to avoid pest damage to the crops.

a. Studying the of potential of plant extracts to manage sugarcane pests and their efficacy in pest management - Continuation
b. Studying the efficacy of changing planting times in sugarcane pest and disease management – Continuation

i. Studying the of potential of plant extracts to manage sugarcane pests and their efficacy in pest management

Plant extracts as control in pest management, have been reported to be eco-friendly, less costly, safer and more compatible with environmental components, compared to synthetic pesticides and fungicides and are now classed as “green agrochemicals” and their increasing use is noted. Thus, plant extracts as biological control has more advantages than synthetic versions. These include: less costly and cheaper than any other methods. They don’t cause toxicity to the plants; Application is safer to the environment and to the person who applies them.

Extracts of onion, garlic, eucalyptus and tobacco are known to control many plant-pathogenic fungi and insects. Finely ground, dried flowers of chrysanthemum, marketed as insecticides, contains an active ingredient, pyrethrin. Pyrethrum is one of the oldest insecticides known. Pyrethrins, have a rapid paralytic action on insects. In local agriculture farmers have been using several plant extract over the years and indigenous knowledge on effective plant is available.

There for this study was started with the objective of identification of the effective plant extracts in sugarcane pest management.

Research is continuing from year 2022 and studies on pesticidal properties of *Lantana camera* and *Azadirachta indica* was conducted for sap sucking pests *i.e.,* Sugarcane Woolly aphid (SWA), Pink mealy bug, *Pyrilla perpusilla* and WLD vector.

Pesticidal plants effective for termite damage also studied. Effect of ethanol extracts of Ipil Ipil pods and leaves, Gliricidia and Lantana leaves were studied over termite in field. Also effect of Wara, Ipil Ipil, Endaru, Neem, Murunga, Gliricidia, papaya and lantana leaves in dry form for termite studied in the field.

Effect of selected pesticidal plant parts and extracts were recorded and studies will be continue with the objective of further identification of the effective plant extracts in sugarcane pest management.

Methods

Literature will be collected on locally available plants (which were not studied during year 2022) with pesticidal properties. Plant extract will be prepared in the most effective extraction procedure to extract effective ingredient i.e., aqua, ethanol, methanol or fresh form. Laboratory experiments will be conducted to study the effectiveness of the extract over each sugarcane pest. Specially, Sugarcane spider mites, woolly aphid, leaf eating caterpillars, leaf hoppers will be used in the study. Relevant pests will be collected from the field and reared in the laboratory in order to get same aged insects for the lab experiment.

I. During the laboratory study, sugarcane leaf pieces (10 cm) from variety SL 96 128 will be immersed in the prepared extracts for 30 seconds and will be placed on the petri dish enclosing the cut ends with wet cotton wools. Insects at same growth stages (nymph, adults etc.) will be introduced to the petri dishes and effect will be studied in 6 hr intervals. Mortality data will be collected and behaviors will be studied.

II. Pot experiment will be conducted in the field cages with effective plant extracts and concentrations using artificially pest inoculated sugarcane plant pots. Damage cause to plant by pest, pest mortality and phytotoxic effects will be evaluated in each treatment in 24 hr intervals up to 2 weeks to evaluate the effectiveness of the extracts.

III. Considering the results, effective concentrations will be determined and field studies will be conducted according to the requirement.

ii. Studying the efficacy of changing planting times in sugarcane pest and disease management

Cultural control of pests based on time of planting follows the principle of growing the target crop when the pest is not present or planting at a time when the pest is least abundant. Despite the many benefits associated with manipulation of planting dates, farmers' choices of sowing dates are affected by many constraints such as labour bottlenecks, traditions, social festivals, illnesses and etc. Therefore this study will be conducted with the objective of identifying the efficacy of changing planting times in sugarcane pest and disease management.

Methods

Field trial was established in RCBD with three replicates and managed according to the SRI recommendations. Size of the plots was 9 m x 6 rows. Trial plots will be harvested from January and ratoon I will be established in each month according to the planting date.

Data collection

The pest populations will be measured from germination of the ratoon I crop; nearly two weeks after ratooning. Incidences of stalk and shoot borers, sugarcane spider mite, sugarcane woolly aphid (SWA) and WLD vector in each plot will be done according to the following schedule in the Table CP2.

Table CP2: Crop ages for observations of pest incidence

Pest	Observation
Shoot borer	At 2nd and 4th month
Woolly aphid	From 90 DAP/R
Internode borer	At 9th month
Termite	From 30 DAP/R up to time of harvesting
Mite	From 30 DAP/R up to time of harvesting
WLD vector	From 3 to 5 month age

Pest incidence will be calculated as,

a. Percentage incidence of SB = $\frac{\text{No. of SB damage s/ dead hearts}}{\text{Total no. of plants observed}} \times 100$

b. Percentage intensity of stalk borers = $\frac{\text{No .of damaged internodes by stalk borers}}{\text{Total no. of internodes inspected}} \times 100$

c. Percentage incidence of Mite/ Termite / Woolly aphid = $\frac{\text{No. of infested plants}}{\text{Total no. of plants observed}} \times 100$

d. WLD vector populations; number of vectors / 100 sweeps

At the same time germination, number of water shoots, brix and cane yield will be collected in each plot separately. Each treatment will be compared using ANOVA. Means were separated with LSD technique.

Action plan for 2023

Activity \ Month	J	F	M	A	M	J	J	A	S	O	N	D
Ratooning the field trial and ratoon management												
Data collection												
Analysis												

II. Evaluation of germplasm for selected pests to find out potential parents to produce tolerant hybrids

Evaluation of different sugarcane varieties for resistance/tolerance to stalk and shoot borers, sugarcane spider mite, leaf sheath mite, WLD vector and sugarcane woolly aphid (SWA).

a. **Pest observations in RYTs**

The varieties in RYTs (2006, 2007, 2008, 2009, 2010 and 2011), adaptability trials and large-scale plots carried out under the crop improvement program will be inspected for the different pest incidences (Table CP3).

Table CP3: Crop ages for observations of pest incidence in RYTs

Trial	Pest	Observation
RYT, Adaptability trials, Large-scale plots	Shoot borer	At 2nd and 4th month
	Woolly aphid	From 90 DAP/R
	Internode borer	At 9th month
	Termite	From 30 DAP/R up to time of harvesting
	Mite	From 30 DAP/R up to time of harvesting

Pest incidence will be calculated as,

a. Percentage incidence of SB = $\frac{\text{No. of SB damage s/ dead hearts}}{\text{Total no. of plants observed}} \times 100$

b. Percentage intensity of stalk borers = $\frac{\text{No .of damaged internodes by stalk borers}}{\text{Total no. of internodes inspected}} \times 100$

c. Percentage incidence of Mite/ Termite / Woolly aphid = $\frac{\text{No. of infested plants}}{\text{Total no. of plants observed}} \times 100$

d. WLD vector populations; number of vectors / 100 sweeps

Location: Research farm, Uda Walawe, Research substation, Siyambalanduwa and Sugar Industry sites at Sevanagala, Pelwatte and Hingurana

Officers responsible

Team Leader: Dr. K.M.G. Chanchala (RO/Crop Protection)
Other Officers: Ms. V.K.A.S.M. Wanasinghe (RO/Crop Protection)
Ms. B.D.S.K. Ariyawansa (SRO/Biometry)
Funding agency: SRI
Duration: Continuous

CP/02/2023: Development of IDM package to manage sugarcane diseases in Sri Lanka

Following researches activities have been planned to be undertaken under the CP/02/23 project

I. Incorporation of resistant/tolerant varieties for major diseases to manage diseases
Screening of different sugarcane varieties for resistance to major diseases and pests

A significant yield loss is caused due to sugarcane diseases in Sri Lanka. Sugarcane white leaf, sugarcane smut, leaf scald are the major sugarcane diseases. Use of resistant or tolerant varieties for diseases is the most appropriate strategy to minimize the yield losses, because it is eco-friendly, economical, long-lasting, less influenced by abiotic factors, compatible with and complementary to other disease management components and user friendly.

Objectives and targets

i. To screen the newly-bred varieties for resistance/tolerance to white leaf disease (WLD), sugarcane smut disease and leaf scald disease (LSD).
ii. To identify and reject the most susceptible sugarcane varieties in RYTs, adaptability trials, maturity studying trials and large-block trials of Crop Improvement program to avoid releasing the most susceptible varieties for pest infestations to commercial cultivations.

Methods

i. Screening the newly-bred varieties for diseases

The newly-bred varieties of the crop improvement program are screened for the major sugarcane diseases, *viz.,* WLD, smut and LSD according to the following standard methods:

a. Screening of sugarcane varieties for resistance/tolerance to WLD

Resistant/tolerant (sugarcane varieties with low disease incidence) of sugarcane varieties to WLD are evaluated at Siyambalanduwa research substation. Three-budded setts of each variety selected from RYT stage of the crop improvement program of SRI will be planted in 1m plots in-between two diseased plant rows to facilitate natural infection. Disease incidence will be recorded at monthly intervals from 30 days after planting (DAP) to 9 months after planting (MAP) up to third ratoon. Percentage disease incidence will be estimated for each variety.

During 2023, ratoon II crop of established trial to screen varieties for WLD in SL 2008 and SL 2009 series will be maintained and disease data recording of disease incidence in every month will be continued. Furthermore, plant crop and ratoon I crop of the field trials established to screen varieties for WLD in SL 2010/11 will be maintained and data recording will be continued.

b. Screening of sugarcane varieties for resistance to smut disease

Three-budded setts obtained from each variety selected from stage III of the crop improvement program will be inoculated with a spore suspension of the fungus using the standard dip inoculation technique and incubated in polythene bags at room temperature for 12-18 hours. Then, the varieties will be planted in 1 m-row plots in three replicates in Randomized Complete Block Design. Three-budded setts of the standard varieties (Co 740, Co 775, Co 997, Co 1001, M 351 57, PH 56 226) treated in the same manner will also be planted along with the testing varieties. Smut disease incidence will be recorded at one-month intervals for a period from 2 to 9 MAP. Percentage disease incidence will be estimated, and the ratings for resistance level will be assigned for the new varieties based on the ratings of the standard varieties.

The established trial in 2022 to screen varieties for smut resistance in SL 2014 series will be continued during 2023. In addition, a new trial will be established to screen varieties in SL 2015 series.

c. Screening of sugarcane varieties for resistance to leaf scald disease (LSD)

The progenies selected from stage III of the selection program are screened. The testing varieties and the standards (Co 740, Co 775, Co 997, Co 1001, Q 68, Troton, Trojan,) will be planted in 1m-row plots in three replicates. Three-month-old plants will be inoculated with the inoculums extracted from the leaf tissue of the diseased plants mixed with bacterial broth culture according to the standard "Aluminium cap" technique. The disease incidence will be recorded at one-month intervals from 2 months after inoculation to ten months. Percentage disease incidence will be estimated, and the ratings for resistance level will be assigned for the new varieties based on the ratings of the standard varieties.

The established trial in 2022 to screen varieties for smut resistance in SL 2014 series will be continued during 2023. In addition, a new trial will be established to screen varieties in SL 2015 series.

d. Disease incidence recordings in RYTs and large-block trials

Recording of disease incidence in different series RYTs and large block trials in the crop improvement program of SRI at different time intervals (Table CP4).

Table CP4: Schedule for recording of disease incidence

Stage of the varietal improvement program	Structure of the experiment	Observation details	Sampling interval
RYTs at Uda Walawe	10 m x 5 rows; plant + ratoon 1 and 2	Disease incidence of smut, WLD and LSD will be taken at monthly intervals until six months from DOP.	1 month
RYTs Hingurana and Pelwatte, Etimale and Kantale	10 m x 5 rows; plant + ratoon 1 and 2	Disease incidence of smut, WLD and LSD will be taken at two-month intervals until six months from DOP.	3 months
Large-block trials and adaptability trials in different locations		Disease incidence of smut, WLD and LSD will be taken at monthly intervals until six months from DOP.	3 months

The varieties of the RYTs in SL 2002, SL 2005, SL 2006, 2007, 2008, 2009 and 2010/11 series in Uda Walawe, Pelwatte, Ethimale Hingurana, and Kantale under crop improvement programme will be inspected for diseases during the year 2023.

Location: Research Farm, Uda Walawe, Siyambalanduwa substation and sugar industries (Sevanagala, Pelwatte, Ethimale, Hingurana and Kantale)

Action plan for 2023

Activity \ Month	J	F	M	A	M	J	J	A	S	O	N	D
Data recording and maintenance of SL 2014 series in varietal screening trials for smut and LSD in Uda Walawe												
Recording of disease incidence in RYTs established in Uda Walawe, Pelwatte, Hingurana, Etimale and Kantale.												
Data recording and maintenance of ratoon II crop of varietal screening for WLD in SL 2008/2009 series in Siyambalnaduwa												
Data recording and maintenance plant crop and of ratoon I crop of varietal screening for WLD in SL 2010/11 series in Siyambalnaduwa												
Establishment of two new trials to screen the varieties in SL 2015 series for Smut and LSD (Time of planting will depend on the material availability of seed material in CI division)												
Establishment of a trial to screen varieties in SL 2012 for WLD in Siyambalanduwa (Time of planting will depend on the material availability of seed material in CI division)												
Recording of disease data in large-scale plot trials of the SL 2003 series varieties												

Benefit to the industry

Production and releasing of resistant/tolerant sugarcane varieties for commercial plantations is the most effective, economical and eco-friendly way to manage sugarcane diseases. Therefore, evaluating of newly-bred varieties for diseases resistance under Sri Lankan conditions is much

important to identify and release resistant/tolerant sugarcane varieties for commercial plantations.

1. Study the effectiveness of resistance inducing chemicals (Elicitors) to reduce phytoplasma titer in sugarcane

Introduction

Sugarcane White Leaf Disease (WLD) has become one of the major threats to sugarcane cultivation in several sugarcane growing countries in Asia and has been identified as the one of the reasons for low cane yield and sugar recoveries recorded in the local sugar industries. Considering the current status of WLD incidence in sugarcane cultivation in the country, development of management program for WLD is at utmost importance state. Therefore, possibility to use resistance inducing chemicals (elicitors) to control of WLD phytoplasma will be studied during year 2023.

Objectives and targets

Study the effectiveness of resistance Inducing chemicals (Elicitors) to reduce phytoplasma titer in sugarcane.

Methods

Three budded setts of sugarcane varieties namely SL 92 5588 and SL 98 2524 will be subjected to Hot Water treatment (HWT) according to the exciting recommendation. Different concentrations of resistance inducing chemicals namely, salicylic acid, jasmonic acid and Benzothiadiazole will be tested in three different concentrations (0.6 mM, 1.2 mm and 2.4 mM) to study the effectiveness resistance inducing chemicals to manage the phytoplasma diseases.

Three budded setts of sugarcane varieties namely SL 92 5588 and SL 98 2524 will be subjected to Hot Water treatment (HWT) according to the exciting recommendation. The hot water treated seed setts will be dipped separately in different concentrations of the above mentioned chemicals for two hrs. Genomic DNA will be extracted just after HWT and after treating with the mentioned chemicals. PCR will be done using universal primers and specific primers to check the presence of the pathogen in the just after hot water treatment and resistance inducing chemicals respectively. qPCR will be done to quantify the available amount of phytoplasma after each treatment. The treatments will be done in triplicates.

The resistance inducing chemicals treated seedsetts with different concentrations will be planted in an insect proof net house as well as an open area. Another set of the same treatments with same varieties will be planted just after hot water treatment and after dipping in a water for two hrs. These setts will be used as control and negative control. Leaf samples will be collected from each treatment in two weeks intervals up to three months. DNA will be extracted and PCR will be done to see the presence of phytoplasma. qPCR will be done to quantify the available amount of phytoplasma in each sampling date.

After qPCR reactions will be completed, threshold values will be adjusted to 1.0 to enable comparison of data sets. Standard curves will be computed using triplicate wells of sugarcane white leaf phytoplasma infected sugarcane DNA in 10-fold dilution series per well. Two replicates will be used for each sample. The mean threshold cycle (Ct) values will be calculated. Quantity calculations of available phytoplasma will be done based on the DNA of phytoplasma standard curve.

Available phytoplasma Quantity will be calculated as copy number value per sample. All the analyses will be done using SAS 9.1 version and mean separation for all analyses will be performed using Duncan's Multiple Range Test (DMRT) at a significant level of $p < 0.05$. The most effective resistance induce chemicals and its concentration will be further tested under field condition in both plant and ratoon crops.

Action plan for 2023

Activity \ Month	J	F	M	A	M	J	J	A	S	O	N	D
Purchasing of chemicals												
Doing HWT, treating with chemicals												
Sample collection and doing PCR												
Quantification of available phytoplasma using q PCR methods												

2. Introduction of molecular- based disease screening methods to screen varieties for smut disease to find out resistant varieties

Molecular analysis of sugarcane varieties during *Sporisorium scitamineum* interaction to develop molecular-based screening methods for smut disease

Introduction

Sugarcane smut is caused by the fungus *Sporisorium scitamineum* Syn. *Ustilago scitaminea* is an important disease of sugarcane in Sri Lanka. Development and severity of this disease mainly depend on the sugarcane variety and on the environmental conditions. Most of the sugarcane diseases are easily managed in plantations around the world through the cultivation of resistant varieties due to minimal environmental impacts and is readily adopted by growers.

Smut infection causes reduction in cane thickness, intermodal length and the number of millable canes that invariably affects the yield. A significant loss in yield and quality was recorded in sugarcane due to smut from different countries.

In Sri Lanka, a crossing program is conducted every year during sugarcane flowering season to generate genetically variable seedling populations. Commercial varieties are selected by conducting a step-wise clonal selection program commencing from these seedling populations. In Sri Lanka, the individuals in the seedling populations developed through the crosses are selected at 12-months of age based on field brix and on the visual observations on morphology and free from pest and diseases. The selected individuals are given variety numbers and advanced into the next variety selection stage while multiplying the planting material vegetatively. Varieties are selected based on cane- and sugar- yield components and on fiber content up to the stage 3 of the variety selection program adopted in Sri Lanka. The materials of the varieties selected from stage 3 are multiplied in varietal multiplication plots to obtain the

required amount of planting materials for the establishment of Preliminary Yield Trials (PYTs). In parallel to this activity, the same varieties are established in separate field experiments designed for screening varieties for their resistance to smut, leaf scald and white leaf diseases. At this stage more than 200 varieties are tested in variety screening trials separately for three major diseases.

For sugarcane smut diseases, the trials are established to screen varieties coming from the stage 3 of the crop improvement program in one meter plots in Randomized Complete Block Design (RCBD) in three replicates after artificial inoculation of the pathogen using standard dip inoculation technique. However, there is conflict between the breeders and the pathologists regarding the plot size of the field trials which is used to screen varieties in the field. In literature, different countries have been used different plot sizes and some countries have been used six pots with single plant of the particular variety to screen the varieties mainly for sugarcane smut while in some other countries have been used 1 m as the plot size to screen varieties.

In Sri Lanka, we have identified that 6 m is the optimum plot size to screen varieties for sugarcane smut under Sri Lankan condition (unpublished data). However, due to scarcity of land and other resource in SRI so far we are conducting research using the 1 m plot size. Even though, the plot size is small there is no any failure in the commercially released varieties regarding the resistance.

Therefore, this research is aimed to develop a molecular-based screening method which can be used for initial screening of the varieties for sugarcane smut. Consequently, the optimum plot size can be used for field establishment of the selected varieties from molecular - based screening methods. As such, the outcome of this research project will be immensely of use to screen sugarcane varieties more accurately and precisely to identify and propagate resistant sugarcane varieties for sugarcane smut disease for sustainable development of the local sugarcane industry.

During 2022, a suitable reference gene for quantification of expressed gene was identified. In addition to that the variation of three expressed genes between resistant and susceptible sugarcane varieties were quantified.

Objective and targets

To study the variation on molecular level variation of the varieties during smut infection to develop a protocol to early selection of sugarcane hybrids/varieties for sugarcane smut disease resistance.

Methods

Validation of quantification of differentially expressed gene

Six (06) sugarcane varieties, two varieties from each highly resistant, moderately resistant and highly susceptible categories will be used for this study. The details of the varieties are, two (02) sugarcane varieties namely SL 98 2524 and Co 740 which have shown highly resistance to *Sporisorium scitamineum* and two (02) sugarcane varieties namely, SL 98 2118 and SL 03 1188 which have shown highly susceptible to the particular pathogen and two (02) sugarcane varieties namely SL 97 1442 and SL 95 2476 which have shown intermediate response (moderately resistant) for sugarcane smut pathogen will be used in this study.

Two sets from each variety will be taken for the test and one set will be treated with the pathogen and the other set will be treated with water (mock inoculation) three replicates in each variety from each treatment will be maintained. The inoculated seed setts will be incubated at 30 ^{0}C for 30 hrs in dark condition for better infection.

Total RNA will be extracted from each smut inoculated and mock inoculated varieties using Trizol method. C-DNA will be prepared using extracted RNA according to the manufacturer's instructions. Reverse transcription PCR (RT PCR) will be done using previously identified three different genes which were produced for genes involved in the resistance of sugarcane smut . Comparison of expressed gene in the inoculated and control samples with respect to their known resistance or susceptibility levels will be done.

Location: Research Farm, Uda Walawe, Faculty of Technology, University of Colombo, Pitipana, Homagama

Action plan for 2023

Month / Activity	J	F	M	A	M	J	J	A	S	O	N	D
Purchasing of chemicals												
Inoculation of the pathogen, doing PCR for confirmation and doing q RTPCR for quantification												

Benefit to the industry

Introduction of a method to screen varieties for smut disease using molecular-based methods

03. Provision of crop protection services to other divisions of SRI, sugar industries and farmers (CP/03/2023)

Introduction

Provision of recommendations for effective control of any probable pest/disease condition is a responsibility of SRI to maintain pest and disease-free sugarcane plantations.

Objective and targets

To manage pests and diseases in sugarcane plantations in Sri Lanka below economic injury level.

Methods

The following activities will be carried out:

i. Regular inspection of SRI seed cane nurseries primary nurseries and selected fields of sugar industries to keep the disease condition of the nurseries according to the SRI seed act and aware industry people on current pest ad disease status.
ii. Continuation of quarantining imported sugarcane varieties and maintaining Hantana quarantine substation.

iii. Inspection, identification further studies and management of the newly emerging pest and diseases in sugarcane plantation of different sugar industries in Sri Lanka

iv. Providing necessary recommendations and advice to farmers/sugar industry personnel when a pest or disease outbreak is noticed.

The consignments of the imported varieties will be inspected at the point of arrival and verified for valid quarantine certificates, and the good condition of the cane setts. If the setts are in deteriorating condition and/or consist of pest and insect injuries, the consignment will be destroyed by burning in an incinerator. The satisfactory consignments will be planted in the open environment at the quarantine station at Hantane after necessary fungicide and insecticide treatments. Regular inspections will be carried out for any new pest and disease emergence during the 1st and the 2nd year.

The varieties which are free of diseases and pests during the observation period will be released to the sugarcane germplasm collection after taking approval of the Director General of the Department of Agriculture (DOA). The varieties which show any alien disease or pest during the observation period will be destroyed by burning.

Regular inspections of the varieties under quarantine will be done once a month.

v. Activities of the Crop Protection Committee (CPC) for sugarcane.

vi. Screening synthetic insecticides and fungicides available in the local market and plant extracts having insecticidal properties to control emerging pest problems in local sugarcane plantations.

vii. Conducting farmer training programs organized by the Technology Transfer and Development Division of SRI.

viii. Guidance of university students for their final-year dissertations and diploma students for entomological and pathological research.

ix. Participating Pesticide Sub Committee in Department of Agriculture.

x. Taking disease incidence in foreign variety trials in Sevanagala, Pelwatte and Hingurana.

Processing Technology Division

The following six research activities under the three main research projects will be undertaken by the Processing Technology Division (PT) of the Sugarcane Research Institute (SRI) in the year 2023.

i. PT/01/2022 - Development of sugarcane-based value-added products
    i. Testing sugarcane varieties for jaggery production
    ii. Development of sugarcane-based value-added products
    iii. Study the effect of organic farming on the quality of jaggery produced from organic sugarcane cultivation

ii. PT/02/2022 - Rectification of milling standards for improvement of processing efficiencies in local sugar factories
    i. Determining optimum conditions for efficient juice clarification process at sugar factories
    ii. Post-harvest deterioration of sugarcane and controlling methods

iii. PT/03/2022 - Isolation of plant growth promoting microorganisms from diverse environment for bio-fertilizer formulation

The details of each research activities are as follows:

PT/01/2022 - Development of sugarcane-based value-added products

i. Testing sugarcane varieties for jaggery production

Introduction

The Sugarcane Research Institute (SRI) promotes jaggery industry in areas where sugarcane cannot be transported to sugar mills. The quality of jaggery produced with different sugarcane varieties differ from each other. The varietal improvement program of the SRI is mainly directed towards the selection of varieties for sugar production. Most of the varieties in the replicated yield trial (RYT) stage of the each breeding series are with high cane yielding potential. However, some of these varieties may not be suitable for jaggery production since jaggery quality and recovery varies with the variety. Evaluation and screening of these varieties for jaggery recovery, quality and other desirable features is of paramount importance in identifying varieties suitable for commercial jaggery production.

In previous years, varieties in SL 2004, SL 2005, SL 2006, SL 2007 and SL 2008 series were evaluated for quality jaggery production. Jaggery produced from varieties SL04 624, SL 06 93 and SL 06 224 had good sensory qualities compared to the standard variety Co 775. It was suggested to re-evaluate the yield and quality performance of these varieties in areas where sugarcane cultivated for cottage level jaggery production. Variety screening for jaggery production is being continued to identify the most superior varieties for quality jaggery production. Therefore, the present study is conducted to select suitable sugarcane varieties for jaggery production.

Objectives and targets

To identify better sugarcane varieties for jaggery production

Methods

All the varieties in the RYT stage of the each breeding series and near-commercial varieties will be tested for jaggery production. Cane yield, jaggery recovery at cane maturity will also be tested for each variety. Subsequently, all the varieties in SL 2010 and SL 2011 series at RYT will be tested for jaggery production. After harvesting, representative juice samples will be brought to the laboratory and will be analyzed for brix %, pol %, purity %, ash %, pH and reducing sugars %. Three replicates will be used for each parameter.

Jaggery will be prepared from each varieties in SL 2010 and SL 2011 series by adding lime solution to bring the pH of juice to 6.8. Okra juice will be added as a clarificant during preparation, and scum will be removed while boiling juice. Jaggery will be prepared on moulds and the freshly-prepared jaggery samples will be randomly selected and analyzed for physiochemical and microbiological properties. Samples will be analyzed for physiochemical properties, such as ash%, color, moisture%, pH, pol% and reducing sugars and non-reducing sugars.

Moisture content will be estimated by a 5 g of sample kept in an oven for 3 hours at 105$\pm$5 ^{0}C. The moisture content will be calculated by using weight differences of dry and fresh sample as a percentage of fresh weight. The ash percentage will be determined by placing the weighed fresh jaggery sample in muffle furnace at 550 ^{0}C for 30 min and weighing the ash content. The color intensity will be measured by spectrophotometer at 540 nm. The reducing sugar and non-reducing sugar percentages will be determined according to the method described in Sri Lanka Standards 521:1981, specification for jaggery. For microbiological analysis, yeast and mould will be counted using potato dextrose media. Each jaggery sample will be replicated thrice for the analysis. Sensory evaluation will be carried out by non-trained sensory panel for freshly-prepared jaggery considering color, flavor, texture, overall acceptability and willingness to purchase. Ranks will be given on the basis of the overall acceptability.

Jaggery samples will be stored in polythene packages and will be analyzed for the same quality parameters in one-month intervals to assess the keeping quality. The varieties will be recommended for production of high-quality jaggery considering all parameters and storage time period.

Location: SRI, Uda Walawe

Officers responsible
Team Leader: Ms. S.M.T.A. Maralanda (ROIC-Processing Technology)
Total estimated cost (Rs): 2 Mn
Funding agency: SRI
Duration: January - December 2023

Action plan for 2023

Activity / Month	J	F	M	A	M	J	J	A	S	O	N	D
Testing of varieties for jaggery production and for quality												
Sensory evaluation of the produced jaggery												
Analysis for physiochemical properties of jaggery												

Benefits to the industry

Increasing jaggery production and incomes of the jaggery millers.

ii Development of sugarcane-based value-added products

Introduction

Some farmers in Badulla and Moneragala districts grow sugarcane and produce jaggery and syrup as a cottage industry. As primitive processing techniques are used for producing jaggery and syrup, the yield and the quality standards of the products are extremely poor. Thus, the value of the products is low and resulted in low profitability. Therefore, production of high-quality jaggery with different forms, flavors, and packing the products with different methods to increase shelf life, etc. could be possible approaches to capture attractive and assured market for jaggery and increase income of the millers. Production of sugarcane-based fruit-flavored juice drinks is another aspect that needs to be investigated to diversify the cottage industry.

Production of sugarcane juice beverage was carried out and it was identified that addition of Ascorbic acid up to 200 ppm concentration improves the shelf-life of the sugarcane juice without adversely affecting the consumer acceptability. Storage of sugarcane juice under refrigerated temperature, together with 200 ppm ascorbic acid increases the shelf-life of the product up to two months. The results revealed that formulation of sugarcane pineapple and lime-blend mixed juice beverage satisfies the consumer taste and preferences. Further improvements are required to extend the shelf life of the sugarcane juice beverage and studying of the sugarcane juice preservation methods are required to improve quality jiggery production.

Sugar production from sugarcane generates many by-products which could be further processed for different value-added products to diversify in industry.

Objectives and targets

i. To develop processes to produce jaggery with different flavors
ii. To produce jaggery with different forms
iii. To enhance the shelf- life of jaggery by using different packaging methods
iv. To produce sugarcane-based fruit-flavored juice drinks jelly, and develop techniques for its preservation.
v. To develop sugarcane based value added product

I. Development of processes to produce jaggery with different flavors

The juice extracted from fresh sugarcane will be filtered and boiled in wide, shallow iron pans with continuous stirring. At the same time, lime solution will be added to juice in required quantity to adjust pH at 6.8. Okra mucilage will be added to the pans as a clarificant. While boiling, brownish foams come to the top will be removed to purify and get golden yellow color of jaggery.

Then different medicinal extracts like *Hathawariya*, *WelPenala*, *Gotukola* and various kinds of nuts (cashew) and flavoring essence (Vanilla, Rose) will be added to the pans to produce jaggery with different tastes and nutritive values.

Sensory evaluation will be carried out by non–trained sensory panel for different flavored jaggery considering flavor, texture, odor, color, overall acceptability and willingness to purchase. Jaggery samples will be analyzed for physiochemical properties such as color, moisture and microbial properties. Samples will be stored in polythene packages to analyze the keeping quality.

II. Production of jaggery with different forms

Solid jaggery: The juice extracted from fresh sugarcane will be filtered and boiled in wide, shallow iron pans with continuous stirring. At the same time, lime solution will be added to juice in required quantity to bring the pH of juice to 6.8. Okra juice will be added to the pans as a clarificant. While boiling, brownish foams come at the top which are continuously removed to get golden yellow color of jaggery. The juice will be boiled and concentrated and solidified in moulds to make jaggery in desired shapes and sizes.

Liquid jaggery: The concentrated sugarcane syrup will be removed from boiling pan in three different temperatures before it reaches striking point temperature. Different ratio of citric acid will be added to avoid crystallization and to make liquid jaggery attractive in color. Potassium metabisulphite or Benzoic acid will be added to improve shelf life of liquid jaggery. The liquid jiggery prepared will be allowed to settle for a period of 8-10 days at ambient conditions and packaged in sterilized bottles after filtration. The chemical composition and the shelf-life of typical liquid jaggery will be examined.

III. Enhancing the shelf life of jaggery by using different packaging method

Jaggery samples will be packed in different packaging materials and stored for a period of five months during which the changes in product parameters such as moisture content, sucrose, reducing sugar and color will be determined at an interval of 30 days.

IV. Development of sugarcane-based fruit-flavored juice drinks and techniques for their preservation

A sugarcane juice-based fruit-flavoured drink was prepared in 2016 by adding different ratios of pineapple juice, lemon juice and sodium metabisulphite as a preservative. The keeping quality of the juice drink prepared was found to be good in ambient temperature and also under refrigerated condition at 4 ^{0}C. Therefore, further studies for the enhancement of shelf life of the sugarcane juice-based fruit-flavoured drink will be conducted by subjecting UV treatment, CO_2 bubbling and adding different preservatives available in the market to constrain growth of bacteria, yeast and mould.

V. Development of sugarcane bagasse-incorporated health foods by extrusion

The sugarcane bagasse will be collected from the jaggery manufacturing plant at the Sugarcane Research Institute and will be dried at 60℃ for 5 hours. The dried bagasse will be ground and sieved to obtain uniform particle-sized powder. This bagasse powder will be incorporate to produce snack and breakfast cereal foods. The product quality parameters, such as expansion due to fibre incorporation and nutritional composition will be investigated. Moreover, the health beneficial bioactivities; antioxidant and anti-diabetic activities of the extruded food products will be determined and compared with the control (without sugarcane bagasse).

VI. Identify a sugarcane waste-based medium as a substitute for mushroom cultivation

Study the feasibility of using sugarcane bagasse (SGB) for the cultivation of *Pleurotus ostreatus* (oyster mushrooms).

Location: SRI, Uda Walawe

Officers Responsible
Team Leader: Ms. S.M.T.A. Maralanda (ROIC-Processing Technology)
Total estimated cost (Rs.): 3.5 Mn
Funding agency: SRI
Duration: 2018-2023

Action plan for 2023

Months / Activities	J	F	M	A	M	J	J	A	S	O	N	D
Development of processes to produce jaggery with different flavours												
Production of jaggery with different forms												
Enhancing the shelf life of jaggery by using different packaging method												
Develop the sugarcane-based fruit-flavoured juice drinks and shelf life												
Sugarcane jaggery production												

Benefits to the industry

The findings of this research will be benefit for cottage-level sugarcane product diversification in Sri Lanka.

iii. Study the effect of organic cultivation on quality sugarcane jaggery production

Introduction

Jaggery is an important natural sweetener widely used in confectionaries, culinary preparations and ayurvedic medicines. Jaggery has got nutritive as well as medicinal values unlike white sugar and is much sweeter than white sugar, by virtue of its higher content of reducing sugars. Jaggery, popularly known as *gur,* is a golden-yellow to dark brown, coarse in texture, wholesome, traditionally used and unrefined sugar, obtained by concentrating sugarcane juice.

In Sri Lanka, Sugarcane cultivated in commercial sugar project areas in Sevanagala, Pelwatte and Hingurana are used to produce sugar. In addition, some farmers grow sugarcane outside the designated sugar project areas in distant localities in Badulla and Moneragala district and produce jaggery and syrup as a cottage industry. Generally, sugarcane varieties have been cultivated inorganically and used a large amount of inorganic fertilizer. Sugarcane crop responds well to the inorganic fertilizer in terms of yield. But it adversely affected the biodiversity of micro and macro fauna of the soil. Therefore, organic cultivation of sugarcane is very much important to improve the soil health and ecosystems. Jaggery made from

organically grown sugarcane is gaining more value in the market. No further research has been done on sugarcane jaggery produced from organic sugarcane cultivation in Sri Lanka.. Therefore, the project will be focused to study the jaggery recovery, yield and juice quality parameters of the selected sugarcane varieties under organic cultivation practices. The experiment will be conducted by using pre-selected sugarcane varieties under organic cultivation practices in two locations in Sri Lanka.

Objectives and targets

i. Evaluate promising sugarcane varieties for quality organic jaggery production in different location in Sri Lanka
ii. Identify the effect of the organic fertilizer for quality jaggery production

Methods

Field experiment

Field experiments will be established at SRI, Uda Walawe, and Badulla with the sugarcane varieties of Co 775, SL 04 624, SL 06 224, SL 88 116, SL 06 93, Gal Uk and Alu Uk under irrigation. The varieties will be laid out in a randomized complete block design with three replicates and the plots size 7 m long 5 cane rows spaced 1.37 m apart for organic conditions.

Sugarcane seedcane obtained from mother plant nursery, which will be established with hot water treated seed cane (54 °C hot water for 30 minutes), will be used in the experiment. All agronomic practices including irrigation, fertilization, weeding and plant protection measures will be conducted under organic conditions and inorganic conditions separately when necessary.

Initially soil samples will be collected from all the experimental plots before and after planting at 90,180 and 300 days. Collected soil samples will be analyzed for available N, P and K. Then germination at 35 DAP, shoot population at 90 DAP and stalk number, stalk weight and plot yields at harvest will be recorded. After harvesting, representative juice samples will be brought to laboratory and will be analyzed for brix %, pol %, and purity %. Three replicates will be used for each parameter. Jaggery recovery based on the cane weight and the jaggery recovery based on the juice weight will be tested for each variety.

Estimation of jaggery recovery

Each sugarcane variety will be harvested separately and transported to the jaggery production unit. Fresh weight of the sugarcane samples, amount of sugarcane juice extracted from the crushed sugarcane samples and weight of the bagasse of each variety will be measured.

Jaggery will be prepared from each recommended sugarcane variety by adding lime solution to bring the pH of juice to 6.8. Okra juice will be added as a clarificant during preparation and scum will be removed while boiling juice. Jaggery will be prepared on moulds and measured the total weight of the jaggery produced from each variety. Jaggery recovery of the each variety will be calculate by using following formula,

$$\text{Jaggery recovery of the sample} = \frac{Total\ jaggery\ weight}{initial\ sugarcane\ weight} \times 100\%$$

The freshly prepared jaggery samples from each varieties will be randomly selected and analyzed for physiochemical properties, such as color and moisture%.

Determination of moisture content

Moisture content of the prepared jaggery will be estimated by a 5g of sample kept in an oven for 3 hours at 105 ± 5^0C. The Moisture content will be calculated by using weight differences of dry and fresh sample as a percentage of fresh weight. Each jaggery sample replicated thrice will be used for this analysis.

Calculation

Moisture percent by mass $= 100 \frac{(m-m1)}{m}$

Where

m = mass, in grams, of the prepared sample taken for the test

m_1 = mass in grams, of the material after drying

Determination of ash content

The oven dried materials (moisture determination) will be heated with the hot plate for about one hour. The ignition will be completed by keeping the material in a muffle furnace at a temperature not exceeding 550 °C. The sample containing crucibles will be cooled in desiccators and weight of each will be measured .drying, cooling and weighing procedure were repeated until the difference of mass between two successive measures does not exceed 1 mg. The final weight will be recorded.

Calculation

m= mass, in grams, of the prepared sample taken for the test

m_2 =mass, in grams, of the ash

Total ash percentage by mass= $\frac{100 * m_2}{m_1}$

Determination of reducing sugar

Reducing sugar of jaggery producing from each variety will be measured according to the Sri Lanka standard specification for jaggery (SLS 521-1981).

Determination of color

Color intensity of the prepared jaggery will be measured by using chromometer.

Sensory evaluation of sugarcane jaggery

Sensory evaluation will be carried out by non-trained sensory panel for freshly-prepared jaggery considering color, flavor, texture, overall acceptability and willingness to purchase. The sensory panel consists of 30 untrained panellists. Ranking will be given on the basis of the overall acceptability.

Determination of pest incidence

Incidences of stalk and shoot borers, sugarcane spider mite and sugarcane woolly aphid (SWA) in each plot will be done according to the following schedule Table PT1.

Table PT1: Crop ages for observations of pest incidence

Pest	Observation
Shoot borer	At 2nd and 4th month
Woolly aphid	From 90 DAP/R
Internode borer	At 9th month
Termite	From 30 DAP/R up to time of harvesting
Mite	From 30 DAP/R up to time of harvesting

Pest incidence will be calculated as,

Percentage incidence of SB = $\frac{\text{No. of SB damage s/ dead hearts}}{\text{Total no. of plants observed}} \times 100$

Percentage intensity of stalk borers = $\frac{\text{No.of damaged internodes by stalk borers}}{\text{Total no. of internodes inspected}} \times 100$

Percentage incidence of Mite/ Termite Woolly aphid = $\frac{\text{No. of infested plants}}{\text{Total no. of plants observed}} \times 100$

Determination of disease incidence

Disease data will be taken with one month interval after planting the trial.

Statistical analysis

Significance of the varietal differences for jaggery recovery and moisture percentage will be tested by analysis of variance using PROC ANOVA procedure of the SAS software package (Version 9.1) and significant means will be identified using Dunnet's Mean Separation procedure at 5% probability level.

Location: SRI, Uda Walawe

Officers responsible
Team Leader: Ms. S.M.T.A. Maralanda (RO- Processing Technology)
Other Officers: Ms. M.G.G.N. Sewwandi (RO- Processing Technology)
Ms. B.D.S.K. Ariyawansha (SRO-Economics Biometry & IT)
Dr. K.M.G. Chanchala (RO-Crop Protection)
Total estimated cost (Rs): 1 Mn
Funding agency: SRI
Duration: 2021-2025

Action plan for 2023

Month / Activities	J	F	M	A	M	J	J	A	S	O	N	D
1 Evaluate promising sugarcane varieties for quality organic jaggery production												
2 Data collection and analysis												

Benefits to the industry

The findings of this research will be benefit for improving knowledge and skills in the production of organic jaggery and syrup.

PT/02/2022 - Rectification of milling standards for improvement of processing efficiencies in local sugar factories

i. Determining optimum conditions for efficient juice clarification process at sugar factories

Introduction

Clarification process in the sugar manufacturing process affects the juice filterability, sucrose crystallization and the quality and yield of raw sugar produced. The main purpose of sugar cane juice clarification is to produce clarified juice (CJ) with the lowest concentration of insoluble and soluble impurities. Screening of juice eradicates only the coarse particles since flocculation is necessary to remove the fine and colloidal particles. Therefore flocculation technique is used in clarification process to provide clarified Juice.

In the conventional method of defecation process of juice clarification, mixed juice is heated from ~35-55 °C to ~76 ^{0}C and treated with milk of lime or lime saccharate to raise the pH from ~5.2 to 7.5–7.8. Lime react with inorganic phosphate present in the cane juice to form calcium phosphate floc. These macro-flocs have a higher density relative to juice and settle by gravity. The settled flocculated mud impurities are extracted from the clarifier to recover trapped sucrose. In order to recover the trapped sucrose, rotating vacuum filters are used. The filtrate is recirculated and combined with mixed juice.

In sugarcane, the natural phosphates are occurring in inorganic (soluble) and organic (insoluble) phosphates. Only the soluble phosphate will react with the lime to form a Calcium Phosphate precipitate. Since presence of phosphates in cane juice is essential for good clarification process, phosphate should be added externally before liming if natural P_2O_5 content (about 200 mg/l) low in mixed juice.

During the defecation process, a wide range of chemical and physical reactions takes place in the juice. The main chemical reactions include: Precipitation of amorphous calcium phosphate, proteins denaturation (and other organics, such as pectins, gums and waxes), inversion of sucrose due to the combined action of pH and temperature, degradation of reducing sugars to organic acids due to high pH and temperature, precipitation of organic and inorganic acid salts, hydrolysis of starch by the natural amylase in the juice and formation of color bodies due to the polymerization (either enzymatically or thermally) of flavonoids and phenolic compounds.

The poor quality of clarified juice contributes to scaling of the evaporators and pans, and also increases the probability of sucrose loss to molasses. Clarification also have an impact on crystal morphology, color, crystal content, and polysaccharide and ash contents of raw sugar. Juice clarification has a great impact on factory evaporators' heat transfer coefficients particularly if scaling occurs from the excessive addition of lime. Therefore, it is important to optimize main operating parameters such as pH, temperature, type & dosage of flocculent to minimize impact to the subsequent process and overcome existing problems associated with the juice clarification process in local sugar factories.

Objectives and targets

i. To select the suitable form of liming mixture. (MOL or Lime saccharate)
   - Solubility of lime in juice increase with its sugar content.
ii. To select the best pH value or range for pre-liming
iii. To select the optimum Baume value of MOL
iv. To select the most suitable clarification scheme.
v. Selection of optimum temperature values for juice heating.

Methods

i. Selection of suitable form of liming mixture

Clarification experiments will be carried out using M.O.L. and saccharate solutions made up with the same CaO alkalinity in order to eliminate any differences in hydroxyl ion concentration. For MOL, powdered, hydrate lime (Ca(OH)2) (91.07 g) will be added to deionized water (1 L) and mixed well. The pH of the MOL solution will be measured at room temperature. For SACCH, a composite CJ from the factory will be collected and powdered; hydrated lime (91.07 g) will be added to the composite CJ (1 L) and mixed well. The pH of the SACCH at room temperature will be measured.

2 L of Mixed juice will be extracted from the sugar mill and four samples will be prepared by measuring 400 ml of mixed juice in to conical flask separately. Then each sample will be treated with M.O.L. or saccarate solutions according to following ways (Table PT2).

Table PT2: Juice samples treating with different form of liming for clarification

Sample	Primary heating	Form of liming	Secondary heating	Flocculant dosing
Sample 1	75-80 ^{0}C	With M.O.L (pH 7.5-7.8)	101-105 ^{0}C	With flocculant
Sample 2	75-80 ^{0}C	With M.O.L (pH 7.5-7.8)	101-105 ^{0}C	Without flocculant
Sample 3	75-80 ^{0}C	With lime saccarate (pH 7.5-7.8)	101-105 ^{0}C	With flocculant
Sample 4	75-80 ^{0}C	With lime saccarate (pH 7.5-7.8)	101-105 ^{0}C	Without flocculant

Each sample should be allowed to settle at least 2 hours after the treatments are finished. Following parameters should be measured before and after the sample preparation.

- Settling rate of mud particles

The settling rate of the flocculated mud particles will be determined by measuring the level of the mud interface at 0.5, 1.0, 2.0 and 3.0 minutes. The initial settling rate will be obtained from a graphical analysis of the data**.**

- Final mud level
- Turbidity

Turbidity of the CJ absorbance (A) will be measured at 900 nm in 1 cm glass cells against distilled water.

- ICUMSA colour
- CaO content
- Brix, Pol, Purity,pH
- Reducing Sugar

ii. Selection of best pH value or range for pre-liming

Preparation of Milk of Lime

Pre liming of mixed juice samples with different pH values will be carried out using Milk of Lime (MOL) solution. The concentration of milk of lime is measured in degree Baume' (°Be'). For juice clarification in sugar factories milk of lime is prepared at a concentration of 6 to 10 °Be'. In this study Milk of Lime solution will be prepared with 10 °Be'. For MOL, powdered, hydrate lime (Ca(OH)2) (37.6 g) was added to preheated (60 °C) deionized water (400 ml) and mixed well.

Treatment of juice sample

6 L of Mixed juice will be extracted from the sugar mill and initial readings of Brix, Pol, Purity, reducing sugar, turbidity, TSS and TDS of mixed juice will be taken. After that six samples will be prepared by measuring 1 L of mixed juice in to conical flask separately. Then each of samples will be treated with prepared Milk of Lime to reach different pH levels according to the following table PT3 and required quantity of MOL volume will be recorded for each sample.

Table PT3: Juice samples treating with different pH liming for clarification

Sample 1 (T1)	Sample 2 (T2)	Sample 3 (T3)	Sample 4 (T4)	Sample 5 (T5)	Sample 6 (T6)
7.0 pH	7.2 pH	7.4 pH	7.6 pH	7.8 pH	8.0 pH

Then each sample should be heated up to 101^0C (little above the boiling point). After that juice samples will be taken and placed in to separate graduated cylinders of 1000 ml capacity for settling at least 2 and half hours. From the graduated cylinders, clear juice samples will be taken and analyzed for Brix, Pol, Purity, reducing sugar, calcium oxide, TSS, TDS, mud volume and turbidity.

iii. Selection of optimum Baume value of MOL solution.

Table PT4: Prepare the lime solution with different baume value

Baume	Density in kg/m3	g CaO per liter	g CaO per 100 g	g water per g CaO
1	1007	7.5	0.74	133
2	1014	16.5	1.64	60
3	1021	26	2.54	38
5	1036	46	4.43	21.6
7	1051	65	6.18	15.6
10	1074	94	8.74	10.4
15	1117	148	13.26	6.5
20	1160	206	17.72	4.6

4 L of Mixed juice will be extracted from the sugar mill and several samples will be prepared by measuring 400 ml of mixed juice in to conical flask separately. Then each sample will be treated with M.O.L. with different baume values (Table PT4). After each sample should be allowed to settle at least 2 hours after the treatments are finished. Following parameters should be measured before and after the sample preparation.

- Required MOL volume to achieve final ph.
- Settling rate of mud particles

The settling rate of the flocculated mud particles will be determined by measuring the level of the mud interface at 0.5, 1.0, 2.0 and 3.0 minutes. The initial settling rate will be obtained from a graphical analysis of the data.

- Final mud level
- Turbidity

Turbidity of the CJ absorbance (A) will be measured at 900 nm in 1 cm glass cells against distilled water.

- ICUMSA colour
- CaO content
- Brix, Pol, Purity, pH
- Reducing Sugar

iv. Selection of suitable clarification scheme.

4 L of Mixed juice will be extracted from the sugar mill and eight samples will be prepared by measuring 400 ml of mixed juice in to conical flask separately. Then each sample will be treated with M.O.L. or saccarate solutions with different manner of lime and heat is used according to following ways (Table PT5).

Table PT5: Juice samples treating with different methods for clarification

Sample	Treatment method	Procedure
Sample 1	Cold Liming with M.O.L	Juice (36^0C), M.O.L to 7.8 pH, heat to 101^0C, add flocculants and clarify.
Sample 2	Cold Liming with Lime Saccharate	Juice (36^0C), Lime Saccharate to 7.8 pH, heat to 101^0C, add flocculants and clarify.
Sample 3	Hot Liming with M.O.L	Juice (36^0C), heat to 76^0C, M.O.L to 7.8 pH, heat to 101^0C, add flocculants and clarify.
Sample 4	Hot Liming with Lime Saccharate	Juice (36^0C), heat to 76^0C, Lime Saccharateto 7.8 pH, heat to 101^0C, add flocculants and clarify.
Sample 5	Fractional Liming with M.O.L	Juice (36^0C), M.O.L to 6.3 pH, heat to 101^0C, M.O.L to 7.8 pH, add flocculants and clarify.

Sample 6	Fractional Liming with Lime Saccharate	Juice (36^0C), Lime Saccharate to 6.3 pH, heat to 101^0C, M.O.L to 7.8 pH, add flocculants and clarify.
Sample 7	Fractional Liming & Double Heating with M.O.L	Juice (36^0C), M.O.L to 6.3 pH, heat to 76^0C, M.O.L to 7.8 pH, heat to 101^0C add flocculants and clarify.
Sample 8	Fractional Liming & Double Heating with Lime Saccharate	Juice (36^0C), Lime Saccharate to 6.3 pH, heat to 76^0C, M.O.L to 7.8 pH, heat to 101^0C add flocculants and clarify

Each sample should be allowed to settle at least 2 hours after the treatments are finished. Following parameters should be measured before and after the sample preparation

- Settling rate of mud particles

The settling rate of the flocculated mud particles will be determined by measuring the level of the mud interface at 0.5, 1.0, 2.0 and 3.0 minutes. The initial settling rate will be obtained from a graphical analysis of the data.

- Final mud level
- Turbidity

Turbidity of the CJ absorbance (A) will be measured at 900 nm in 1 cm glass cells against distilled water.

- ICUMSA colour
- CaO content
- Brix, Pol, Purity,pH
- Reducing Sugar

v. Selection of optimum temperature for juice heating

4 L of Mixed juice will be extracted from the sugar mill and eight samples will be prepared by measuring 400 ml of mixed juice in to conical flask separately. Each sample should be treated with MOL to reach sample pH value to 7.5 and measure the required quantity of MOL for each sample. Then each of samples should be heated up to different temperature according to following way (Table PT6).

Table PT6: Juice samples treating with different temperature for clarification

Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Room temperature	40 ^{0}C	50 ^{0}C	60 ^{0}C	70 ^{0}C	80 ^{0}C	90 ^{0}C	100^{0}C

Finally same quantity of flocculants should be added for each sample. Each sample should be allowed to settle at least 2 hours after the treatments are finished. Following parameters should be measured before and after the sample preparation.

- Settling rate of mud particles

The settling rate of the flocculated mud particles will be determined by measuring the level of the mud interface at 0.5, 1.0, 2.0 and 3.0 minutes. The initial settling rate will be obtained from a graphical analysis of the data.

- Final mud level
- Turbidity

Turbidity of the CJ absorbance (A) will be measured at 900 nm in 1 cm glass cells against distilled water.

- ICUMSA colour
- CaO content
- Brix, Pol, Purity, pH
- Reducing Sugar

All of above mentioned researches are ongoing based on the variety.

Location: SRI, Uda Walawe

Officers responsible
Team Leader: Ms. M.G.G.N. Sewwandi (RO-Processing Technology)
Other Officer: Ms. B.D.S.K. Ariyawansha (SRO-Economics Biometry & IT)
Total estimated cost (Rs): 2 Mn
Funding Agency: SRI
Duration: January - December 2023

Action plan for 2023

Activity \ Month	J	F	M	A	M	J	J	A	S	O	N	D
1. Selection of optimum temperature for juice heating												
2. Selection of suitable clarification scheme												
3. Data computerizing and analysis												

Benefits to the industry

The findings of this research will be benefit to minimize sucrose inversion and other existing problems associated with the clarification process and subsequent process in local sugar factories.

ii. Post-harvest deterioration of sugarcane and controlling methods

Introduction

The cane harvesting and supply management is a huge barrier in maintaining quality of cane and obtaining high sugar recovery in Sri Lanka. Studies have indicated that nearly 20-30% of total sucrose synthesized by sugarcane plant is lost during various stages of raw material handling and sugar mill processing. The post-harvest sugar loss is one of the most alarming problems of sugar industry and has attracted widespread attention in the recent years. However,

not much harm is caused if cane is crushed within 24 hours of harvesting. Staling beyond 24 hours results in considerable loss in cane weight due to moisture loss and reduction in juice sucrose content due to inversion. In majority of sugar factories, this time lag ranges between 3 to 10 days leads to huge losses in recoverable sugar (sucrose) due to degradation of harvested cane.

One of the biggest challenges for the sugar industry is to supply the harvested cane to the mill as quickly as possible to minimize the loss of sucrose content in the juice and also to avoid the degradation with microbes. Basically the harvesting is carried out by manually. However, some of the sugar factories have introduced sugarcane harvesters in their fields. Whereas in Sri Lanka, there is a shortage of labor for harvesting cane. But the contradiction is harvesting, bundling and cane loading require lot of labors based on the increase of sugarcane cultivation area. Thereby as the practical scenario, there is a significant time lag between harvesting and milling.

Post-harvest deterioration directly affected to the sugar factories, because sucrose is converted to the invert sugar substances. Not only millers, but also post-harvest deterioration is directly affected to the growers due to reduction of cane weight (Hussnain *et al.,* 2018). As well as, due to post harvest deterioration several difficulties are indirectly affected during the subsequences process of the sugar manufacturing process. Some problems are associated with the dextran which is formed due to post harvest deterioration. Due to increase of dextran concentrations, lower crystallization rates, poor purging in the centrifugal and poor quality of final products can be happened (RAVNÖ and PURCHASE, 2005).

Therefore, this study will be conducted to examine harvesting and supply management system in Sri Lanka to identify the factors affected to increase the time lag between harvesting to crushing and the possibility of few controlling methods to control the post-harvest deterioration.

Objectives and targets

i. To find out drawbacks of harvesting and supply management system in Sri Lankan sugar industry.
ii. To analyze different techniques and their practical applicability to minimize the post-harvest losses.

Methods

i. Surveying harvesting and supply management system

Randomly selected sugarcane farmer fields will be evaluated from the date of commencement of sugarcane harvest to the date of completion. Essential data (Field No., Variety, Date of commencement of harvest, Date of completion of harvest, Number of workers employed to harvest, Time taken to fill a tractor load) will be collected by inspecting famer fields for every days throughout the time of harvesting is carried out. Collected data will be used to identify the factors affected to the post-harvest time lag from harvesting to crushing. This survey will be carried out throughout the year to get better understand the factors variation at different time of the year.

ii. Post-harvest sugarcane quality under manual (whole cane) and mechanical (billet) harvesting

Sample collection

SL 96 128 is locally adopted commercial sugarcane variety in Sri Lanka. Canes of uniform size of SL 96 128 will be harvested manually (whole cane) and mechanically (billets) at SRI Uda Walawe farm. Mechanically and manually harvested cane lots will be stored separately in open environment. Ten replications from each lots consisting of 12 canes per replication will be brought to the laboratory immediately after harvesting for fresh analysis (0 day) and the rest of the canes will be stored at natural conditions. The deterioration of cane quality assessment will be performed at six storage treatments under natural conditions from 0 day, 1 day, 2 days, 3 days, 4 days and 7 days.

Sample analysis methods

Samples will be weighed each day for determining the changes in cane weight for two different harvesting methods. Cane weight will be recorded for each sample immediately after the harvest and before the crushing at each interval. The weight variations will be converted into percent changes. Loss of cane weight % will be calculated using initial and final weights in following formula:

Loss of cane weight % = [(initial weight - final weight)/initial weight] × 100

Number of 10 cane bundles as 10 replicates with 12 cane stalks from each storage treatment used above will be sent to the SRI laboratory at the interval of 0 day, 1 day, 2 days, 3 days, 4 days and 7 days for analysis. Extracted juice from clean power operated vertical crusher will be filtered and used for the analysis of main juice quality parameters.

Main juice quality parameters included, percentage of Brix will be measured from the separated juice using digital brix meter. It is represented percentage of total soluble solids in given juice sample. Pol % juice (apparent sucrose) will be measured from the same juice by using Polarimeter and Purity will be calculated as Pol/Brix×100. Reducing sugars will be measured from cane juice using Lane & Eynon (original) method (Varma, 1998). Brix%, Pol%, POCS%, Purity% and reducing sugar% will be calculated for each storage treatment and the values will be presented as average of ten replications.

Statistical analysis

Data will be analyzed using analysis of variance (ANOVA). The Duncan's Mean separation procedure will be used to compare the different storage treatment and harvesting methods.

iii. Post-harvest sugarcane quality under open and closed storage conditions

Sample collection

Freshly harvested sugarcane (variety SL 96 128) will be collected from SRI Farm, Uda Walawe. Collected sugarcane will be divided into two lots and stored for 10 days under different storage methods i.e. one lot will be kept open while other lot will be covered with sugarcane trash. The samples of sugarcane will be taken at an interval of 24 hours to assess the quality parameters.

Sample analysis methods

Samples will be weighed each day for determining the changes in cane weight for two different storage methods. Cane weight will be recorded for each sample immediately after the harvest and before the crushing at each interval. The weight variations will be later converted into percent changes. Loss of cane weight % will be calculated initial and final weights using following formula:

Loss of cane weight % = [(initial weight - final weight)/initial weight] × 100

Number of 10 cane bundles as 10 replicates with 12 cane stalks from each storage treatment used above will be sent to the SRI laboratory at the interval of 0 day, 1 day, 2 days, 3 days, 4 days and 7 days for analysis. Extracted juice from clean power operated vertical crusher will be filtered and used for the analysis of main juice quality parameters.

Main juice quality parameters included, percentage of Brix will be measured from the separated juice using digital brix meter. It is represented percentage of total soluble solids in given juice sample. Pol % juice (apparent sucrose) will be measured from the same juice by using Polarimeter and Purity will be calculated as Pol/Brix×100. Reducing sugars will be measured from cane juice using Lane & Eynon (original) method (Varma, 1998). Brix%, Pol%, POCS%, Purity% and reducing sugar% will be calculated for each storage treatment and the values will be presented as average of ten replications.

Statistical analysis

Data will be analyzed using analysis of variance (ANOVA). The Duncan's Mean separation procedure will be used to compare the different storage treatment and harvesting methods.

iv. post-harvest deterioration with immature, matured and over matured cane
Sample collection

Freshly harvested sugarcane (SL 96 128 variety) will be collected from SRI Farm, Udawalawe. Collected canes will be divided into two lots according to the matured conditions i.e. one lot will be selected as matured canes while other lot will be selected as immature canes. Ten replications from each lots consisting of 12 canes per replication will be brought to the laboratory immediately after harvesting for fresh analysis (0 day) and the rest of the canes will be stored at natural conditions. The deterioration of cane quality assessment will be performed at six storage treatments under natural conditions from 0 day, 1 day, 2 days, 3 days, 4 days and 7 days.

Sample analysis methods

Samples will be weighted each day for determining the changes in cane weight for every treatments. Cane weight will be recorded for each sample immediately after the harvest and before the crushing at each interval. The weight variations will be later converted into percent changes. Loss of cane weight % will be calculated by using both initial weight and final weight by using following formula:

Loss of cane weight % = [(initial weight - final weight)/initial weight] X 100

Number of 10 cane bundles as 10 replicates with 12 cane stalks from each storage treatment used above will be sent to the SRI laboratory at the interval of 0 day, 1 day, 2 days, 3 days, 4

days and 7 days for analysis. Extracted juice from clean power operated vertical crusher will be filtered and used for the analysis of main juice quality parameters.

Main juice quality parameters included, percentage of Brix will be measured from the separated juice using digital brix meter. It is represented percentage of total soluble solids in given juice sample. Pol % juice (apparent sucrose) will be measured from the same juice by using Polarimeter and Purity will be calculated as Pol/Brix×100. Reducing sugars will be measured from cane juice using Lane & Eynon (original) method (Varma, 1998). Brix%, Pol%, POCS%, Purity% and reducing sugar% will be calculated for each storage treatment and the values will be presented as average of ten replications.

Statistical analysis

Data will be analyzed using analysis of variance (ANOVA). The Duncan's Mean separation procedure will be used to compare the different storage treatment and harvesting methods.

Location: SRI, Uda Walawe

Officers responsible
Team Leader: Ms. M.G.G.N. Sewwandi (RO-Processing Technology)
Other Officer: Ms. B.D.S.K. Ariyawansha (SRO-Economics Biometry & IT)
Total estimated cost (Rs): 1 Mn
Funding agency: SRI
Duration: 2022-2024

Action plan for 2023

Month **Activity**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Surveying harvesting and supply management system												
Analysing post-harvest deterioration with mechanical harvesting												
Analysing post-harvest deterioration with open and closed stored												
Analysing post-harvest deterioration with immature, matured and over matured cane												
Analysing different techniques for the controlling post-harvest deterioration												

Benefits to the industry

The findings of controlling methods for the post-harvest deterioration will be benefit for farmers to enhance their revenue and sugar factories to improve their recovery.

PT/03/2022 Isolation of plant growth promoting microorganisms from diverse environment for bio-fertilizer formulation

Introduction

Sugarcane plants require large amount of plant nutrients such as nitrogen (N), phosphorous (P), and potassium (K) and as well as other micro nutrients. Microorganisms associated with sugarcane play a vital role in maintaining soil fertility and plant health. As inorganic fertilizers are expensive, and they have the potential to become environmental pollutents, incorporation of beneficial microorganisms to the soil is very important in sugarcane sector for sustainable crop production.

Microorganisms that are commonly used as bio-fertilizers including nitrogen-fixing soil bacteria, phosphate-solubilizing bacteria, potassium solubilizing bacteria and cyanobacteria. These microorganisms are involve to improved nutrient uptake, plant growth and plant tolerance to abiotic and biotic stress and also there are several naturally occurring soil microbes that inhibited the growth of plant pathogens and improve the plants' growth by disease suppression (Singh, 2014). Therefore use of beneficial microorganism as bio-fertilizers is being considered as a better alternative for inorganic fertilizer.

Nitrogen (N_2) is an essential element for the support of all forms of life. N_2 is the most abundant gas in the atmosphere; it is extremely unusable by most living organisms. All organisms use the ammonia (NH_3) form of nitrogen to manufacture amino acids, proteins, nucleic acids, and other nitrogen-containing components necessary for life. Biological nitrogen fixation (BNF) process changes inert N_2 to useful NH_3. It is carried out only by prokaryotes, which may be symbiotic or free-living in nature. It is well documented that biological nitrogen fixation mediated by nitrogenase enzymes is a process important to the biological activity of soil. The nitrogen provided by the BNF is less subjected to leaching and denitrification .Biological nitrogen fixation is required to improve the sustainable crop production by decreasing the use of inorganic fertilizer.

Nitrogenase activity in soil depends on ecological conditions in association with the specific nitrogen fixation capabilities of certain microorganisms and plant genotypes under various climatic conditions. However, the degree of nitrogenase activity is plant specific. The nitrogen fixing activity of free-living, non-photosynthetic aerobic bacteria is strongly dependent on favorable moisture conditions; oxygen concentration and a supply of organic C substrates. Nitrogen-fixing organisms are generally active in plant root zone soil. Plants that are capable of releasing exudates exhibit higher nitrogen fixation activity in soil (Shridhar, 2012).

In the free-living system, plants gain benefit when the bacteria die and release nitrogen to the environment, or when the bacteria are loosely associated with the roots of plants. In legumes and a few other plants, the bacteria live in small club-like growths on the roots called nodules. Within these nodules, N_2 fixation occurs, and the NH_3 produced is directly absorbed by the plant. N-Fixing bacteria such as *Azotobacter, Azospirillum*, *Rhizobium*, Meso *Rhizobium* and Sino *Rhizobium* are well known for their ability to improve plant development. Many of these bacteria can produce and excrete one or more hormone types to their cultures.

Agriculturally important grasses such as sugarcane (*Saccharum* sp.), rice (*Oryza sativa)*, wheat (*Triticum aestivum*), sorghum (*Sorghum bicolor*), maize (*Zea mays*), and *Panicum maximum* contain numerous diasotrophic bacteria, such as, *Azospirillum* spp, *Azotobactor, Enterobacter spp* as biological nitrogen fixers. (James and Oliverous, 1998)

The second most important element in plant nutrient is Phosphorous, which participates in root branching and contributes to plant vitality and disease resistance. (Rodrigues, 2016).However, a greater part of soil phosphorus, approximately 95–99% is present in the form of insoluble phosphates, and hence cannot be utilized by the plants. Phosphate-solubilizing microorganisms (PSMs) play an important role in supplementing phosphorus to the plants, allowing a sustainable use of phosphate fertilizers.

In Sri Lanka, sugarcane has been cultivated as a commercial crop and further expansion is being carried out to fulfil the domestic sugar requirement. Sugarcane crop responds well to the inorganic fertilizer in terms of their yield. But the cost of inorganic fertilizers consumed in large quantities by the crop is increasing rapidly. Thus, there is a vast potential to reduce sugarcane production cost by reducing application of organic fertilizers. This could be achieved by the application of beneficial microorganisms to the soil and reduce production costs. Several other countries in the world where sugarcane is grown utilize these plant growth promoting bacteria to produce bio-fertilizers. In principle, bio-fertilizers are less expensive and are more environmentally safe than inorganic fertilizers.

Therefore present study is focused to isolating and identification of plant growth promoting microorganisms and application to the sugarcane cultivation field as a substitute of inorganic fertilizer.

Objectives and targets

i. To isolate plant growth promotive microorganisms associated with sugarcane and other grasses.
ii. To evaluate nitrogen-fixing potentials and phosphate solubilizing potential of the isolated microorganisms.
iii. To investigate the possibility of utilizing these microorganisms to supply plant growth promotive factors for sugarcane plant growth.

Methods

Sample collection: Collection of soil, fresh root and leaf samples of healthy sugarcane plants and other grasses from diverse environment.

Isolation and Purification of nitrogen fixing microorganisms:

The rhizosphere soil and roots samples will be collected from the sugarcane cultivating area at different locations in Sri Lanka. Approximately, 10g of soil sample will be taken into the 250 ml conical flask with 90 ml sterilized water and glass bids will be added to the flask. The sample will be mixed thoroughly with the water and mixture will be shaking on a shaker for 200 rpm at 30 °C. 1 ml suspension will be taken in a test tube contained with 9 ml sterile water for the isolation.
For root sample, 1g of healthy roots will be weighed, washed with distilled water to remove adhering soil particles and again washed with 3% H_2O_2 for 3 minutes for surface sterilization. Then the roots will be washed 6-7 times with sterile water. The roots will be finely ground with the pestle and motor with 99 ml sterile water and the mixture will be vortex 2 to 3 minutes. (Alam *et al*., 2016)

Serial dilution (up to 10 dilutes) followed by spread plate method will be carried out to isolate - microorganisms. The plates of isolates will be incubated at 28°C. The following different culture media will be used for isolation of different species of nitrogen- fixing and phosphate

solubilizing microorganisms (Root nodule bacteria *(rhizobia), Azospirillum* spp*, Azotobactor, Herbaspirillum* spp).

- Root nodule bacteria *(rhizobia)* **-** YMA (Yeast- Mannitol Agar) medium containing Congo red.10g mannitol; K_2 HPO_4- 0.5 g; NaCl-0.1g;$MgSO_4.7H_2O$-0.2 g:yeast extract-1g;congo red1%-2.5ml;agar 20g
- Azotobacter Medium (Azotobacter spp)- Distilled water1000ml, Mannitol-20g,Glucose-20g,K_2 HPO_4- 0.2 g, $MgSO_4.7H_2O$-0.1 g, $CaCO_3$ -5g, Agar -20g, NaCl-0.2g, K_2SO_4-0.1g
- Clostridium Medium - Distilled water1000ml, sucrose-0.01g, K_2 HPO_4- 0.5g, $MgSO_4.7H_2O$ -0.5 g, NaCl-0.0015g , $FeSO_4$-0.01g Agar agar-15g, P^H-5.4
- Azospirillum Medium- Distilled water1000ml, K_2 HPO_4- 6g, $KHPO_4$-4g,MgSO4- 0.2 g, NaCl-0.1g, KOH-40g ,yeast extract -0.1g ,Agar agar-20g,sucrose-5g,$CaCl_2$-0.02g,NH_4Cal -1g,NaOH-5g, MnSO4-2.1mg,$FeCl_3$-10mg, Na_2MoO_4.0.2mg ,H_3BO_3-2mg, $Cu(NO_3)_2$-0.04mg $ZnSO_4$-0.2mg,bromothymol blue5 %-2ml,P^H-6.5
- Jensen's medium will be used to isolate *Herbaspirillumspp(*Distilled water1000ml, sucrose-20g, K_2 HPO_4- 1g, $MgSO_4.7H_2O$ -0.5 g, NaCl-0.5g , $FeSO_4$-0.01g , Na_2MoO_4-0.005g ,Agar agar-15g, P^H-7.5
- The Picovaskaya's (PVK) (glucose – 10 g, Ca3(PO4)2 – 5 g, $(NH_4)_2SO_4$ – 0.5 g, KCl – 0.2 g, MgSO4 –0.1 g, MnSO4 – traces, FeSO4 – traces, Yeast Extract – 0.5 g, Agar – 15 g, Distilled water – 1 L, pH – 7.0) media will be used to isolate phosphate-solubalising bacteria

Morphological characterization

Isolated microorganisms will be characterized by using cell gram stain and colony (shape, color, margin, nature of colony and texture) test.

Bio chemical characterization

Determination of biochemical properties will be conducted by using different biochemical tests such as nitrate reductase, citrate utilization, methyl red, VP, catalase (cover-slip method), and oxidation test.

Screening of nitrogen-fixing bacteria

The efficiency of N_2 fixation of the isolated bacteria will be identified in semi-solid Nfb medium containing 0.05% of malate as carbon source. Malate 5 g, K_2HPO_4 0.5 g, $MgSO_4.7H_2O$ 0.2 g, NaCl 0.1 g, $CaCl_2$ x $7H_2O$ 1.0 g, $FeSO_4.7H_2O$ 0.1 g, Bromothymol blue 0.5%, 0.2 M KOH 2 ml, Vitamin solution 1 ml, and Micronutrient solution 2 ml, for 1 l of distilled water. pH will be adjusted to 6.5. After inoculation, the isolated bacteria will be incubated at 28^0C up to 24h. The isolated bacteria that produce blue colored zone will be marked as nitrogen fixers in the solid culture conditions. The coloring zone will be calculated by deducting the colony diameter from the coloring zone diameter.

Evaluation of N-fixing capabilities of isolates:

Acetylene Reduction Assay (RAR) method and ^{15}N dilution method will be used to evaluate the N-fixing ability of isolated microorganisms. Acetylene reduction assay and colorimetric estimation of indole acetic acid production. The nitrogenase activity of the isolates will be carried out by acetylene reduction assay. The 10 fold serial dilutions of the suspension will be used to inoculate N-free semisolid LGIM media in triplicate (Estrada *et al*., 2002). 1%

acetylene gas will be injected. After 96 h of incubation, vials will be assayed for acetylene reduction activity (Mascarua-Esparza *et al.* 1988). Nitrogenase positive isolates will be selected. (Alam *et al.,* 2016).

Screening of phosphate-solubilizing bacteria

Phosphate solubilization is indicated by the formation of a solubilization or a clear zone around the bacterial colonies. Single bacterial colonies having clear solubilization zones will be isolated separately on to fresh Pikovskaya's agar plates and incubated at 30±5 ºC for 10 days. The zone of solubilization around the colony growth will be measured. The solubilization efficiency (E) of these isolates will be calculated according to the relationship developed by Nguyen *et al*., (1992).

$$\text{Solubilization efficiency (E)} = \frac{\text{Solubilization diameter(S)}}{\text{Growth diameter (G)}} \times 100$$

The solubilization index will be determined according to Premono *et al.* (1996).

$$\text{Phosphate Solubilization Index} = \frac{\text{Total diameter (colony + halo zone)}}{\text{Diameter of colony}}$$

According to Phosphorus-solubilizing efficiency and index, the most efficient bacteria for bio-fertilizer preparation will be selected.

Screening the isolated microorganisms for their growth promoting activities

Ammonia production ability

All isolated microorganisms will be tested for the production of ammonia in peptone water. Freshly grown microbial cultures will be inoculated in 10 ml peptone watering each tube and incubated for 48–72 h at 21 °C. Nessler's reagent (0.5 ml) will be added in each tube. Development of brown to yellow colour will be test for ammonia production (Cappuccino and Sherman, 1992).

Assay for indole acetic acid (IAA) production

Isolated microorganisms will be cultured in their respective media at 28±2 °C and fully grown cultures were centrifuged at 3000 rpm for 30 min. The supernatant (2 ml) will be mixed with two drops of orthophosphoric acid and 4 ml of the Salkowski reagent (50 ml, 35% of perchloric acid, 1 ml 0.5 M $FeCl_3$ solution). Development of pink colour indicates IAA production. Optical density will be measured at 530 nm with the help of spectrophotometer Spectronic 20 D+. Concentration of IAA produced by cultures will be measured with the help of standard graph of IAA (Hi-media) obtained in the range of 10–100 µg/ml.

Identification of hydrogen cyanide (HCN) production

Hydrogen cyanide production will be measured by using the method described at Bakker and Schippers, (1987). King's B medium containing per liter of distilled water: 10 g proteose peptone, 10 ml glycerol, 1.5 g K_2HPO_4, 1.5 g $MgSO_4$, 20 g agar, pH 7.2 will be prepared and King's B medium plates will be amended with 0.4% of L-Glycine will be used for the purpose. The isolates will be streaked on the media plates and Whatman No. 1 filter paper strips soaked in a 0.5% picric acid+2% Na_2CO_3 solution were placed on the lids and tighly wrapped with a

parafilm and incubated. A change in the colour of the filter paper will be checked and noted from brown to dark reddish brown

Siderophore production

Isolated microorganisms will be assayed for siderophores production on the Chrome azurol S agar medium (Schwyn and Neilands, 1987). Chrome azurol S agar plates will be prepared and divided into equal sectors and spot inoculated with test organism (10 ml of 10^6 CFU/ml) and incubated at 28±21 °C for 48–72 h. Development of yellow–orange halo around the growth was considered as positive for siderophore production.

Antifungal activity

All isolated microorganism will be evaluated for their in vitro antifungal activity by dual culture assays on NA + potato dextrose agar (1:1) plate against the plant pathogens, *Ustilago scitaminea* and *Ceratocystis paradoxa* according to Singh *et al.* (2014).

Molecular identification of microbes

Molecular identification of all isolated strains will be carried out based on the 16S rRNA sequence analysis.

Production of bio-fertilizer

The suitable carrier medium containing sugar factory and distillery waste will be selected and sterilized. Inoculants will be prepared by using selected microorganism with high N--fixing ability. Bio-fertilizer will be prepared by mixing carrier media and inoculants.

Evaluation of bio-fertilizer

Effectiveness of the produced bio-fertilizer will be assessed by conducting a pot experiment followed by a field experiment.

Location: SRI, Uda Walawe

Officers responsible
Team Leader: Ms. S.M.T.A. Maralanda (RO-Processing Technology)
Total estimated cost (Rs): 0.6 Million
Funding agency: SRI
Duration: 2021-2025

Action plan for 2023

Activity / Month	J	F	M	A	M	J	J	A	S	O	N	D
1. Isolation of plant growth promoting micro organisms												
2. Characterization of the isolated microorganisms												

Benefit to the industry

This project will produce plant growth promoting microorganism containing bio-fertilizer which could be used to increase the sugarcane yield.

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Future direction and road map of each priority area of the division

Project Name	Activities conduct under each project
Development of sugarcane based value added product	• Improving quality of jaggery • Evaluate promising varieties for sugarcane jaggery production • Study the post-harvest delay effect for the quality jaggery production • Sugarcane based product development • Shelf life enhancement of sugarcane jaggery through different packaging materials • Studying the sugarcane juice preservation methods
Remedies for improvement of processing efficiencies of local sugar industries	• Determining optimum conditions for efficient juice clarification process at local sugar factories. • Quantification of variety vise post-harvest cane quality losses with mini-mill test and large-mill test. • Sustainable waste management in local sugar industries.

Mechanization Technology Division

The Mechanisation Technology (MT) Division will continue the following two research projects and two services projects in 2023:

Research

i. MT/01/22: Operational evaluation and energy efficiency improvement of Hot Water Treatment (HWT) plant operates at different sugar industries and SRI
ii. MT/02/22: Application of system approach concept to the Appropriate Mechanization, Energy Optimization and Smart Agriculture (AMEOSA) for improving the productivity of Sugarcane farming

Services

i. MT/RS/01/19.: Construction and maintenance of protected fences for sugarcane
ii. MT/RS/02/19.: Repair and maintenance of vehicles, tractors, and farm implements

Details of each project are given below:

MT/01/22: Operational evaluation and energy efficiency improvement of hot water treatment (HWT) plant operates in different sugar industries and SRI

Introduction

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 loss in yield and quality of sugarcane. SRI recommends hot water treatment of seedcane at 54 °C for 50 minutes to eliminate the pathogens of above-mentioned diseases. In this treatment, the temperature-time combination used is critical for the successful elimination of the pathogens of the diseases. The treatment plants available in sugar companies are not performing well to meet the above-mentioned standards and sometimes are not efficient enough to meet their seedcane requirement for new planting. This causes for planting fields with untreated or improperly-treated seedcane. Also, for the new sugar projects, HWT plants have to be designed and constructed according to their requirements.

Arrangements have been made to modify/ establish the seed treatment plants in the existing sugar project areas, namely, Sevanagala, Pelwatte, and Gal Oya and the new sugar project in Ethimale. The HWT plant available at SRI and that is being constructed at Kantale will also be modified to allow provisions for cold-soak treatment.

MT Division of the institute has designed semi-automatic HWT 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.

Objectives and targets

Design construction and/or modifications of hot-water treatment plants to maintain the recommended temperature for the required duration to eliminate the major sugarcane disease-causing pathogens.

Methods

The following activities will be carried out for the HWT plants of SRI Uda Walawe and Kantale and those in sugar companies:

- Energy efficiency improvement of the HWT plant
- Development of the HWT plant
- Evaluation of the HWT plants in four sugar industries and Kantale sub-station of SRI based on their request
- Development of an IoT platform for monitoring the temperature distribution of HWT plant

Location: Uda Walawe, Kantale, Sevanagala, Pelwatte, Hingurana and Ethimale

Officers responsible
Team Leader: Mr. K.H.D. Abeyrathna (RO-Mechanization Technology)
Other Officers: Dr. K.T. Ariyawansha (RO-Mechanization Technology)
Mr. K.A.D. Kodituwakku (RO-Economics Biometry & IT)
Mr. M.K.P.C. Gunawardhana (DO-Kantale)
Mr. U.W.L.M. Kumarasiri (RO-Crop Nutrition)

Collaborating organization/s: Lanka Sugar Company (Pvt) Ltd. Sevanagala and Pelwatte.
Gal Oya Plantation (Pvt) Ltd. Hingurana
Ethimale Plantation (Pvt) Ltd. Ethimale
Total estimated cost (Rs): 3,004,455.00
Funding agency: SRI
Duration: January - December 2023

Action plan for 2023

Activity \ Month	J	F	M	A	M	J	J	A	S	O	N	D
Energy efficiency improvement of HWT plant												
Suitability testing of combined steam generator for mobile HWT plant												
Evaluation of the HWT plants in sugar industries based on their request												
Develop certification procedure for HWT plant												
Annual inspection and start certification of HWT plant located in all industries												
Day-to-day maintenance of HWT plant at Kantale and Udawalawe												
Development of an IoT platform for monitoring the temperature distribution of HWT plant												

Benefits to the industry

Control of sett-borne sugarcane diseases through proper hot-water treatment and hence contributing to increase sugarcane yield.

MT/02/22: Application of system approach concept to the appropriate mechanization, energy optimization and smart agriculture (AMEOSA) for improving the productivity of sugarcane farming

Introduction

Supply of the sugarcane at the correct time with minimum cost to the sugar factories is the most essential component in the sugar sector for its continuous operation with maximum productivity. Thus, there should be a well-planned system that cultivates sugarcane timely with using minimizing inputs, maximizing output while maximizing growers' income. Therefore, the sugarcane cultivation system is a complicated system, and significant changes to that system can create problems for its stability. Also, the protection of the environment and human health is the most significant factor when maximizing sugarcane output. Sugarcane cultivation is a very harassed practice for humans; thus, the availability of labor is reducing day by day, and demand for labor is increasing rapidly. Mechanization is the way of simplifying the farming practices by minimizing labor use and the time need to complete the task. However, all the machine available in all around the world is not suitable for the Sri Lankan conditions due to many different factors, such as land layout, land size, cost, and varying environmental conditions, etc. Therefore, appropriate mechanization is the way of proper use of suitable machinery in relevant practice. Further use of machines needs energy, however, the cost for energy is increasing gradually because most of the agricultural machinery is powered using fossil fuel-derived fuels such as diesel, gasoline, etc. The burning of those fossil fuels creates harmful gases that create environmental problems.

Therefore, optimization of energy use is another great advantage to minimize cost and environmental damage. Hence, the system approach concept is an essential framework for the proper use of suitable machines in a more energy-efficient way. To use the farm machines appropriately with optimum energy use line up with other agricultural practices to gain maximum sugarcane yield, minimize resource use and cost, all most all the data in real-time is essential to record and analyze to take the correct decision at the correct time. Internet of thing (IoT) is a way of getting real-time data (using a sensor system or as input from a human), analyze those data instantly, and storing those data in relevant places with the connected network through the internet.

Also use of unmanned aerial vehicles (UAV) or drones is another way of getting real-time special data and analyze those data accurately with the help of sophisticated software. The data collected through IoT systems and UAVs can be analyzed to make the proper decision without or partial involvement of humans using well-established algorithms or using Artificial Intelligence (AI) combine with robotics or automated machines. With help of IoT, UAVs, AI connect with machines or robots help to optimize resource use for smartly getting maximum output. The application of technologies such as IoT, UAVs, AI with sophisticated machines or robots is called smart farming. Applications of the Smart farming concept by sugarcane growers will have enormous potential to maximize their profit while supplying maximum sugarcane to the factories with minimum cost while improving growers' and workers' wellbeing with minimum damage to the environment.

At present in Sri Lanka, sugarcane growers do not have a well-established system for practice either appropriate mechanization, Energy optimization, and Smart agriculture. Therefore, there is an urgent need to study the present system carefully industry-wise with help of stakeholders. Then after studying the system, we can propose a system approach concept for implementing appropriate mechanization with energy optimization for establishing a smart farming (AMEOSA) system in Sri Lanka. Formerly we trust that with help of the AMEOSA system approach, there is a possibility to produce quality sugarcane at low cost while maximizing framer profit in a timely. Therefore, objectives of this project are presented as follows:

Objectives and targets

- To identify the system diversity of each industry system in Sri Lanka from planting to factory gate
- To develop /introduce appropriate machinery/ implements for sugarcane cultivation in each system
- To optimize energy use for mechanization
- To collect real-time data with help of IoT and spatial data with help of UAVs
- To introduce system dynamic integrated into the IoT system for continually monitoring the system

Methods

To achieve the above-mentioned objectives, we created short-term and long-term activity plans. In the short term, we will introduce or develop urgent machinery needs while observing the existing conditions. In the long term, we divert the current system to a new system that is appropriate for each industry. In 2023, following activities will be done:

- Testing evaluation and improvement of the fertilizer applicator for applying pellets and inorganic fertilizer in real field conditions (SRI - FX 402)
- Testing evaluation and improvement of the trash-cutting machine (SRI- TMX 401) in real-field conditions
- Development of implements for Inter-cultivation suitable for mini tractors
- Design of combined planter for minimizing energy use in sugarcane planting
- Design of IoT platform for machinery management
- Collecting spatial data using UAV and analyzing it

Locations: Uda Walawe, Sevanagala, Pelwatte, Hingurana, Ethimale and Kantale

Officers responsible

Team Leader:	Dr. K.T. Ariyawansha (RO-Mechanization Technology)
Other Officers:	Mr. K.H.D. Abeyrathna (RO-Mechanization Technology)
	Mr. K.A.D. Kodituwakku (RO-Economics Biometry & IT)
	Mr. L.M.J.R. Wijewardhana (RO-Crop & Resource Management)
	Mr. D.P.W. Pottawela (Technology Transfer Officer)
	Mr. U.W.L.M. Kumarasiri (RO-Crop Nutrition)
Sugar industries:	Lanka Sugar Company (Pvt) Ltd. Sevanagala and Pelwatte.
	Gal Oya Plantation (Pvt) Ltd. Hingurana
	Ethimale Plantation (Pvt) Ltd. Ethimale

Collaborating persons/ organization/s:

- Professor Noguchi Ryozo, Laboratory of Agricultural System Engineering, Graduate School of Agriculture, Kyoto University, Japan
- Associate Professor Tofael Ahamed, Laboratory of Bioproduction and Machinery, Graduate School of Life and Environmental Sciences, University of Tsukuba, Japan
- Mr. Rajitha Athukorala, Geoinformatics Center - Asian Institute of Technology, Thailand
- Professor G.Y Jayasinghe, Ms. C.P. Rupasinhe, Anushka Chaturanga Bandara, Department of Agricultural Engineering, Faculty of Agriculture, University of Ruhuna, Sri Lanka.
- Dr. G.V.T.V Weerasooriya, Mr. P.D. Kahandage, Department of Agricultural Engineering & Soil Science, Faculty of Agriculture, Rajarata University of Sri Lanka
- Agri machinery division, Diesel & Motor Engineering PLC (DIMO)
- ACECAM (Pvt) Limited

Total estimated cost (Rs): 5,683,832.00
Funding agency: SRI
Duration: January - December 2023

Action plan for 2023

Activity \ Month	J	F	M	A	M	J	J	A	S	O	N	D
Testing and improvement of the mechanism of trash cutting machine (SRI - TMX 401)												
Field evaluation & demonstration of SRI - TMX 401												
Testing fertilizer applicator for applying organic fertilizer pellets (SRI - FX 401)												
Improvement of fertilizer applicator for applying inorganic fertilizers (SRI - FX 402)												
Modification of available inter-cultivators for mini tractors												
Testing & evaluations of modified inter-cultivators												
Preliminary studies for combined planter												
Design of combined planter for minimizing energy use in sugarcane planting												
Design of IoT platform for machinery management												
Collecting spatial data using UAV and analyzing it												

Benefits to the industry

AMEOSA system approach, produce quality sugarcane timely at low cost while maximizing framer and industry profit with minimizing environmental damage.

Economics, Biometry and Information Technology Division

Following three research projects and the two research related services projects will be continued by the Economics, Biometry and Information Technology (EBIT) Division of sugarcane Research Institute (SRI) in the year 2023.

Research

i. EBIT/01/2023: Economic assessment of new sugarcane technologies
ii. EBIT/02/2023: Economic assessment of sugarcane cultivation and sugar production in Sri Lanka for the year 2021
iii. EBIT/ 03/2023 Development of appropriate protocol for detection of smut reaction of the sugarcane varieties

Research-related services

i. EBIT/04/2023: Maintaining and updating SRI web site
ii. EBIT/05/2023: providing services to the other divisions of SRI

Details of the research projects are given below:

EBIT/01/2023 Economic assessment of new sugarcane technologies

Introduction

It is necessary to evaluate economic viability of new technologies, such as sugarcane varieties, crop management practices, machinery and sugarcane-based products before releasing them for commercial adoption.

Objectives and targets

To assess costs and returns of new sugarcane technologies introduced by the SRI.
To make recommendations to improve the economic viability of the technology

Methods

Analysis of economic viability of these new technologies will be undertaken in collaboration with the research staff of the relevant divisions based on the data collected by them. Price and other information required for the analysis will be obtained from relevant sources. Economic viability will be assessed in terms of net return to the grower and /or processor.

Location: Sugarcane Research Institute, Uda Walawe
Duration: January to December 2023

Action plan for 2023

Activities \ Months	J	F	M	A	M	J	J	A	S	O	N	D
Data analysis and report writing												

Benefits to the industry

This enables to introduce technologies that are economically viable.

EBIT/02/2023 Economic assessment of sugarcane cultivation and sugar production in Sri Lanka for year 2022

Introduction

The costs and returns of sugarcane and sugar production vary due to the change of input and output prices. Therefore, it is important to update costs and returns of sugarcane cultivation and sugar production for the year 2022 to obtain information for various purposes viz. research planning, taking policy and management decisions, and for scholarly activities. The economics of sugarcane and sugar production at Sevanagala, Pelwatte and Hingurana mill-areas will be updated using the prices and production for the year 2022/23.

Objective and targets

To update costs and returns of sugarcane cultivation and sugar production for the year 2022.

Methods

Input, output and price data relevant to the cropping year 2022/23 will be collected from Sevanagala, Pelwatte and Gal Oya Sugar Industries. The costs and returns of sugarcane cultivation and sugar production for the year 2022 will be updated using the collected information.

Location: Hingurana, Pelwatte and Sevanagala

Officers responsible

Team Leader:	Mr. K.A.D. Kodithuwakku (SRO-EBIT)
Other Officers:	Ms. B.D.S.K. Ariyawansha (SRO-EBIT)
Collaborating organisation/s:	Hingurana, Pelwatte and Sevanagala
Duration:	January to December 2023

Action plan for 2023

Months / Activities	J	F	M	A	M	J	J	A	S	O	N	D
Data collection												
Data Analysis& report writing												

Benefits to the industry

The results could be used for planning sugar sector development.

EBIT/03/2023 Development of appropriate protocol for detection of smut reaction of the sugarcane varieties

Introduction

In this research program it is expected to develop a new set of standard varieties for sugarcane smut disease and make suitable modifications for the smut screening trials through past data analysis, studying methods practiced in other countries and by conducting field trials.

Objectives and targets

To make suitable modifications to improve the accuracy of the varietal screening trials for Smut disease

Specific objectives

1. To evaluate consistency of the disease ratings and reaction to climate related epidemiological factors of the standard varieties.
2. To identify new set of standard varieties for smut screening trials.
3. To identify optimum plot size for smut screening trials.
4. To identify appropriate method (stool, stalk) and stage (age, plant crop vs. plant +ratoon) of data collection.
5. To develop a new method of statistical analysis for smut screening trials.

Methods

Literature on the disease screening trials conducted in other sugarcane growing countries will be collected and suitable modifications will also be identified. By analysis of past data of the disease screening trials gaps and possible improvements will be proposed.

Evaluation of consistency of the disease ratings and reaction to climate related epidemiological factors of the standard varieties

Rainfall, temperature, and relative humidity are considered as important factors in smut epidemiology. Monthly data on disease incidences of standard varieties were regressed against monthly averages of rainfall, temperature and humidity values to study the response of standard varieties to epidemiological factors. Consistencies of the disease ratings of the standard varieties were studied using yearly time series data on the smut trials conducted at Uda Walawe.

Identification of new set of standard varieties for smut screening trials

The currently-used standard varieties for both diseases along with imported and local varieties of the germplasm with different resistance levels will be field established at two months intervals (6 standard variety identification trials). Disease incidence counting will be done in 1 month intervals according to the sequence of field establishment. After summarizing the disease levels of each variety, a set of standard varieties with known resistance levels will be identified based on the consistency of their disease reaction. Moreover, in addition to the plant crop, disease reactions will be evaluated in two ratoon crops.

Identification of optimum plot size for smut trials

Presently 1m length plot size has being used for smut trials at SRI, while other countries use length plot sizes between 1m to 10 m. Therefore, plot size for the smut screening trials will be determined after analyzing data of the optimum plot size trial conducted in 2016 and standard variety identification trials to be established under this project.

Identification of appropriate method (stool, stalk) and stage (age, plant crop vs. plant + ratoon) of data collection.

Data will be collected from stool and stalk basis from plant and ratoon stages at monthly intervals from the trials to be conducted to identify new set of standard varieties. After

analyzing the disease incidence data of the plant crop and ratoon crops of the standard variety identification trials appropriate data collection method and stage of data collection will be determined based on representativeness and cost involved.

Introducing a new method of statistical analysis for smut screening trials.

Past data on disease screening trials and the data obtained from standard variety identification trials will be used for introducing a new method of statistical analysis. Analysis of performance of standard varieties using presently practiced method (linear regression) and using linear mixed model with logit transformed disease score (proposed method). Linear mixed model analyze variety as fixed effect and replicate (trial) and variety* trial as random effects. Standard varieties separated into groups based on proposed method using full historical data set. Compare results (assigned ratings) of proposed method and presently practiced method. Test varieties are placed in to groups based on two methods and compare proportion of test varieties selected by each method.

Location: Sugarcane Research Institute, Uda Walawe

Officers responsible
Team Leader: Ms. B.D.S.K. Ariyawansha (SRO-EBIT)
Other Officers: Ms. A.N.W.S. Thushari (RO-CP)
Duration: January 2019 December 2023

Action plan for 2023

Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year 2023												
Data collection, analysis and report writing												

Benefits to the industry

Achieving higher production levels by growing smut disease resistant varieties.

Services

EBIT/04/2023 Maintenance and updating of SRI web site

The web site consists of basic information of SRI and need to update it regularly to include current information about SRI and Sugar industries of Sri Lanka.

Objectives and targets

i. To provide on- line access to the information of SRI to interested uses and parties
ii. Enhance the user interface of the designed web site of SRI
iii. Include updated information of SRI such as research findings, sugar statistics, etc. for interested people.

Methods

Relevant information will be collected from respective divisions and updated information will be published in SRI web page.

Location: Sugarcane Research Institute, Uda Walawe

Officers responsible
Team Leader: Mr. K.A.D. Kodithuwakku (SRO-EBIT)
Other Officers: Ms. B.D.S.K. Ariyawansha (SRO-EBIT)
Duration: January to December 2023

Action plan for 2023

Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Updating website												

Benefits to the industry

Provide necessary information to the stake holders of the sugar industry and general public.

EBIT/05/23 Provide services to the other divisions of SRI and the outside institutions

Objectives and targets

i. To assist other divisions in planning and designing of experiments and field surveys.
ii. To assist other divisions in computer and IT related activities
iii. Prepare INFORM budget and data base of Sugarcane Research Institute for year 2022 to be included in the national database maintained and updated by the CARP.
iv. Analysis and interpretation of data received from other divisions.
v. Provide computer related vocational training to the students

Methods

Depends on the experiments and the requirements of the other divisions.

Location: SRI, Uda Walawe

Officers responsible
Team Leader: Mr. K.A.D. Kodithuwakku (SRO-EBIT)
Other Officers: Ms. B.D.S.K. Ariyawansha (SRO-EBIT)
Duration: January to December 2023

Action plan for 2023

Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Providing data analytical services												

Benefits to the industry

Provide reliable and statistically validated research out puts and develop IT related facilities of the institute

Technology Transfer and Development Division

The following six projects will be undertaken by Technology Transfer and Development (TTD) Division during the year 2023:

1. Promotion of technologies on sugarcane cultivation, processing, and by-products utilization - TTD/01/23
2. Development of Cottage-Level Sugar Industry Project: -TTD/02/23
3. SRI Sub-Station at Kantale – TTD/03/23
4. Sugarcane nursery development (Sevanagala, Pelwatte, Ethimale, and Hingurana) – TTD/04/23
5. Information and Promotion Centre (Colombo) – TTD/05/23
6. Requested program by the stakeholders, and other programs - TTD/06/23

TTD/01/23: Promotion of technologies on sugarcane cultivation, processing, and by-products utilization

Introduction

SRI has been conducting number of training/awareness/demonstration program on technologies of sugarcane cultivation and processing assuming the continuous updating the knowledge, skills, and changing attitudes on the same would definitely help to raise the level of adoption by the end users. Accordingly, the TTD division has planned to conduct various extension/training activities especially on increasing the diversity of sugarcane varieties in the commercial plantations, improved crop management practices including intercropping with sugarcane**,** small-scale farm machinery, management/control of pests and diseases, improvement soil and plant nutrition, sugarcane mechanization, processing and by-products utilization, and entrepreneurship development of the farmers and officers of sugar companies etc. It is expected to conduct extension/training programs on the above aspects for farmers/officers of each and every sugar companies in the year 2023.

Objectives

i. To increase the level of adoption of improved crop management practices including intercropping with sugarcane**,** small-scale farm machinery, management/control of pests and diseases, improvement soil and plant nutrition, sugarcane mechanization, processing and by-products utilization and entrepreneurship development among farmers and sugar companies.
ii. To improve the sugarcane farming as a business venture through the development of entrepreneurship skills of farmers and field officers.

Methods/Activities

The following activities will be carried out:

i. Conducting farmer/officer extension/training programs on improved crop management practices including intercropping with sugarcane**,** small-scale farm machinery, management/control of pests and diseases, improvement soil and plant nutrition, sugarcane mechanization, processing and by-products utilization and entrepreneurship development among farmers and sugar companies.
ii. Production of extension/teaching materials
    a. Updating/reprinting of advisory pamphlets/information sheets, i.e.
        i. Management of Sugarcane White Leaf Disease

ii. Weeds management in Sugarcane
iii. Organic sugarcane farming

iii. Establishment demonstration fields on intercropping with sugarcane at Sevanagala, Pelwatte, Siyambalanduwa, Ethimale, and Hingurana
iv. Conducting farmer/officer training program on development of entrepreneurship skills
v. Regular updating and maintenance of SRI e-educational platforms (SRI's web page, e-sms service of TTD, SRI Facebook page, YouTube channel of TTD) and SRI *Puwath Hasuna*

Officers responsible

Team Leader:	Mr. D.P.W. Pottawela (Technology Transfer Officer)
Other Officers:	Mr. A.P. Karunathilake (Development Officer)
	Mr. W.G.M.S. Weragoda (DO)
	Mr. A.N.M.B.R. Prabath (DO)
Total estimated cost (Rs):	4.96 Mn
Funding agency:	SRI
Duration:	January - December 2023

Action plan for 2023

Activity	J	F	M	A	M	J	J	A	S	O	N	D
i												
ii												
iii												
iv												
v												

TTD/02/23: Development of cottage-level sugar industry

Introduction

Cultivation and processing of sugarcane into jaggery/syrup has been one of the mainstays of the people in some of the areas in different parts of the country. However, production efficiencies/quality of their products is at sub-optimum level and need to be improved to capture an assured sustainable market.

SRI has planned and implemented a program for expansion of sugarcane cultivation and quality enhancement of jaggery and syrup production; with the aims at expanding sugarcane cultivation in different parts of the country by increasing knowledge and skills of the millers and facilitating make use of available resources to promote jaggery and syrup production. Even though the jaggery production was started at commercial level in newly-expanded areas, further expansion has to be curtailed with the discontinuation of sugarcane cultivation by most of farmers due to decreased market prize of jaggery, absence of institutional mechanism to support processing and marketing and high production cost as a commercial ventures, and the absence of proper political support for the programs. The education and giving initial supports will be done during the year 2023.

Objectives and targets

i. To increase extent of sugarcane lands for jaggery/syrup production
ii. To enhance knowledge and skills of jaggery/syrup producers on increasing quality of their products

iii. To facilitate rehabilitation/improvements of jaggery mills

Methods and activities

The following activities will be carried out during 2023

i. Providing the initial stock of seedcane to establish and multiply the cane required for a jaggery mill
ii. Assisting the cooperative societies to establish and maintain jaggery/syrup production units.
iii. Coordination/exploring of marketing mechanism and quality increase of farmers' products
iv. Educating the farmers on sugarcane cultivation and processing as a small-scale venture
v. Updating and reprinting of advisory pamphlet on Jaggery/syrup production

Action plan for 2023

Activity	J	F	M	A	M	J	J	A	S	O	N	D
i												
ii												
iii												
iv												
v												

Officers responsible
Team Leader: Mr. D.P.W. Pottawela (Technology Transfer Officer)
Other Officers: Mr. A.P. Karunathilake (DO)
Mr. W.G.M.S. Weragoda (DO)
Mr. A.N.M.B.R. Prabath (DO)
Total estimated cost (Rs): 1.08 Mn
Funding agency: SRI
Duration: January - December 2023

Note: The Ministry of Plantation (MoP) has initiated a program to develop cottage-level jaggery/syrup production in the different parts of the country. The MoP has proposed the treasury requesting fund for the program. If the proposal is accepted by the treasury, it will also be included in this project.

TTD/03/22: SRI sub-station at Kantale

Introduction

Kantale sub-station of the Institute was established and has been functioning for the purpose of assisting by especially for supply of seedcane for the re-opening of Kantale Sugar Factory. In addition, it was identified other such functions as establishing adaptability trials to find out suitable cane varieties for the area, establish other research trials, and providing other required infrastructures for the stakeholders. With further delay of re-opening the Kantale sugar factory, at present, production of seedcane for nursery development program, providing supporting services to the researches are being implemented at the sub-station. However, as per the instructions of Ministry of Plantation, the SRI has decided to continue the functions of Kantale sub-station of SRI.

Objectives and targets

i. To produce disease-free seedcane for the use of nursery development program of the division
ii. To provide assistance to the research trials (adaptability and other research)
iii. To produce seedcane requirement of Kantale sugar factory which is to be re-opened.
iv. To produce and sell the cane harvest to third party requests

Methods/Activities

i. Establishment and maintenance of 20 ha cane plantation. These will be used for the initial seedcane requirement of the Kantale sugar factory when it reopens.
ii. Filling seedcane requirements of the nursery development activities
iii. Maintenance of previously established nurseries
iv. Assisting research trials of the SRI's research divisions
v. Production and sell of cane to third parties

Officers responsible

Team Leader:	Mr. D.P.W. Pottawela (Technology Transfer Officer)
Other Officers:	Mr. M.K.P.C. Gunawardane (DO)
Total estimated cost (Rs):	8.80 Mn
Funding agency:	SRI
Duration:	January - December 2023

Action plan for 2023

Activity	J	F	M	A	M	J	J	A	S	O	N	D
i												
ii												
iii												
iv												
v												

TTD/04/23: Sugarcane nursery development (Sevanagala, Pelwatte, Ethimale, and Hingurana)

Introduction

The absence of proper nursery management system to supply healthy planting material has been the main reason for spreading sugarcane diseases, particularly sugarcane white leaf disease, continuously at an alarming rate throughout all sugar industries. It further hinders the management of varietal spectrum of the sugarcane plantations within targeted directions. So, as the initial step of a long-term program to rectify the said situation for assured disease-free sugarcane plantations, SRI and sugar industries will launch as a collaborative program to replace the existing disease-infected sugarcane nurseries and commercial plantations in Sevanagala, Pelwatte, Ethimale and Hingurana.

In addition, providing the information about sugarcane varieties, sugarcane farming practices and material required initially for developing nurseries/demonstration/ multiplication etc. have been providing the sugar companies/farmers by SRI and those activities will also be continued in 2023.

Objectives and targets

i. To popularize SRI recommended and newly released varieties
ii. To enhance the varietal spectrum in the commercial cane plantations.
iii. To assist the companies to establish healthy nurseries by providing initial stock of treated-seedcane of the SRI recommended varieties.
iv. To train farmers to increase their knowledge on the importance of establishment of nurseries and importance of enhancing varietal spectrum in the cane plantations.
v. Preparation/printing of information sheet on Nursery Management of sugarcane cultivation

Methods/activities

i. Providing am minimum amount of treated seedcane of new varieties to the industries.
ii. Conducting training sessions on nursery management for officers/farmers in each industry.
iii. Preparation/Printing of information sheet on nursery management of sugarcane cultivation

Officers responsible

Team Leader:	Mr. D.P.W. Pottawela (Technology Transfer Officer)
Other Officers:	Mr. A.P. Karunathilake (DO)
	Mr. W.G.M.S. Weragoda (DO)
	Mr. A.N.M.B.R. Prabath (DO)
Total estimated cost (Rs):	3.30 Mn
Funding agency:	SRI
Duration:	January - December 2023

Action plan for 2023

Activity	J	F	M	A	M	J	J	A	S	O	N	D
i												
ii												
iii												

TTD/05/23: Information and promotion centre (Colombo)

Introduction

A systematic arrangement for the dissemination/promotion of technologies, and new products developed by the institute among the stakeholders is timely needed. In addition, an ease access for catering technical and other information for the entrepreneurs who wish to enter the local sugar industry, students of higher educational institution, researchers, and other relevant parties is emphasized. With the view of these requirements, it is proposed to establish a centre called "Information and Promotion Centre" for the same at SRI's Colombo Office.

Objectives and targets

i. To disseminate/promote SRI developed technologies/products among the public
ii. To cater the information need of the researchers/entrepreneurs/students etc.
iii. To promote/market SRI developed products and the products of local producers
iv. To provide analytical (soil, leaf) services for the interested parties in collaboration with CN division

Method/Activities

The above objective will be achieved through the IP Centre, established at the Colombo Office of SRI. In addition, it is expected to produce some display materials for the centre. Note: It is required to recruit a new officer for the centre.

Officers responsible
Team Leader: Mr. D.P.W. Pottawela (Technology Transfer Officer)
Other Officers: Mr. A.P. Karunathilake (DO)
Mr. A.N.M.B.R. Prabath (DO)
Total estimated cost (Rs): 0.74 Mn
Funding agency: SRI
Duration: January - December 2023

Action plan for 2023

Activity	J	F	M	A	M	J	J	A	S	O	N	D
(i)												

TTD/06/23: Requested program by the stakeholders, and other programs

Introduction

Sugar companies, governmental and non-governmental organizations, and other stakeholders request some training on sugarcane cultivation and processing and to participate for exhibitions/other events from SRI from time to time. The division will arrange suitable programs on such requests. In addition, the division make arrangements the printing/publishing activities such as SRI Annual Reports, and other printing requirements of the institute

Methods/activities

i. Conducting training sessions, exhibitions and assisting industry development activities etc. at their request.
ii. Conducting field/famer visits
iii. Publishing SRI annual reports, Sugarcane Sri Lanka Journal, other printing requirements of the institute
iv. Attending District/divisional Coordination Committee meetings and District/Divisional Agricultural Coordination Committee meetings of Moneragala, Ampara, Trincomalee and Badulla districts.

Officers responsible
Team Leader: Mr. D.P.W. Pottawela (Technology Transfer Officer)
Other Officers: Mr. A.P. Karunathilake (DO)

Mr. W.G.M.S. Weragoda (DO)
Mr. A.N.M.B.R. Prabath (DO)
Mr. M.P.C. Gunawardane (DO)

Total estimated cost (Rs): 2.55 Mn
Funding agency: SRI
Duration: January - December 2023

Action plan for 2023

Activity	J	F	M	A	M	J	J	A	S	O	N	D
(i)												
(ii)												
(iii)												
(iv)												