

International Society of
Sugar Cane Technologists

100

1924–2024

Centennial Volume

History and Development
—
Research Advances and Impact

Edited by
L. Jean Claude Autrey, A. Salem Saumtally,
Raul O. Castillo Torres and Peter G. Allsopp

The First 100 Years of the International Society of Sugar Cane Technologists

1924-2024

Editors:

L. Jean Claude Autrey

A. Salem Saumtally

Raúl O. Castillo Torres

Peter G. Allsopp

International Society of Sugar Cane Technologists

August 2025

Copyright the Authors 2025. All rights reserved.

The authors and editors each assert their moral rights, including the right to be identified as the author or editor.

Published by:
International Society of Sugar Cane Technologists
Jean Espitalier Noël Building
MSIRI Complex
Moka Road
Réduit 80835
Mauritius
Email: issct@intnet.mu

ISBN 978-99993-0-273-9

The views expressed in this publication are those of the author(s) and do not necessarily represent those of, and should not be attributed to, the International Society of Sugar Cane Technologists. The copyright owner shall not be liable for technical or other errors or omissions contained herein. The reader/user accepts all risks and responsibility for losses, damages, costs, and other consequences resulting directly or indirectly from using this information.

CONTENTS

FOREWORD v

PART 1 – History and Development of the Society 1924-2023
L Jean Claude Autrey, A Salem Saumtally and Asha Dookun-Saumtally

Origin and early days of ISSCT (1924-1938) 1

Establishment - post World War II congresses (1950-1974) 7

Development – recent congresses (1970s onwards) 10

Conclusions 31

PART 2 - *Research Advances and Impact*

AGRICULTURAL COMMISSION

Agronomy 1924-1938 45
L Ronald Ng Cheong and Adess Gooljar

Agronomy 1950-1974 50
Abraham Singels and Jan Meyer

Agronomy 1975-1999 56
Hardev Sandhu and Amandeep Sharma

Agronomy 2000-2023 61
Bernard L Schroeder

Agricultural Engineering 1924-1938 68
Carmina Fandos, Pablo Scandaliaris, Somwang Leekar, Nonthawat Chainarong and Sombat Khawprateep

Agricultural Engineering 1950-1974 76
Bernard L Schroeder

Agricultural Engineering 1975-1999 80
Troy A Jensen

Agricultural Engineering 2000-2023 85
Pierre Todoroff

BIOLOGICAL COMMISSION

Germplasm and Breeding 1924-1938 89
Raúl O Castillo Torres and Freddy Martin

Germplasm and Breeding 1950-1974 94
Anthony J Kennedy

Germplasm and Breeding 1975-1999 97
Anthony J Kennedy

Germplasm and Breeding 2000-2023 100
Goolam Badaloo, Deepack Santchurn, Nazline Meethoo and Hashini Kaniah

Plant Physiology 1924-1938 107
Michael K Butterfield

Plant Physiology 1950-1974 109
Michael K Butterfield

Physiology and Molecular Biology 1975-1999 114
Asha Dookun-Saumtally

Molecular Biology 2000-2023 121
Angélique D'Hont and Nathalie Piperidis

Entomology 1924-1938 127
Cecilia Easdale

Entomology 1950-1974 133
Peter G Allsopp

Entomology 1975-1999 139
Régis Goebel

Entomology 2000-2023 145
Julien Beuzelin

Plant Pathology 1924-1938 154
Jeffrey W Hoy

Plant Pathology 1950-1974 160
Philippe Rott

Plant Pathology 1975-1999 166
Jack Comstock

Plant Pathology 2000-2023 173
Jean Heinrich Daugrois

FACTORY COMMISSION

Factory Engineering 1924-1938 178
Juliusz Lewinski, Sergio Guzman and Manuel Enriquez Poy

Factory Engineering 1950-1974 184
Geoffrey A Kent

Factory Engineering 1975-1999 190
Peter W Rein

Factory Engineering 2000-2023 193
Boris Morgenroth, Harjeet Singh Bola and Saiedeh Wicht

Factory Processing 1924-1938 200
Steve Davis

Factory Processing 1950-1974 205
Ross Broadfoot

Factory Processing 1975-1999 211
Gillian Eggleston

Factory Processing 2000-2023 216
Roderick J Steindl

CO-PRODUCTS COMMISSION

Co-products 1924-1938 221
Oscar Almazan

Co-products 1950-1974 225
Pedro Avram-Waganoff and Gunshiam Umrit

Co-products 1975-1999 232
Darryn Rackemann and Giovanna Aita

Co-products 2000-2023 238
Bryan Lavarack

MANAGEMENT COMMISSION

Management 1924-1938 246
James M Shine, Jr

Management 1950-1974 252
David Calcino

Management1975-1999 258
Carolyn M Baker

Management 2000-2023 263
Kerry A Redshaw

FOREWORD

The International Society of Sugar Cane Technologists (ISSCT) was created in 1924 in Hawaii. To celebrate its Centennial, its Council decided at the XXXI Congress held in India in 2023 on a range of activities. Among these is the production of a volume marking both its History and Development and the technological advances that it has brought and their impact.

This two-part Centennial Volume commemorates not only the longevity of the Society, as can be seen from its development and adaptation over the years, but also its profound impact on the global sugarcane industry. Since its origin, the ISSCT has been the major focus for the generation, exchange, and application of knowledge across the entire sugarcane value chain. It has facilitated collaboration across continents, disciplines and generations, helping to drive the scientific and technological evolution of the sector.

This volume is the culmination of a deep and insightful review of the 31 ISSCT Congress Proceedings held over the past century. While the first part reviews the administrative evolution of the Society, the second part outlines the development as well as the emergence of ten key sections within the Society: Agronomy, Agricultural Engineering, Germplasm and Breeding, Physiology and Molecular Biology, Entomology, Pathology, Factory Engineering, Factory Processing, Co-products, and Management. The chapters are structured around four historical periods: 1924–1938, 1950–1974, 1975–1999, and 2000–2023, each representing a quarter of a century. These allow one to observe, with clarity and depth, the evolution of themes, the emergence of new research frontiers, and the resilience and innovation of the industry in responding to new challenges.

One of the most rewarding aspects of this retrospective has been the realization that the ISSCT has stood firmly on the shoulders of remarkable technologists over the decades. Many of these individuals are acknowledged throughout the chapters, not merely as historical references but as pioneers who laid the groundwork for the Society's continuing relevance. Their work has shaped the very fabric of sugarcane research and industry practice, and their legacy continues to inspire new generations.

The value of the ISSCT lies not only in its role as a convenor of triennial congresses, thematic workshops, preservation of scientific and technological resources, webinars and occasional publications, but also in its ability to foster the cumulative generation of knowledge that informs of the very best of practices, stimulating innovation, and strengthening international cooperation. This publication exemplifies that role. It captures the collaborative spirit, scientific rigor, and practical orientation that have long defined the ISSCT and its global community of members.

We extend our deep appreciation to all authors of the chapters, whose remarkable contributions made this publication possible. Their dedication to revisiting, documenting, and synthesizing decades of progress has resulted in this landmark volume that we trust will be a reference for many years to come. We also thank Mrs Vanina Barbier, ISSCT Confidential Secretary, who has coordinated the various versions of the manuscripts.

As we reflect on a century of achievement, we are equally mindful of the road ahead. The challenges of climate change, digital transformation, and sustainability demand renewed engagement, fresh thinking, and interdisciplinary solutions. We are confident that the ISSCT will continue to serve as a vibrant and unifying force, bringing together scientists, technologists, managers, innovators and business companies to shape the future of the sugarcane industry.

We invite all members, young and seasoned alike, to carry forward this legacy with renewed energy and commitment.

ISSCT Centennial Volume Editorial Committee
L. Jean Claude Autrey
A. Salem Saumtally
Raúl O. Castillo Torres
Peter G. Allsopp

Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

History and Development 1924-2023

L Jean Claude Autrey, A Salem Saumtally and Asha Dookun-Saumtally

issctsecretariat@gmail.com

ORIGIN AND EARLY DAYS OF ISSCT (1924-1938)

The origin of the International Society of Sugar Cane Technologists (ISSCT) can be traced back to the Pan-Pacific Food Conservation Conference, held in Honolulu, Hawaii, from 28 July to 14 August 1924. This multifaceted event was divided into several thematic sections, many of which, such as sugar industry, fisheries, marine biology, oceanography, plant entomology and pathology, quarantine, logistics, and international laws and agreements, remain pertinent to global discussions today.

The Sugar Industry Section marked the historic inception of what became the First Congress of the ISSCT, aiming at promoting international collaboration in sugar cane research, technology and industry development. This first gathering was tagged the 'International Conference of Sugar Cane Men', reflecting its male-dominated attendance.

A total of 47 delegates from 11 countries gathered in Hawaii for this pioneering event, from Australia (3), British West Indies (1), Continental United States (4), Cuba (2), Fiji (1), Formosa (Taiwan) (2), India (1), Mexico (1), Philippine Islands (2), Porto Rico (now Puerto Rico) (1), and Hawaii (29) to exchange knowledge and research findings in the sugar industry.

The Congress featured technical sessions covering a variety of technical topics in both agriculture and processing. There were 13 key sessions led by experts in their respective fields: Cane Breeding (E.W. Brandes), Cane Quarantine, (H.L. Lyon), Cultivation Methods (H. Freeman), Varieties & Identification Systems (M. Calvino), Cane Diseases (D.S. North), Bud Selection (H.F. Clarke), Cane Entomology (O.H. Swezey), Soils and Fertilizers (K. Oshima and G.R. Stewart), Rodent Control (C.E. Pemberton), Factory Engineering (N. Kay), Factory Operation and Control (W.R. McAllep), and Irrigation (W.P. Alexander). Cane breeding was deemed critical enough to merit two sessions.

Building on this foundation, the ISSCT rapidly expanded its membership to include individuals and institutions from many countries. The Society established itself as a global platform for sugar cane science, technology and industry innovation. The ISSCT has inspired sugar technologists across the world to create local associations in their respective countries. In turn, these associations have joined the ISSCT making it a stronger organization, which has been the driving force for advancing knowledge of the sugarcane value chain.

To date, 31 congresses have been organized in various locations across the global sugarcane-producing regions (Table 1). Some countries have hosted the congress multiple times, including Australia, Brazil, and India (each three times), as well as Cuba, Hawaii, Indonesia, Puerto Rico, South Africa, Thailand, and mainland USA (each twice). Eight other countries have hosted the congress once.

Table 1. ISSCT Congresses held from 1924 to 2023.

Year	No.	City	Country	Year	No.	City	Country
1924	I	Honolulu	Hawaii, USA	1980	XVII	Manila	Philippines
1927	II	Havana	Cuba	1983	XVIII	Havana	Cuba
1929	III	Soerabaia	Indonesia	1986	XIX	Jakarta	Indonesia
1932	IV	San Juan	Puerto Rico	1989	XX	São Paulo	Brazil
1935	V	Brisbane	Australia	1992	XXI	Bangkok	Thailand
1938	VI	Baton Rouge	USA	1995	XXII	Carthagena	Colombia
1950	VII	Brisbane	Australia	1999	XXIII	New Delhi	India
1953	VIII	Bridgetown	Barbados	2001	XXIV	Brisbane	Australia
1956	IX	New Delhi	India	2005	XXV	Guatemala City	Guatemala
1959	X	Honolulu	Hawaii, USA	2007	XXVI	Durban	South Africa
1962	XI	Réduit	Mauritius	2010	XXVII	Veracruz	Mexico
1965	XII	San Juan	Puerto Rico	2013	XXVIII	São Paulo	Brazil
1968	XIII	Taipei	Taiwan	2016	XXIX	Chiang Mai	Thailand
1971	XIV	New Orleans	USA	2019	XXX	Tucumán	Argentina
1974	XV	Durban	South Africa	2023	XXXI	Hyderabad	India
1977	XVI	São Paulo	Brazil				

The second international congress took place in Havana, Cuba, from 12 to 25 March 1927. This event attracted 61 foreign delegates and 98 local participants. Formal welcomes addresses were extended by Cuban officials who recognized the sugar industry's significance and reaffirmed the value of scientific collaboration. H.P. Agee (Hawaii), General Chairman, ISSCT, highlighted Cuba's global significance in sugar production and noted the suitability of Havana as a conference venue due to its strategic and agricultural importance. His welcome was followed by that of the Director, Cuban Agricultural Experiment Station, who emphasized on the scientific exchange and knowledge sharing among delegates, while two more speakers, D.L. Van Dine from Tropical Plant Research Foundation, Cuba, and E.W. Brandes from Bureau of the Plant Industry, Washington D.C., emphasized on the significance of international collaboration in sugarcane science and the need for continued research and cooperation across borders.

The Opening Session was presided over by the General Chairman and welcome speeches were delivered from senior officials from the government of Cuba.

Six technical committees were established, each focusing on a specific area of sugarcane science and technology:

1. Protective Quarantine Measures (Chairman, E.W. Brandes (USA) + 7 members)
2. Insect Pests of Sugar Cane (including the use of parasites (Chairman, D.L. Van Dine (Cuba) + 12 members)
3. Sugar Cane Diseases (Chairman, J.R. Johnston (Cuba) + 14 members)
4. Sugar Cane Varieties (including propagation and selection) (Chairman, J. Jeswiet (Java) + 10 members)
5. Cultivation and Field Operations (including soil management and fertilizer use) (Chairman, H.F. Clarke (Fiji) + 15 members)
6. Factory Operation and Chemical Control (Chairman, W.R. McAllep (Hawaii) + 2 members)

Each committee was tasked to gather and share scientific information within its area.

Notable resolutions were passed during the final session, addressing both operational and scientific matters:

- Approval of the financial report and authorization for the transfer of funds to the incoming Chairman;
- Revision of membership dues policy based on the date of payment relative to the conference: dues collected from members previous to five days before the opening of the Havana Conference would apply to the period ending with the Havana Conference, but all subsequent dues collected would apply to the period ending with the Java Conference;

- Appeals to the Japanese Experiment Station in Formosa and Dutch Experiment station in Java for English translations of their research publications, and these to be made available to the Society;
- Recommendations for the publication of J. Jeswiet's work on sugarcane botany, breeding, propagation and selection to be published in English;
- Adoption of a resolution recognizing the pioneering work of J. Bovell, from Barbados, in sugarcane seedling development;
- Establishment of Regular Standing Committees for each technical topic, with the aim of continuing collaborative research and publication between conferences.

The Congress saw 27 papers presented in the various disciplines, in addition to explanations and discussions on topics relevant to the industry such as Boiler Plant, Cane Stem Galls, Cultivation and Cane Operations, Gumming Disease and Milling.

During the final session of the congress, Java was chosen to host the III Triennial Conference of the Society. An Executive Committee was also elected with J. Jeswiet as General Chairman, D.L. Van Dine as General Secretary, and V. Koningsberger as Assistant Secretary and Treasurer to serve during the third triennial period.

At the end of the technical and business sessions, a tour across Cuba was organised, thanks to the Cuban Government. A special train was arranged to enable participants to tour the island and observe the status of Cuba's sugar industry. A thoughtfully planned itinerary of over 2500 km in 6 days offered a comprehensive view of the island's sugar industry, including visits to key sugar mills. One of the highlights was a visit to the Cuba Sugar Club Experiment Station at Baraguá, where delegates witnessed pioneering scientific work under the direction of D.L. Van Dine.

In 1929, the III Congress was held in Soerabaia (now Surabaya), in Java, Indonesia from 7 to 19 June, under the chairmanship of J. Jeswiet, Chairman of the Executive Committee. Two other committees, the Preparation Committee and a Sub-Committee for Accommodation, also assisted the Executive Committee in the Congress.

That congress attracted 145 international delegates from 12 countries including Australia (3), British India (5), Egypt (1), Hawaii (13), Indochina (1), Japan and Formosa (now Taiwan) (4), Java (95), Mauritius (1), Philippine Islands (12), Puerto Rico (2), Trinidad (1), and USA (7) and 95 locals. Amongst the attendees were four women, signalling gradual diversification in participation. The Congress began with formal ceremonies and a series of lectures:

- V.J. Koningsberger: Half a century of cane growing in Java
- E.C. von Pritzelwitz van der Horst: The development of sugar machinery in Java in the present century
- P. Honing: The development of the methods of manufacture in the Java sugar industry
- J. Jesweit: The development of selection and breeding of the sugar cane in Java.

During the General Meeting, proposals from the government of Puerto Rico and the Queensland government (Australia) and a verbal invitation from Louisiana (USA) were submitted to host the IV Congress in 1932. The Congress voted for Puerto Rico, honouring a rule established at the Havana Congress in 1927 that required alternate congress locations between Eastern and Western Hemispheres.

Six Regular Standing Committees were established: Sugarcane Quarantine, Insect Pests of Sugarcane, Diseases of Sugarcane, Varieties including Propagation and Selection, Cultivation and Field Operations, and Factory Operation and Chemical Control. In addition, four Special Standing Committees were constituted: Description and Identification of the Original Cane Varieties, Forestry, Uniformity in Reporting Factory Data and Soils, and Technique of Field Experiments. Local Chairmen were also appointed in different countries to facilitate ISSCT activities.

Nine resolutions were also passed to advance the global sugarcane science and industry:

1. Commendation of E.W Brandes for discovering the transmission of sugarcane mosaic by the aphid *Aphis maidis* (now known as *Rhopalosiphum maidis*).
2. Global focus on irrigation and drainage with scientific experimentation recommended.
3. Soil classification and fertility studies urged for sustainable sugarcane cultivation.
4. Genetic and taxonomic investigations with establishment of varietal collection gardens in 2–3 countries and that the Executive Committee takes necessary steps for the establishment of such collections.
5. Controlled importation of varieties, through recognized institutions, with proper documentation to reduce risks of introduction of new diseases in any country.
6. Abstracts required in English language for all technical papers submitted for future Congress periodicals.
7. Metric system adoption was recommended across cane sugar industries for publishing all field and factory results.
8. A Committee be appointed to revive the International Commission for Uniform Methods of Sugar Analysis, by approaching prominent sugar chemists in important countries producing sugar from beet or cane.
9. Creation of a new Special Standing Committee on Field Experimentation Techniques to harmonize methods and data analysis.

Three Honorary Members were elected for their contributions:

- E.W. Brandes for his research on sugarcane mosaic disease
- N. Deerr for his landmark contributions to sugar technology
- F. Muir for achievements in biological control of insect pests.

Technical papers were presented in the following sessions as well as lectures and discussions held on various topics of the papers:

- Section A I. Protective Sugar Cane Quarantine (2)
- Section A II. Diseases of Sugar Cane (5)
- Section A III. Insect Pests of Sugar Cane (6)
- Section B. Cultivation and Field Operations (15)
- Section C. Varieties including propagation and selection (4 and 1 lecture)
- Section D: Factory Operation and Chemical Control (9 and 2 lectures)

An excursion week was organised at the end, one for agriculturists; soil experts, pathologists and entomologists with 33 participants and a second for factory experts with 27 participants.

The IV Congress, under the Chairmanship of the General Chairman of ISSCT, F.W. Zerban, held in San Juan, Puerto Rico from 1-16 March 1932, continued to attract many members. At this time ISSCT had grown to include 589 members across the globe: Australia (11), British Empire (6), British West Indies (27), Colombia (11), Cuba (36), Dominican Republic (8), Egypt (2), Formosa and Japan (22), France (1), Hawaii (23), Holland (27), India (14), Indo China (1), Java (57), Louisiana (33), Mauritius (16), Mexico (1), Peru (21), Philippine Islands (14), Puerto Rico (130), Queensland (25), Réunion (33), South Africa (26), USA Continental (43) and Venezuela (1). A total of 63 foreign delegates attended the Congress, including participants from Australia/Fiji (2), Brazil (1), British West Indies (10), Cuba (5), Dominican Republic (2), France (1), Germany (1), Hawaii (6), Java (1), Peru (3), Philippine Islands (1), Queensland (2), South Africa (3), UK (2), USA (22) and Venezuela (1).

Plenary session highlighted Puerto Rico's sugar industry transformation with a series of lectures:

- *The Varietal Revolution in Puerto Rico* by C.E. Chardón, Chancellor of the University of Puerto Rico
- *The Development of Sugar House Machinery and Methods of Manufacture in Puerto Rico During the Last Quarter of the Century"* by M.A. del Valle
- *Sugar Cane Growing in Puerto Rico* by F.A. López Domínguez
- *Soil Classifications* by C.F. Marbut
- *The Process Used in the Manufacture of Snow-White Sugar at Central Mercedita* by J.R. Junghans.

An Industrial Exhibit also took place, showcasing a broad array of equipment and technologies such as sugar house machinery, agricultural implements, tractors, fertilizers, pumps, and electrical controls.

The Business session featured reports from the General Chairman, General Secretary, and Assistant Secretary, marking a new requirement for all three officers to report at each Congress. The General Chairman, F.W. Zerban reviewed progress on resolutions from the 1929 Java Congress, and the Assistant Secretary presented the Society's financial report. Among technical matters, a decision was taken to discontinue the Committee on 'Forestry' due to inactivity. Newsletters were published during the inter-congress period to maintain communication and it was stressed that efforts would be required for better distribution.

A significant development at this Congress was adoption of major constitutional amendments to streamline the Society's administration and membership processes:

- Amending Article IV, Section 4 to allow regional sections to elect their own vice-chairmen, enhancing autonomy.
- Clarifying membership dues under Article V to align with the triennial Congress cycle.
- Revising Article VI to mandate regular meetings at intervals not exceeding three years.
- Removing the limit of 25 members per regional section in Article II to accommodate more members from larger sugar-producing countries.
- Streamlining membership application procedures with standardized forms and clearer guidelines.
- Modifying Article IV, Section 5 to require the Assistant Secretary to reside in the country of the next Congress, facilitating logistical planning.

Fourteen resolutions were adopted, nine of which addressed scientific, agricultural, and industry challenges of the time:

1. Establishing a central culture collection for microorganisms at the Central Bureau voor Schimmelcultures in the Netherlands.
2. Forming a standing committee on field experiment techniques.
3. Standardizing the spelling of "sugar cane" as two words in all Society publications.
4. Resolving a minimum five-year testing period before releasing new sugarcane varieties.
5. Supporting global cane variety collections in Puerto Rico and Java.
6. Withholding endorsement of mass-reared *Trichogramma* for borer control without stronger statistical evidence.
7. Compiling a global list and bibliography of insect pests and their natural enemies, instead of producing a full manual.
8. Advocating for entomological and pathological surveys in tropical America.
9. Exploring ways to increase sugar consumption and utilize by-products amid global overproduction.

Reports were also received from the Committee on Publications of Abstracts and the Committee for the Re-establishment of the International Commission for Uniform Methods of Sugar Analysis.

Sectional meetings were organized as follows:

- Section A: Diseases of Sugar Cane – General Papers (9), Virus Diseases (8), Root and Bacterial Diseases (13), Joint Session on Diseases and Insects Pests of Sugar Cane (6).
- Section B: Agronomics of Sugar Cane – Cultivation and Field Operations (11), Soils (22), Field Experiment Techniques (8).
- Section C: Sugar Cane Varieties – Identification and Testing (9), Breeding (6).
- Section D: Factory Operations and Chemical Control – General Papers (9), Crystallization Symposium (10), Factory Control (3).
- Section E: Insect Pests of Sugar Cane – Biological Control (14), Survey Problems (2), Joint Session (6).

The Congress also featured social events, including a garden party, excursions to sugar-growing regions and a farewell dinner reinforcing networking and cultural exchange among participants. A

decision was made to hold the V Congress in Brisbane, Australia, in 1935, following proposals from both Australia and the Philippine Islands.

In August 1935, Brisbane hosted the V Congress that took place from 27 August to 14 September and welcomed 32 foreign delegates from British India (3), British West Indies (1), Cuba (1), Great Britain (1), Hawaii (5), Java (4), Peru (1), South Africa (6) and USA (8), and 90 Australasian members: Fiji (1), Victoria (3), New South Wales (19) and Queensland (67). The Society's membership stood at 510 at the beginning of the V Congress, down from 589 from last Congress, a decline attributed to the turbulent economic conditions affecting the sugar industry. Committees consisted of the Honorary Committee, Administrative Executive, Congress Committee, Itinerary Sub-Committee, Entertainment Sub-Committee, Publication Sub-Committee and Ladies' Sub-Committee.

The Congress was officially opened by the Governor of Queensland and lectures were given on *Economics of Sugar in Australia* and *Certain Social Oddities* in North Queensland.

During the Plenary Session, the General Chairman of ISSCT, A.J. Gibson, reviewed the Society's progress and proposed a shift to quinquennial meetings to reduce financial and logistic strain. The General Secretary-Treasurer's reported for the period 1932-1935 and the financial reports indicated a healthy surplus. It is interesting to note that in 1935, the Society had two fixed deposits of £392 1s. Consequent upon the falling due, the fund was invested in Australia Government Bonds, with an interest rate of 5%.

Constitutional amendments were introduced to shift from triennial to quinquennial congresses, to define dues based on a fixed reference currency set at USD 5.00, to create an Administrative Executive with powers to fill vacancies, and to adjust dues based on currency fluctuations. A major amendment was to appoint a Permanent Trustee to safeguard Society funds, and to establish a Permanent Custodian of Records. Both roles of the Trustee Custodian of Records were proposed to be based in Hawaii, given its status as the Society's birthplace and a central location in the sugar cane world. Sectional meetings were organized as follows:

- Agricultural Section: 22 papers and reports of the Committee 'on Labour Saving Devices' and Committee of soils and publications relating to 'Sugar Cane Soil Investigations';
- Pathological and Entomological Sections (joint): 3 papers;
- Pathological and Entomological Sections (joint session on quarantine and varietal resistance): 5 papers;
- Agricultural, Pathological and Entomological Sections (joint session): 1 paper and report of the Committee on 'Field Experimentation';
- Manufacturing Section: 17 papers, one report of Special Committee of 'Uniformity in Reporting Factory Data', one lecturette on 'Sugar cane Factory pH Control in Java' with a film;
- Entomological Section: 10 papers;
- Pathological Section: 14 papers; and
- Cane Breeding: 13 papers.

The decision to hold the VI ISSCT Congress in Louisiana at Baton Rouge in 1938, was unanimously approved. E.W. Brandes was nominated as the next General Chairman of the Society, with P. Honig as Vice-Chairman, while C.W. Edgerton was nominated as the General-Secretary Treasurer of the Society.

Regular standing committees and special standing committees and their chairmen were appointed as follows:

- Insect pests of sugar cane (W.E. Hinds)
- Diseases of sugar cane (R.D. Rands)
- Varieties (J.B. Sartoris)
- Cultivation (W.G. Taggart)
- Factory Operation (C. Nadler)
- Labour-saving devices (H.C. Barr)

- Description of varieties (W.W.G. Moir)
- Uniformity in reporting factory data (F.W. Zerban)
- Soils (O. Schreiner)
- Technique of field experiments (G. Arceneaux).

The Congress concluded with a two-week tour of the major sugar districts of Australia.

The VI ISSCT Congress convened at Louisiana State University, Baton Rouge from 24 October to 5 November 1938 and attracted 143 foreign delegates from Australia (10), Brazil (1), British Guiana (1), British West Indies (14), Cuba (38), Dominican Republic (3), Egypt (2), Fiji (1), Great Britain (4), Hawaii (16), India (2), Java (2), Mexico (8), Puerto Rico (31), South Africa (10), and 155 local participants.

ISSCT membership at this Congress had grown to 815 individuals, about 250 members more than at the previous Congress. The event began with a week-long tour of Louisiana's sugar industry including visits to industrial alcohol plant, sugar refinery, a plant making artificial board from bagasse, milling factory, agronomic research and processing technologies.

During the Business session in the second week, under the chairmanship of E.W. Brandes, a Resolutions Committee was appointed. An Administrative Committee, consisting of three executive office bearers of the Society and the regional Chairman of the different sections was also constituted.

Constitutional amendments included the return to triennial Congresses and the creation of an Interim Committee, comprising P. Honig (Chair), E.W. Brandes, C.W. Edgerton, M.S. Moody-Stuart, H.H. Dodds, R.C. Srivastava, and W.E. Dickinson, with full authority to determine the venue for the next Congress as no formal invitation to host the 1941 meeting had been received. A motion was also adopted recommending that, should no invitation be received from a sugar-producing country within one year, the Interim Committee should consider holding the 1941 Congress in London or another suitable European location.

The Congress saw over 130 technical papers in various sections: Physiology and Taxonomy: 11; Breeding including variety investigations: 13; Pathology: 27; Entomology: 27; Field Operations: 13; Soils and Fertility Studies: 16; Techniques of Field Experiments: 11; and Milling investigations: 38.

The Secretary-Treasurer's report showed that the Society's assets had increased by approximately £520, equivalent to around USD 2,000 at the time.

This 14-year span from 1924 to 1938 marked the early years of ISSCT, as it evolved from a regional gathering into a formalised international sugar cane scientific society. Each Congress strengthened the Society's technical and administrative focus, laying a strong foundation for the years ahead. Unfortunately, World War II was going to impact adversely on the Society with no congress being held until 1950.

ESTABLISHMENT - POST WORLD WAR II CONGRESSES (1950-1974)

Structuring of Congresses

From the VII to the XV Congress, held between 1950 and 1974, the ISSCT firmly established its triennial congresses not only as premier forums for scientific exchange but also as elaborate events rich in ceremony, symbolic recognition, and learning. As is the case for past and present congresses, the formalization of Opening Ceremonies and the integration of pre- and post-Congress technical tours, added depth, visibility, and diplomatic relationship to the Society's scientific pursuits. The Opening Ceremonies were graced by high-ranking dignitaries, including government ministers, governors, heads of agricultural institutions, and at times, even the heads of state. The Closing Sessions were usually an ISSCT internal matter but sometimes outside speakers were included. The opening ceremony and the congress were given wide coverage in the local media as well as in the international ones. These

inaugural moments served to affirm the ISSCT's global status and the strategic importance of the sugar cane industry within host countries.

At the VII Congress in Brisbane in 1950, the event was opened by the Governor of Queensland and the Minister of Agriculture and Stock. The General Chairman delivered a Presidential Address entitled *Developments in Cane Production since 1938* reaffirming the Society's continuity after the war. Similarly, at the VIII Congress in Barbados in 1953, the Acting Governor of Barbados opened the proceedings, followed by a centenary reflection on Barbadian sugar production by the General Chairman of the Congress. These early events laid the groundwork for a dignified and reflective tone at each Congress. The following Congresses continued the same traditions. They were also accompanied by engaging keynote addresses. The XIV Congress in New Orleans received institutional endorsements from both governmental and industry bodies. The Governor of Louisiana formally declared the Congress period as the "ISSCT Fortnight," a symbolic recognition of its stature. The XV Congress in Durban was inaugurated by the Prime Minister of South Africa, with other addresses by regional administrators, signifying the global diplomatic importance of ISSCT gatherings.

Complementing these formal ceremonies were the extensive technical and cultural tours, which became a hallmark of ISSCT Congresses. These tours allowed delegates to observe local innovations, engage in comparative analysis, and form enduring international networks. The VII Congress in 1950 included a two-week tour from Brisbane to Cairns, covering Queensland's major sugar districts with visits to mills and experimental fields. The VIII Congress in 1953 featured a Caribbean itinerary, including Jamaica, Trinidad, and Guyana. In 1956 in India, the VIIII Congress offered an 18-day tour covering research institutes, universities, and sugar estates across several Indian states. In Hawaii in 1959, delegates toured multiple islands, split into factory and field groups, while in 1962, Mauritius and Réunion Island complemented each other in a blend of scientific visits and sister-island linkage. At the XIII Congress, Taiwan hosted a week-long pre-Congress tour, and delegates were later welcomed for a post-Congress tour in the Philippines. The XIV Congress, in 1971, concluded with a post-Congress tour to the sugar industry of Florida, and the XV Congress in 1974 included a pre-Congress field and factory tour in South Africa, and a post-Congress visit to Mauritius.

Standing and Special Committees

At the II Congress in Cuba, Regular Standing Committees were proposed for technical topics, with the aim of continuing collaborative research and publication between conferences. Between the VII and XV ISSCT Congresses, the introduction and progressive institutionalization of Standing and Special Committees provided valuable contributions into transforming the Society into an organized, responsive, and forward-looking professional body. These committees became the backbone of ISSCT's scientific, administrative, and strategic functions. The first Standing Committees came into operation during the VII Congress (1950) in Brisbane. This marked the beginning of ISSCT's structured internal decision-making processes.

From the VIII Congress in 1953, onward, Standing Committees focused on specific thematic and technical domains. Key among them were the Standing Committee on Sugarcane Diseases and the Committee on Uniformity in Reporting Factory Data, both of which were instrumental in creating global references and harmonizing research outputs. These committees ensured continuity between congresses and enabled expert groups to work on long-term collaborative projects. By the X Congress in Hawaii in 1959, several additional Standing Committees were functioning, including those on Germplasm and Breeding, Sugarcane Insects of the World, and Factory Reporting Systems. These committees facilitated the coordination of international research efforts, maintained and expanded world collections of sugarcane germplasm, supported the publication of technical newsletters, and provided leadership on disease monitoring and varietal development.

As the Society grew in complexity, Special Committees were adopted to address emerging or time-bound issues. For example, at the XI Congress in Mauritius, in 1962, a Special Committee was tasked with recommending names for Life Membership and for updating the *System of Cane Sugar Factory*

Control. Similarly, the XII Congress (1965) revived the Life Membership Committee and emphasized the role of invited symposia through a dedicated Special Committee on Programme structure. From the XIII Congress (1968) onward, Special Committees addressed topics such as Variety Yield Decline and Mechanical Harvesting, compiling data and guiding member countries in adapting to technological shifts in field operations. The inclusion of these committees reflected ISSCT's commitment to tackling critical challenges through multidisciplinary input. By the XIV and XV Congresses (1971, 1974), the Standing Committees had matured into indispensable structures. New ones were created for Sugarcane Quality and International Germplasm Expedition in Papua New Guinea, while existing ones (Diseases, Breeding, Quarantine, Factory Data) expanded their work. Other initiatives included clone cataloguing, monographs, and slide collections. These committees ensured scientific continuity, drove harmonization of methodologies, and influenced global best practices. These activities and discussions led to the publication of a world disease list, the Sugarcane Pathologists' Newsletter, International Cane Disease Index (Incandex), affiliation with international society for sugarcane Pathology, and reprinting of the book *Sugar Cane Diseases of the World Vol. I* after its updating by Elsevier in 1961.

Standing and Special Committees significantly enhanced the ISSCT's capacity to respond to new challenges and promote coordinated scientific progress. Their creation and functioning during the period 1950 to the 1970s, laid a strong foundation for the ISSCT's reputation as a globally engaged, knowledge-driven organization.

The gradual introduction and institutionalisation of symposia sessions during the post-war period represented an important evolution in the structure of ISSCT Congresses. Initially featured during the IX Congress in India in 1956, early symposia focused on key operational challenges such as sugar engineering, juice clarification, and payment systems for cane, with the objective of in-depth examination beyond standard section presentations. This format gained momentum at the X Congress in Hawaii (1959), where dedicated sessions addressed pressing concerns including milling performance and varietal yield decline. These discussions allowed for comparative analyses across regions and supported consensus among countries on technical solutions. A significant expansion occurred at the XIII Congress in Taiwan (1968), where six symposia covered themes ranging from yield enhancement and factory automation to education, industry diversification, and sugar quality. This broadening of scope reflected the engagement of ISSCT into factory performance, value-addition and the socioeconomic dimensions of sugarcane production.

Recognizing their impact, the XIV Congress (1971) formally recommended the continued inclusion of symposia in future Congresses as a key format. By the XV Congress held in 1974, symposia were firmly embedded within the Congress structure, enabling focused, cross-disciplinary engagement on critical topics of both scientific and strategic relevance. Through this mechanism, ISSCT enhanced its capacity to respond to issues of a global nature and enhancing scientific and technological cooperation. Symposia continued on in later years such as in 1986 and 1992. The spirit animating this initiative was later transformed in the later years to Panel Sessions, Panel Discussions and Fora (see below).

Resolution Committee

Resolutions were commonly discussed since the start of the Congresses which addressed scientific, agricultural, and industry challenges of the time. Resolutions were also ceremonial, regarding vote of thanks and condolences. A formal Resolution Committee was approved as from the VI Congress, in 1938, to consider and frame any resolutions. Some examples of adopted resolutions at the Congresses were:

- VII Congress: The Department of Entomology, Experiment Station of HSPA was designated as the permanent secretariat for the Section on Pests of Sugar Cane of ISSCT; funds amounting to USD 1000 from the reserve funds were allocated for the printing of *A Bibliography of the Sugar Cane Insects of the World*;
- VIII Congress: Initiatives to undertake collection of sugar cane varieties and wild relatives; a World Collection of Sugar Cane Varieties was needed to replace the one lost in Java and to supplement that of USDA;

- IX Congress: a Constitution and Regulation Committee be appointed to revise the Constitution;
- X Congress: the Government of India authorising the expansion of the cane collection at SBI, Coimbatore to the status of World Cane Collection, essentially duplicating the one at USDA and ISSCT recognized the two as World Cane Collections.
- XII Congress: the methods of raw sugar analysis be those recommended by ICUMSA, or in their absence, tentative methods be adopted; the inclusion of Symposia at Congresses as a new and effective approach for discussions; that the design embodying the initials ISSCT employed at the XIII Congress be adopted as permanent;
- XIV Congress: to dispense with the time-consuming procedure of including discussions of papers in the Proceedings for its timely publication; that as far as possible to have a chairman and a vice-chairman for each section one of whom should be proficient in both English and Spanish, a summary in Spanish for each paper, and to assure the opportunity for questions and discussions in both languages.

At each congress the report of the Resolution Committee included in Constitution was considered and it ensured that the cultural identities of the Society are recognised and maintained, especially concerning Spanish and French through simultaneous translation and provision of summaries of papers and eventually posters in these two languages, although at the XXXI Congress in India it was decided not to include these given the evolution taking place at international level. However, simultaneous translation was maintained for certain activities such as Opening Ceremonies, Plenary Sessions, etc.

The other resolutions were of technical nature concerning Germplasm and Breeding, Mechanical Harvesting and Sugarcane Quality, Sugarcane diseases and Editorship of the Plant, Breeding, Pathology and Entomology Newsletters as well as other publications of the Society

The Resolutions Committee dealt with the usual items about thanking the host and recognising the assistance received for the holding of the congress, the conferment of the Honorary Life Membership for deserving members and expression of sympathy for members who had passed away. Praiseworthy comments were made on the Standing Committees and the assistance received from several institutions of various countries. However, with time, the Resolutions Committee played a less important role at congress.

Through these dignified ceremonies and far-reaching tours, the ISSCT Congresses of 1950–1974 created a unique model of scientific diplomacy. They were not only valuable exchanges in sugar cane science and technology, but also strengthened bilateral and regional ties, elevated the visibility of host nations, and reinforced the identity of ISSCT as the apex sugar cane society.

DEVELOPMENT - RECENT CONGRESSES (1970s onwards)

Organisation

In the 1970s the ISSCT was organised around four Divisions: Agriculture, Biology, Factory and Product which in turn comprised nine disciplines: Agronomy, Plant Breeding, Entomology, Plant Pathology, Plant Physiology, Agricultural Engineering, Factory Engineering, Processing and By-Products. Each Section had a Chairman and a Spanish-speaking Vice-Chairman. In 1983, a French-speaking Vice-Chairman was also appointed. In 1983, in Cuba, an Energy Section was created, while in 1986, the Cane Breeding Section became Germplasm and Breeding.

A Technical Coordination Committee, comprising the Vice-Chairman of the Executive as ex-officio Chairman, the Commissioners and any Congress Officer nominated by COC, was created in 1988 and held its first meeting in São Paulo, Brazil in March 1988. It was decided that it should meet between Congresses and its objectives were defined. The first Technical Panel meeting comprising the Technical Coordination Committee was held on 15 October 1989 in Brazil at the XX Congress.

In 1992 Plant Physiology was replaced by Molecular Biology. Thus, the ISSCT was reorganised into four Commissions: Agriculture Commission (Agronomy and Agricultural Engineering), Biology Commission (Germplasm & Breeding, Pathology, Entomology and Molecular Biology), Factory Commission (Processing and Engineering) and Products Commission (Energy and By-Products). Each Commission had a Deputy-Commissioner for Spanish and one for French. At the XXVII Congress in 2010 in Mexico, posts of Deputy-Commissioners in Spanish and French were abolished as members fluent in these languages were appointed for each Section.

In 1999, the Energy Section merged with the Factory Engineering Section and the Products Commission became Co-products Commission. A new Commission, the Management Commission, was established before the XXV Congress in Guatemala in 2005 and it held its first workshop in 2006 in South Africa. Extension initially formed part of the Management Commission but was incorporated into the Agriculture Commission in 2015. There has been no change or new entity created since 2006.

The Technical Programme Committee (TPC) was created in 2010 to replace the Technical Coordination Committee and a TPC Operations Manual was produced in 2013. It has been amended after each Congress to ensure the smooth running of the technical aspects of the congresses.

The present organigramme is given in Appendix 1.

Mission Statement

A sub-committee of the Executive consisting of Colin Ryan, Jean Claude Autrey and Altaf Saleem was constituted at the XXIII Congress in 1999 to formulate a mission statement for the Society. This was accepted by Executive with minor amendments:

> *The Society is committed to the economic and sustainable advancement of the sugar cane industries of the world and associated communities, through promoting innovative research, development and the adoption of technology, and by sharing knowledge among its members for their professional development*.

At the XXX Congress in 2019, the Mission Statement was amended by removing the words "*economic and*" and becoming:

> *The Society is committed to the sustainable advancement of the sugar cane industries of the world and associated communities, through promoting innovative research, development and the adoption of technology, and by sharing the knowledge among its members for their professional development.*

Constitution

Although a constitution was not reported in the first Congress Proceedings, amendments to it were mentioned at the IV Congress, inferring that it had existed at least in draft form for some time. At the IV Congress, discussions were held that saw the adoption of major constitutional amendments, aiming to improve clarity, administrative efficiency, and inclusivity as the Society continued to expand internationally.

At the VII Congress, amendments resolved that "The objects of this Society shall be to promote the discussion of the technical problems of the sugar-cane industry in both field and factory by means of conventions held as far as practicable every three years, and to foster at all times the free and frank interchange of technical information by medium of publications or other means." The amended Constitution of ISSCT was adopted at the Congress. The Constitution then remained unchanged until the X and XI Congresses where additional amendments were made. At the XII Congress, a new Section was introduced regarding the formation of a class of Life Members, not exceeding 20, who shall not be required to pay dues and with non-voting status. At the XV Congress, further changes concerned increase in membership fees and Life Members deemed to be fully paid-up members at all times.

Significant changes were made to the Constitution from the late 1970s and throughout the 1980s. A Steering Committee was set up at the XV Congress in 1974 in Durban to develop amendments to bring the constitution in line with the requirements of the Society. The Committee was composed of 10 regions: South, Central and North America, Hawaii, South Africa, India and Pakistan, Philippines and Southeast Asia, Australia and Pacific Region, East Africa, Mauritius and Réunion; Europe. Owen Sturgess (Australia) chaired the Committee with Robert Antoine (Mauritius) as secretary.

Following exhausting deliberations of the Steering Committee the proposed revised Constitution of ISSCT which embodied the recommendation of the Steering Committee was presented at the meeting of the Administrative Committee held at the XVII Congress in Philippines in 1980 and was adopted unanimously.

There was a common resolve that the existing objects of the Society should remain sacrosanct. Additional objects were written into the revised Constitution to allow for the formation of technical commissions and sections and for the affiliation of national and local societies of sugar cane technologists. The structure of the Society was also amended with the creation of a Board of Trustees whose duties were to uphold the Constitution and assist or guide the Commissions in the international advancement of sugar cane technology. After ratification at the Business Meeting, the former regional Vice-Chairmen, then restyled Councillors, elected 10 members of the Board of Trustees: Robert Antoine, Carols Bell Raymond, Deven T. Loupe, August John Viltos and Gerald Thompson for six-year terms; Fernando Z. Cordovez, Kobe Shoji, Owen Sturgess, Luis Rivas and J. L. du Toit for three-year terms. The members elected Owen Sturgess as Chair and Robert Antoine as Secretary.

The new Constitution comprised:

- Article I: Name and objects – 2 clauses
- Article II: Membership – 3 clauses
- Article III: Structure of the Society – 1 clause
- Article IV: The Offices – 7 clauses
- Article V: Board of Trustees – 7 clauses
- Article VI: The Congress – 5 clauses
- Article VII: Congress Organising Committee – 14 clauses
- Article VIII: The Council – 8 clauses
- Article IX: The Commissions – 11 clauses
- Article X: Finance – 3 clauses
- Article XI: General – 4 clauses
- Article XII: Implementation – 1 clause

At the XVIII Congress in 1983, in recognition of proposed new executive powers to be given to the Board of Trustees, it was proposed that the name of that body be changed to 'the Executive Committee of Council'; members of the Executive Committee would be ex officio members of Council, and the Officers of the Executive Committee would be the Officers of the Society. The proposals submitted were approved by the necessary two-thirds majority of votes. At the same time, the Constitution was further amended to include:

- In Article I – By-Laws I on the Society symbols including the logo in gold letters mounted in the centre of a green background. The flag of the Society shall be displayed during Congress.
- In Article V- Board of Trustees, Clause 8 a Quorum for the meetings of Board of Trustees shall be five members. Article V – By-Laws – Entry visa, simultaneous translation, congress Newsletter, daily Newsletters and Price of Proceedings.
- In Article VIII – The Council, By-Laws Election of Trustees, Membership dues, Guidelines to encourage continuity of membership, Resolutions Committee on vote of thanks and expression of sympathy.
- In Article IX: The Commissions – 1 By-Laws replacement of members having resigned between congresses.

Two Articles, XI: General – 4 clauses, and Article XII: Implementation – 1 clause, were removed.

In 1986 at the XIX Congress, Council members approved far-reaching amendments to the Constitution and By-Laws proposed by the Board of Trustees. The main purpose of the amendments was to strengthen the organisation of the Society (as opposed to that of the Congress, which was entirely satisfactory). The main change was the provision of an executive body which would be an integral part of the Council but would provide continuity and management during periods between Congresses. This task had, to a large extent, been performed by the Trustees and in consequence it was confirmed that in the future the Trustees - while retaining also their previous advisory function - should have executive powers and be known as the Executive Committee. The Officers of the Executive Committee would, ex officio, be the Officers of the Society. Other amendments were designed to increase the strength of the technical focus of the Society and to enhance liaison between the Technical Commissions and Sections, the new Executive Committee and the Congress Organising Committee. The amended Constitution of ISSCT comprised:

- Article I: Name and Objects: 2 Clauses and 1 By-Laws
- Article II: The Members: 3 Clauses and 2 By-Laws
- Article III: The Structure of the Society: 1 Clause - Creation of the Executive Committee of Council
- Article IV: The Council: 8 Clauses, 4 By-Laws, one related to election of Executive
- Article V: The Executive Committee: 11 Clauses and 4 By-Laws
- Article VI: The Congress Offices: 7 Clauses and 1 By-Law
- Article VII: The Congress: 5 Clauses and 2 By-Law
- Article VIII: The Congress Organising Committee: Clauses and 6 By-Laws
- Article IX: The Commission: 13 Clauses and 2 By-Laws
- Article X: Finance: 3 Clauses
- Article XI: General: 4 Clauses and 4 By-Laws.

At each following congress the Constitution was reviewed and appropriate amendments made. The creation of the Permanent Secretariat in 1995 drove amendments to cater for this important new development. Subsequently, a review by Sir Victor Glover, then Chief Justice of Mauritius, led to the a Constitution with 11 articles: Article I: Name and Objects, Article II: The Members, Article III: The Structure of the ISSCT, Article IV: The Council¸ Article V: The Executive Committee, Article VI: The Technical Programme Committee, Technical Panel, Commissions, Technical Section Committees and Workshops, Article VII: The Secretariat, Article VIII: The Congress Officers and Organizing Committee, Article IX: The Congress, Article X: Finance and Article XI: General.

To support the implementation of the Constitution, both a Policy and Procedures were developed. These gave flexibility in the application of the various clauses without having in many instances to amend the Constitution itself. The Executive Committee was empowered to appoint three standing committees to deal with specific issues and it could also appoint temporary ad hoc sub-committees to study other issues not covered by the three standing committees:

1. Compliance Committee, comprising the Chair of the Executive, the General Secretary and two Councillors appointed at the first meeting of Council at Congress. Its duties are:
   - examine and express its opinion to the Executive on nominations received for Honorary Life Membership and report to Council;
   - examine nominations for election to the position of member of the Executive and ascertain that they comply with the qualifications and obligations as defined, to express its opinion to the Executive and report to Council;
   - examine applications to host Congress and report to Council;
   - examine applications for Affiliated Membership and review their eligibility for membership;
   - examine and make recommendations on any question brought up by the General Secretary regarding membership;
   - study and report to the Executive on all matters related to languages.

2. Finance Committee, comprising three members of the Executive and chaired by one who is not from the country hosting the Secretariat. Its duties are to scrutinise the budget proposed by the General Secretary and audit the finances of the ISSCT and make relevant recommendations to the Executive

and Council. The term of office of the Finance sub-committee coincides with the budget period and starts the next month following the end of a Congress and continues until the Interim accounts for the subsequent inter-congress period have been fully audited and signed by the Chair of the outgoing Executive.

3. Constitution and Resolutions Committee, comprising three members of the Executive. Its duties are to review the Constitution and propose amendments as and when necessary, working in close collaboration with the Chair and the General Secretary, and to prepare a list of resolutions taken at Congress for presentation to delegates at the final plenary session.

The Constitution, Policy and Procedures may be accessed through the link https://issct.org/about-issct/constitution/. Hard copies are available at the ISSCT Secretariat for consultation.

Office Bearers

The Society for its proper functioning has appointed Office Bearers throughout his existence. With the major developments at the level of the Constitution as from the 1980s there were significant changes in the Governance of the Society with the Council, the Board of Trustees which became the Executive Committee, the Commissions and Sections. Those who have occupied the most important function, i.e. General Chairman, Chair of Council and Chair of Executive Committee, are listed in Table 2.

Table 2. General Chairman, Chair of Council and Chair of Executive Committee of ISSCT.

Years	Chair	Country	Years	Chair	Country
1924-1927	H.P. Agee	Hawaii	1980-1983	Luis Galvez	Cuba
1927-1929	J. Jeswiet	Java	1983-1986	R. Moljono Hadipoero	Indonesia
1929-1932	F.W. Zerban	USA	1986-1989	Owen Sturgess	Australia
1932-1935	A.J. Gibson	Australia	1989-1992	Robert Antoine	Mauritius
1935-1938	E.W. Brandes	USA	1992-1995	Brian Egan	Australia
1950-1953	P. Honig	West Indies	1995-1999	Dhruv Sawhney	India
1953-1956	J. Saint	Barbados	1999-2001	Peter Rein	South Africa
1956-1959	D.R. Narang	India	2001-2005	Jean Claude Autrey	Mauritius
1959-1962	L.D. Baver	Hawaii	2005-2007	Victor Mason	Australia
1959-1962	P.O. Wiehe	Mauritius	2007-2010	Freddie Martin	USA
1962-1965	E. Hugot	Réunion	2010-2013	Timothy Murray	South Africa
1965-1968	C.M.H. Yuan	China	2013-2016	Timothy Murray	South Africa
1968-1971	F.A. Graugnard	USA	2016-2019	Philippe Rott	France
1971-1974	T.G. Cleasby	South Africa	2019-2023	Raul Castillo Torres	Ecuador
1974-1977	H. Morganti	Brazil	2023-2025	Sanjay Awasthi	India
1977-1980	Roberto S. Benedicto	Philippines			

Full lists of Office Bearers of ISSCT from 1983 to 2025 are given in Appendices 2 and 3.

The Secretariat

The ISSCT which was created in 1924 in Hawaii did not have a permanent structure until the establishment of its Secretariat in 1996. The Hawaii Sugar Planters' Association (HSPA) was custodian of records for the Society. Each time a congress was held, all the documents stayed with the Congress Organising Committee, except the Proceedings which were kept in Hawaii. When the Constitution of ISSCT was rethought in the 1980s, the idea of having a Secretariat was launched. Robert Antoine, a prominent member of ISSCT and Chair of the then Board of Trustees, proposed establishing a Secretariat during his mandate in 1989-1992. The idea was pursued by Brian Egan during his tenure as Chair of Council in 1992-1995.

At the XXII Congress in Colombia in 1995, the establishment of the ISSCT Secretariat was approved. Of nine institutions having shown interest in hosting the Secretariat, only one application eventuated from the MSIRI, Mauritius. The proposal was accepted by the Executive Committee and the Council. A Memorandum of Understanding was negotiated and signed in at the XXII Congress in Colombia in 1995. By a set of circumstances, Claude Ricaud, Director of MSIRI who had held various positions at ISSCT, the last one being Vice-Chairman of Executive 1992-1995, was about to retire. Both ISSCT and MSIRI agreed that he would be the Permanent Secretary of the Secretariat. The Secretariat was hosted by the MSIRI under a Memorandum of Understanding (MoU) between the two parties. MSIRI agreed to provide support, some financial and other resources to its running, although the Secretariat was located in an office building in Quatre Bornes, 6 km from the MSIRI, as no office space was then available at the MSIRI.

In early 1996 all the records with the HSPA were shifted to the Permanent Secretariat in Mauritius. A letter of thanks on behalf of ISSCT and a plaque to commemorate the first congress was presented to HSPA in 1996.

Jean Claude Autrey, Director of MSIRI at the time of the creation of the Secretariat, was responsible for the implementation of the initial MoU. Claude Ricaud retired in August 2007 after the XXVI Congress and was succeeded by Jean Claude Autrey; he had been active in ISSCT since 1983 and had occupied many positions in the Society including Chair of ISSCT Council 2001-2005. A new MoU was signed between ISSCT and the MSIRI. The post of Permanent Secretary was restyled General Secretary, while the Permanent Secretariat was to be known as Secretariat.

This MoU was renewed at the XXVII and XXVIII Congresses with letters of interest from the Director of MSIRI - in 2012 the MSIRI operated under the Mauritius Cane Industry Authority (MCIA). At the XXIX Congress, the MCIA/MSIRI made known that it was still interested in continuing to host the Secretariat and was prepared to increase its support. However, the ISSCT Executive decided that hosting of the Secretariat should be by bid as provided by the Constitution. The decision of the Executive Committee was approved by Council.

In November 2017, letters were sent to all Affiliated and Institutional members of ISSCT inviting them to make a bid for hosting the Secretariat. As there was only one bidder, the Secretariat was entrusted to the MCIA/MSIRI for six years from 2019 at the XXX Congress in Argentina to the XXXII Congress in 2025 in Colombia, with a review at the Mid-Term Meeting between the XXXI Congress in India and XXXII Congress. Both parties expressed the wish to have the Secretariat hosted by the MCIA/MSIRI. The latter indicated that after the XXX Congress the Secretariat would be housed in a building on the MCIA/MSIRI premises in the heart of the sugar cane industry and that it would provide extended facilities for the running of the Secretariat.

At its meeting held on 29 May 2024 the ISSCT Executive Committee expressed the wish that the Secretariat be entrusted to the MCIA/MSIRI until such time that one of the two parties would express the wish to discontinue the arrangement, with the proviso that a three-year notice period be given to the other party. The parent Ministry of the MCIA/MSIRI was agreeable to host the ISSCT Secretariat until such time that the two parties wish to discontinue, provided that a three-year notice be given to the other party.

The role of the Secretariat as defined in the Constitution is:

- provide a permanent address and focal point for ISSCT;
- coordinate the activities of ISSCT, maintain communication among members and the various bodies of ISSCT, and foster public relations;
- maintain a database for membership and for technical information related to ISSCT activities and the sugar cane industry;
- hold in custody and safekeeping the assets of the ISSCT, including a copy of all proceedings, newsletters and any other records or reports of commissions or committees to be retained by the ISSCT for future use;
- process membership renewals and applications;

- prepare budgets and financial statements, have accounts audited, and implement revenue raising activities;
- support activities and other functions including congress and workshops.

Since its establishment, the ISSCT Secretariat has ensured the smooth running of the Society; this has been warmly acknowledged in each annual report of the Chairs of the Executive Committee. The activities of the Secretariat had been reinforced and broadened to suit the needs and expectations of the membership. Thus, the Website of the Society had been revamped, made more attractive and user-friendly. It is regularly updated to convey relevant information to members. Among other initiatives are online application for membership and settlement of dues which has allowed ISSCT to recover these more efficiently and at less cost.

A Member's Corner was created in 2010 to add value to membership with private information only to ISSCT members. The Proceedings of all ISSCT Congresses have been digitalized and put on-line on the portal for open accessibility. Members are kept regularly informed through emails, circular letters, bulletins and numerous announcements for the main events, i.e. Congresses, Webinars and Workshops. Whenever necessary, links are provided to other websites and sources of information to enable members to keep in touch with the latest developments of the Society, and the activities of the Affiliated Members. The latest development is the creation of a website specific to Sugar Cane Varieties of the World. Documents are issued in English, French and Spanish to cater for the cultural diversity of the membership. The Secretariat provides services 17 hours daily for 7 days per week. The response time is in minutes or hours and rarely exceeds 24 hours. Members of ISSCT have on many occasions complimented the Secretariat for its efficiency and commitment.

Table 3. ISSCT membership, countries and members' participation at Congresses.

Congresses	ISSCT Members	ISSCT Member Countries	Delegates at Congress	Countries at Congress
1924, I, Honolulu, Hawaii, USA	-	-	47	11
1927, II, Havana, CUBA	NR	NR*	159	15
1929, III, Soerabaia, INDONESIA	NR	NR*	145	12
1932, IV, San Juan, PUERTO RICO	589	25	63*(foreign delegates)	20
1935, V, Brisbane, Queensland, AUSTRALIA	510	NR*	100	12
1938, VI, Baton Rouge, Louisiana, USA	815	NR*	293	15
1950, VII, Brisbane, Queensland, AUSTRALIA	548	17	126	11
1953, VIII, Barbados, BRITISH WEST INDIES	796	26	277	23
1956, IX, New Delhi, INDIA	1123	32	287	24
1959, X, Honolulu, Hawaii, USA	1212	31	473	21
1962, XI, Réduit, MAURITIUS	1114	37	357	27
1965, XII, San Juan, PUERTO RICO	1487	52	403	38
1968, XIII, Taipei, TAIWAN	1167	48	469	34
1971, XIV, New Orleans, Louisiana, USA	1565	62	704	57
1974, XV, Durban, SOUTH AFRICA	2081	70	821	32
1977, XVI, Sao Paulo, BRAZIL	2584	75	1631	75
1980, XVII, Manila, PHILIPPINES	1988	76	953	65
1983, XVIII, Havana, CUBA	2233	75	1440	60
1986, XIX, Jakarta, INDONESIA	2056	71	931	56
1989, XX, São Paulo, BRAZIL	1635	70	934	57
1992, XXI, Bangkok, THAILAND	1423	65	784	50
1995, XXII, Carthagena, COLOMBIA	1476	79	850	NR*
1999, XXIII, New Delhi, INDIA	1177	61	610	44
2001, XXIV, Brisbane, Queensland, AUSTRALIA	1134	57	710	51
2005, XXV, Guatemala City, GUATEMALA	1320	63	813	51
2007, XXVI, Durban, SOUTH AFRICA	1212	64	791	63
2010, XXVII, Veracruz, MEXICO	1087	57	611	33
2013, XXVIII, São Paulo, BRAZIL	1448	54	850	41
2016, XXIX, Chiang Mai, THAILAND	1166	60	685	44
2019, XXX, Tucumán, ARGENTINA	1216	64	738	45
2023, XXXI, Hyderabad, INDIA	791	48	523	38

*Not reported

Membership of ISSCT

Under the Constitution there are six categories of members:

1. Individual members: scientists, technologists and administrators concerned with the technical progress of the sugar cane industry.
2. Honorary life members.
3. Affiliated members: national societies of sugar cane technologists, with objects consistent with those of the ISSCT.
4. Associate members: other societies of sugar cane technologists in countries represented by an affiliated member.
5. Institutional members: research institutions, libraries, companies and other organizations which are non-profit making and support the objects of the ISSCT.
6. Corporate members: industrial and commercial organizations, which are associated with the sugar cane industry and which support the objects of the ISSCT occasionally.

Membership of ISSCT has varied widely from one congress to another, as has participation of members at congresses (Table 3).

Table 4. Honorary Life Members of ISSCT.

P.G. Allsopp	Australia	2019	M. Melgar	Guatemala	2010
O. Almazan	Cuba	1983	P.H. Moore	USA	2016
L.J.C. Autrey	Mauritius	2010	T.J. Murray	South Africa	2019
T.G. Cleasby	South Africa	1983	R. Puri	India	2023
J.C. Comstock	USA	2016	P.W. Rein	USA	2005
R.M. Hadipoero	Indonesia	1992	B.C. Ricaud	Mauritius	2005
S. Kartasasmita	Indonesia	1986	P. Rott	France	2023
M.R.L.V. Leal	Brazil	2019	D.M. Sawhney	India	2001
M. Leopairote	Thailand	1992	R.J. Steindl	Australia	2016
E A.L. Lincoln	France	1989	R.J. Stupiello	Brazil	1989
F. Martin	USA	2013	O.W. Sturgess	Australia	1992
V. Mason	Australia	2007			

Those who have passed away

E.V. Abbott	USA	1968	J.E. Irvine	USA	2001
J.R. Allen	Australia	1986	H.W. Kerr	Australia	1974
R. Antoine	Mauritius	1983	C.D. Grassl	USA	1977
G. Arceneaux	USA	1971	N.J. King	Australia	1971
L. Baissac	Mauritius	1965	B.L. Legendre	USA	2005
M.C. Bennett	UK	2001	C.L. Locsin	Philippines	1968
S. Flores Caceres	Mexico	2007	D.T. Loupe	USA	1986
F. Cordovez	Venezuela	1989	G.P. Meade	USA	1971
J.L. Clayton	Australia	1983	H. Morganti	Brazil	1977
H F. Clements	Hawaii, USA	1968	S.G. Patil	India	1999
H.H. Dodds	South Africa	1965	J.M. Paturau	Mauritius	1977
K. Douwes-Dekker	Spain	1974	C.E. Pemberton	Hawaii, USA	1965
J.L. du Toit	South Africa	1974	C.B. Raymond	Philippines	1980
C.W. Edgerton	USA	1965	J. Saint	UK	1965
B.T. Egan	Australia	1995	K. Shoji	Hawaii, USA	1989
A.L. Fors	USA	1995	D. Smith	Puerto Rico	1977
A.G. Gallardo	Mexico	1965	G.D. Thompson	South Africa	1992
K. Gard	Australia	1965	A.J. Vlitos	UK	1986
D.M. Hogarth	Australia	2007	P.O. Wiehe	Mauritius	1974
E. Hugot	Réunion	1974			

Honorary Life Members

Honorary Life Membership of the Society was initiated at the XI Congress in 1962 in Mauritius, and is conferred upon individual members who have distinguished themselves in the sugar cane industry and have made an outstanding contribution to the ISSCT. The first members were elected at the XII

Congress in 1965 in Puerto Rico. At most congresses since then deserving members were conferred the highest distinction of the Society. The number is limited to 25 living recipients. To date Honorary Life Membership has been conferred on 62 members of whom 39 have passed away (Table 4).

Congress bidding and organisation

In the early period from 1924 to 1974, there was no formal competitive bidding for the holding of congresses. At each congress an affiliated member made a proposal for holding the following one which was considered and accepted. If there were more than one proposal, such as happened for the XI and XIII Congresses, where four countries expressed interest, one was eventually selected. The dates of the following congress and associated activities were proposed and accepted so that members knew some three years in advance about the venue and the time which enabled advanced preparations. ISSCT Congress Officers were designated as a General Chairman, a General Vice-Chairman, a General Secretary-Treasurer and in some cases a General Superintendent. For the organisation of Congress itself the congress officers were General Chairman Agriculture, General Chairman Factory, Editor and Assistant-Editor.

These responsibilities evolved over time. From 1999 a formal Congress Operations Manual was introduced together with a bidding system and affiliated members were encouraged to make bids which were in a specific format and was improved with time. At some congresses there were two or even three bidders. The final decision rested with Council after presentation of the bids by the Affiliated members concerned. However, at the last two congresses there was only one bidder. The bid document was comprehensive and encompassed all matters concerning congress and related activities (Pre- and Post- Congress Tours, Trade Exhibition, hotel accommodation, and social activities). Bidders were encouraged to hire the services of a professional congress organising company. The procedure also included a congress host fee paid to ISSCT. The bidding system has led to congresses being better organised and prepared, to the satisfaction of the membership.

The Congress programme usually comprised a Pre-Congress Tour with technical visits and touristic activities, usually over two to three days. Congress was run over four days with an additional day for Plenary Sessions, Closing Ceremonies and Banquet. In the last few congresses, it ran for only four days.

In many instances, post-Congress Tours were held over three days but sometimes owing to lack of interest, there was no post-Congress Tour. If post-Congress Tours were usually held in the host country, in many instances they were held in different countries such as for the XV Congress in Durban, South Africa, where the Post-Congress Tour was in Mauritius. Similarly, for the XXVI Congress in Mexico, the Post-Congress Tour was held in Colombia.

Between Congresses the Congress Organising Committee would send out Newsletters to members to inform them of the various aspects related to the following event; up to seven such Newsletters were mailed to members. When the Secretariat was created the Newsletters were a joint venture between it and the Congress Organising Committee. At some congresses daily Newsletters were published to inform delegates of the various events taking place at congress and related activities, especially social functions. These Newsletters were abundantly illustrated.

In those days Proceedings were published after congresses (see section on Proceedings). The first congress saw mostly themes and discussions of issues; at the following congresses the number of papers presented were: 1927 – 27; 1929-44; 1932-136; 1935- 87; and 1938 - 130, a total of 424. For the period 1950-2023, the number of papers presented at the different congresses is given in Appendix 4. At the XXIV Congress, workshops on Molecular Biology and Processing were held within the Congress, accounting for the high number of papers in those two disciplines at the Congress, 29 for Molecular Biology and 37 for Processing.

Papers

The congresses were essentially about science and technology and there was a call to all members to make presentations. Thus, at the XVI Congress in Brazil, 272 papers were proposed in Agriculture and 114 in Factory, an all-time record number of 386 submissions. There was some sort of review and in the end 198 (73%) were approved in Agriculture and 88 (77%) in the Factory group, totalling 286 which were included in the Proceedings.

Free exchange of scientific and technical information has been at the heart of the philosophy and action of ISSCT since its inception in 1924. This took place initially through papers until the 1980s when posters were introduced at congresses. In addition to papers presented individually or by a group of authors, exchange of information also took place through Panel Discussions, Plenary Sessions, Fora, Keynote addresses and Symposia

Initially there was no review process of submissions. With the increase in their number, a review process was introduced as from the 1970s which became formal with the appointment of an Editor in 2001. It is of note that all editors until today have complained about the poor quality of many submissions in spite of remedial actions which have been proposed over the years. The guidelines for submission of papers have been conveyed to the membership at each congress and were formally incorporated in the original of the TPC Operations Manual of 2013 and which has been updated at each congress.

Posters

Posters have been an integral part of ISSCT congresses since they were presented for the first time at the XVIII Congress in 1983 when this innovation was favourably received by delegates.

Over the years posters have increased in number given the higher status that was given to them to increase their numbers and encourage greater involvement from the ISSCT members. Authors were required to submit a short (1000 words) abstract of their posters and to submit a form as is the case for papers. The posters underwent peer reviewing as part of the process of reviewing all papers submitted to ISSCT.

Numbers of posters were:

- XVIII Congress: Agronomy (6), Plant Physiology (6), Agricultural Engineering (6), Cane Breeding (2), Plant Pathology (8), Factory Engineering (8), Processing (7), By-Products (8) and Energy (3).
- XIX Congress: None.
- XX Congress: 26 posters.
- XXI Congress: 24 posters.
- XXII Congress: None.
- XXIII Congress: Agriculture (6), Molecular Biology (8), Pathology (8), Breeding (10) and Factory (14).
- XXIV Congress: Agronomy (27), Agricultural Engineering (5), Entomology (7), Pathology (6), Breeding (5), Processing (14) and Engineering (8).
- XXV Congress: Agronomy (11), Agricultural Engineering (4), Breeding (8), Molecular Biology (3), Pathology (7), Entomology (5), Processing (9), Engineering (2) and Co-Products (3).
- XXVI Congress: Agronomy (45), Agricultural Engineering (5), Breeding (10), Molecular Biology (5), Pathology (6), Entomology (5), Processing (7), Engineering (4) and Co-Products (1). For the first time there were Posters in the Management Commission (4).
- XXVII Congress: Agronomy (11), Agricultural Engineering (4), Breeding (12), Molecular Biology (4), Pathology (3), Entomology (5), Processing (7), Engineering (5) and Co-Products (11).
- XXVIII Congress: Agronomy (21), Agricultural Engineering (8), Breeding (27), Molecular Biology (15), Pathology (9), Entomology (8), Processing (16), Engineering (9), Co-Products (16) and Management (5).
- XXIX Congress: Agronomy (25), Agricultural Engineering (9), Breeding (19), Molecular Biology (9), Pathology (13), Entomology (15), Processing (17), Engineering (4), Co-Products (8) and Management (8).

- XXX Congress: Agronomy (29), Agricultural Engineering (13), Breeding (25), Molecular Biology (7), Pathology (15), Entomology (4), Processing (12), Engineering (7), Co-Products (7) and Management (7).
- XXXI Congress: Agronomy (26), Agricultural Engineering (5), Breeding (4), Molecular Biology (3), Pathology (2), Entomology (6), Processing (3), Engineering (5), Co-Products (3) and Management (1).

At congresses there were special areas where posters were displayed to make them more visible and the programme included in recent congresses special sessions for poster presentation during which the authors were present to interact with delegates and provide additional information when required. Up to now posters have been displayed on boards, but at the XXXII Congress in Colombia they will be shown on digital screens, a significant improvement that would make them more appealing, the more so that they will be interactive.

Proceedings

The ISSCT has published Proceedings of each of the 31 congresses, providing a great record of development and innovation across the industry. The Congress Organisers initially appointed an Editor who could be from the country where the congress was being held or from outside based on competency of the various persons. Initial Proceedings included not only the speeches, reports and papers but also the discussions held after the presentation of reports and papers. Proceedings were usually published as quickly as possible after each congress and sent by post to all ISSCT members including congress delegates. After some congresses there was a delay of up to three years for the Proceedings to reach those to which they were destined. It was then resolved that Proceedings should be published within 6 months after the close of the Congress.

It was common for Editors to emphasize the difficulties they had to produce the Proceedings, especially when the authors wrote in a language in which they were not totally at ease. At times, many of the papers arrived in a deplorable state, with many of the authors paying no attention to the guidelines on overall presentations, figures, tables, references and in recent years in the required electronic format. Furthermore, many submissions arrived way beyond the deadline. This made editing and publishing a very time-consuming process.

Much progress was achieved at the XXIV Congress in Brisbane when a system of peer refereeing was introduced to improve the overall standard of papers. Referees are also asked to assist authors whose first language was not English. The referees and Section Chairs did an excellent job leading to an increased level in the standard of papers. The then Editor, Mac Hogarth, suggested that all submissions be sent to a central person who would then distribute them to the relevant Commissioners and Section Chairmen. This suggestion was accepted and led to the appointment of an Editor for ISSCT. This post was held by Dr. Hogarth for five Congresses.

When Mac Hogarth retired, the responsibility for editorship was entrusted to Peter Allsopp for the Congresses held in Thailand, Argentina, India and Colombia. With the cessation of printed Proceedings and associated minimisation of page numbers, the page size, font and general layout were changed with more ‘white space’ to give a contemporary look. Although there has been much progress in the submission of papers and posters and their editing, some issues remain such as manuscripts from non-English speaking authors. The advent of the internet and the use of emails especially since the congress in Brisbane have greatly facilitated the movement and handling of manuscripts. Special software such as Dropbox, We Transfer have been useful for the communications of large files.

At congresses until the 1980s authors were very often provided with pre-prints of their papers at congress for checking. However, at the XIX Congress in 1986, Proceedings were handed over to delegates on arrival for the first time. The Proceedings were published in one volume until the 1960s, when it was common to have them in two or even three volumes. At the XXVI Congress in 2007 and at the XXVII Congress in 2010 Proceedings contained on CDs were handed over to participants. At the

following congresses a Proceedings contained on USBs were made available to delegates on their arrival. However, for convenience booklets containing Abstracts of all papers and posters in English, Spanish and French were provided to delegates as from the XXVII Congress in 2010. At the XXXI Congress in 2023 only English abstracts were provided.

To ensure wider dissemination especially of congress papers agreement was reached with four journals for the republication of selected ones: *Sugar Journal* (USA), *Sugar Industry International* (Germany) and *Sugar Tech* (India). *International Sugar Journal* (UK) participated until it ceased publication in 2023. Three libraries were selected as depositories for ISSCT Proceedings, the State Library of Queensland (Australia), the British Library (UK) and the National Agricultural Library (USA).

Plenary Sessions, Panel Discussions, Fora, Keynote Addresses and Symposia

At the origin and the establishment of ISSCT, Plenary Sessions served as the formal backbone of ISSCT Congresses, outlining and discussing both the administrative functioning and scientific vision of the Society. Typically held at the beginning and end of each Congress, these sessions provided a platform for leadership addresses, key institutional decisions, and the adoption of resolutions guiding the Society's development.

At the VII Congress in Brisbane, the plenary format was re-established following World War II, setting a standard that would persist. The first session included official welcomes, the General Chairman's Presidential Address, and a business meeting that adopted amendments to the Constitution. A second plenary closed the Congress with financial reports and the passage of 13 resolutions, including the designation of a permanent secretariat for entomological records and bibliographic initiatives. Subsequent Congresses maintained this dual structure.

At the VIII Congress in Barbados, the plenary sessions were used to review Standing and Special Committee reports and to pass resolutions. Similarly, the IX Congress in New Delhi featured Plenary Sessions where resolutions were passed to revise the Constitution and enhance international coordination. The Plenary at the X Congress in Hawaii addressed recommendations on finance, publication, and the expanding role of Standing Committees. By this time, the plenary had clearly become the principal mechanism for formalizing the Society's direction.

As the Congresses grew in scope, the agendas of plenary sessions became more elaborate. The XI Congress in Mauritius reviewed the activities of multiple Standing Committees, including those on germplasm, disease documentation, and factory control systems. It also formalized new procedures for publications and life membership. At the XII Congress in Puerto Rico, the first plenary included a eulogy and keynote address, while the closing session addressed rising membership, finances, and the structure of future Congresses. By the XIII Congress in Taiwan and the XIV in New Orleans, plenary sessions had expanded to include multilingual considerations, symposia coordination, and the inclusion of international standards. The adoption of key resolutions—on data reporting, publication timelines, and section leadership—highlighted their role as governance instruments. The XV Congress in Durban marked the culmination of this period's evolution. With record participation, the plenary sessions adopted important decisions on membership fees, germplasm funding, disease documentation, and quality standards. The standing and special committee reports presented therein reflected the Society's scientific maturity and institutional capacity.

Throughout the origin and establishment era of ISSCT, plenary sessions provided continuity, legitimacy, and strategic oversight, enabling ISSCT to align its expanding technical agenda with strong organizational governance and inclusive participation. Later, plenary sessions at ISSCT changed to focus more on issues of concerns to the industry and future orientations.

Thus, the technical programme included, in addition to papers and later posters, Panel Discussions, Plenary Sessions, Fora, Keynote Addresses and Symposia which were of high standard and great interest to delegates given the areas that they covered. Sessions at different congresses reflected the

technological evolution as well as the concerns and challenges of the sugar cane industry in the face of evolving international contexts. A wide range of subjects was covered, from cane deterioration, to the international impact of competitive sweeteners on the cane sugar industry, to molecular-based approaches to crop improvement, to potential of sugar cane as an energy source, to nitrate in groundwaters, to strategies for research and technology transfer.

These activities have met their main objectives which were to update knowledge of delegates on important, if not, vital issues, to give rise to interactions through Q&A sessions which brought further light on the issues being considered and, in the end, allow delegates to draw their own judgement on sometimes delicate issues that they had to address.

Workshops

ISSCT Workshops originated from decisions taken at the XVIII Congress in Cuba when it was decided to hold technical workshops in Agricultural Engineering and in Pathology. These workshops were eventually held in Bundaberg, Australia for Agricultural Engineering and at USDA facilities, Beltsville, Maryland, USA for Pathology, both in 1984. They met with huge success and the participants unanimously recommended that they should be continued because they allowed interaction among ISSCT members between two congresses, they enabled exchange of views, discussions, decisions on matters of common and great interest to the disciplines concerned and their cost of participation was much lower than for congresses. More members, especially younger ones, could find the resources to participate in these events. In addition, they led to the establishment of networks which was very useful for common goals.

The ISSCT supported this initiative and provided financial resources for them to be extended to other disciplines. The recommendations for future organisation of workshops were conceived and implemented at the XIX Congress in Indonesia. Formal guidelines were contained in the TPC Operations Manual of 2013 and subsequently updated.

Each of the ISSCT Section Committees proposes a workshop to be held in the inter-congress period (or possibly during a congress) and subsequently to organise and run those workshops. Section Committees can propose a joint workshop provided they share themes of mutual interest. There are no firm rules governing what should or should not be done at workshops, but they should provide significant time for discussion rather than formal presentations. The Chair of the Section Committee is responsible for organising the workshop in collaboration with the committee members. The original guidelines for hosting of workshop were revised and two documents are provided for general guidelines concerning the procedures associated with proposing, approving, financing and organising a workshop. A second document consists of a form, Application to Host a Workshop, available on the ISSCT website as a Microsoft Word document. Announcements are sent by email to all ISSCT members and are posted on the ISSCT Website.

A booklet containing the list of abstracts of presentations made at workshops usually handed over to participants at each workshop. They are also uploaded on the ISSCT website. Reports on each workshop are submitted by the Chair of each Section to the Commissioner and to the Chair of the Technical Programme Committee and are presented at the following Congress. They are included in the Congress Proceedings.

Most workshops were concerned with single disciplines, but combined workshops were also held. Most workshops were held during the inter-congress period, but there were occasions where they were held during congresses, for example at the XXIV Congress in Brisbane for Molecular Biology and Factory Processing. Workshops of the Management Commission were held outside the congresses in South Africa in 2006, in Australia in 2008 and in India in 2011, but to enable greater attendance and for convenience, they were eventually organised within congresses as from the 2016 Congress in Thailand.

Appendix 5 lists full details of the workshops, showing that they were geographically well spread and covered a wide range of themes. Their success is evident by the number of participants.

Workshops form a very important part of ISSCT in providing a unique and effective vehicle for exchange of information and development of personal relationships. They should continue as a routine activity of ISSCT and will be supported and encouraged.

Webinars

During the inter-congress period 2019-2023 because of restrictions on travelling induced by the COVID-19 pandemic, workshops could not be held. Instead, Webinars were resorted to keep ISSCT active and to ensure communication on technical matters with its members (Table 5).

A first Webinar entitled *The impact of COVID-19 on the sustainability of the sugarcane industry worldwide* was held on 20 July 2020 and organized by ISSCT in partnership with Bonsucro Ltd and International Sugar Organisation (ISO). It was a success based on feedback received from some of the over 590 participants from 48 countries.

Table 5. Webinars held during the inter-Congress period 2019-2023.

Commission/ Section	Theme	Date	No. of Registrants	No. of Participants	No. of Countries
Engineering	The contribution of the cane sugar industry for decarbonization	29 March 2022	70	53	17
Pathology 1	Sugarcane streak mosaic virus – research and updates	23 June 2022	42	35	15
Pathology 2	Pathogen diagnostics and surveillance	30 June 2023	39	27	15
Germplasm and Breeding	Technology use in advancing progress in germplasm use for the development of improved cane varieties	7 July 2022	66	54	19
Co-Products	Value adding to bagasse	28 July 2022	65	45	16
Molecular Biology	Genome editing of sugarcane	2 August 2022	54	43	20
Entomology	Advances in proactive and non-chemical sugarcane insect management	18 August 2022	39	30	15
Agriculture	Aspects of agro-ecological approaches in sugarcane farming systems	27 September 2022	69	59	20
Processing	Current factory processing challenges for the international sugar industry	29 September 2022	70	51	21
Total			514	397	

Given the considerable interest and the cancellation of workshops, the Technical Programme Committee (TPC) with the assistance of the ISSCT Secretariat organised nine webinars. Each lasted for 2-3 hours and was held in English. A specific announcement was produced for each webinar, as well as a flyer that was uploaded on the ISSCT website and on social media. Only compliant members, i.e., those who have settled their dues for the period 2019-2023, have participated in the webinars. All the webinars have been recorded and were available on the Cloud until the end of February 2023 to all participants.

Publications

At the XIV Congress in Louisiana, a resolution was adopted commending the Berlin Sugar Institute for its proposal to create a Central Sugar Library and expressing the hope of the Society that it could be put into effect at an early date. The Central Library was established, and co-operation was initiated with

the Tate and Lyle Library and with the Mauritius Sugar Industry Research Institute. However, no detailed program was submitted covering the organisation, administrative, or financial implications of this Library, nor did the Berlin Sugar Institute sent a representative to the 1974 at XV Congress in Durban, South Africa to explain such matters or to reach a working arrangement for co-operative action between the Society and the Library. The operations of the library, the scope of its services to sugar scientists and technical organisations, the various two-way commitments expected, and the many other phases of co-operative arrangements were considered of importance to the Society.

It was recommended to the XVI Congress in Brazil that a committee of three members be established to study the above-mentioned aspects of the Central Sugar Library and to report to that Congress, with recommendations.

The first outline of a long-term project on a sugar bibliography was issued under the title of *International List of Serials dealing with Sugar and Related Subjects*. Four issues of a publication called *New Sugar Titles* were produced with the collaboration of the Mauritius Sugar Industry Research Institute, the Tate & Lyle Group (Research and Development) and 14 libraries. However, as no corporative action could be pursued it was proposed that consideration be given to the establishment of a network library information services whereby any contact made with one library automatically ensured contact with all libraries of the network. It was recommended that sugar libraries around the world be invited to participate in the library network and every effort was made to publicise the existence of the network. This was functional for some years but subsequently lapsed.

Four books by sugar cane specialists have been published under the auspices of the ISSCT by Elsevier:

- Sugar-Cane Diseases of the World, Volume I (J.P. Martin, E.V. Abbott and C.G. Hughes, Eds., 1961)
- Sugar-Cane Diseases of the World, Volume II (C.G. Hughes, E.V. Abbott and C.A. Wismer, Eds., 1964)
- Pests of Sugar Cane (J.R. Williams, J.R. Metcalfe, R.W. Mungomery and R. Mathes, Eds.,1969)
- Diseases of Sugarcane – Major Diseases (C. Ricaud, B.T. Egan, A.G. Gillespie Jr and C.G. Hughes, Eds., 1989)

In 1991 following the Pathology Workshop in Mauritius, a meeting was held with the FAO and the International Board for Plant Genetic Resources (IBPGR) for develop methodsf or the safe movement of sugar cane germplasm. A booklet *Technical Guidelines for the Safe Movement of Sugarcane Germplasm* was subsequently published.

Another book on sugar cane diseases was published by the French CIRAD in 2000 *A Guide to Sugarcane Diseases*. The Editorial Committee consisted of P. Rott, Chairman, (CIRAD, France), R.A. Bailey (SASEX, South Africa), J.C. Comstock (USDA-ARS, USA), B.J. Croft (BSES, Australia) and S. Saumtally (MSIRI, Mauritius), all members of the Pathology Section Committee. A new edition of the Guide supported by ISSCT with updated information due to the evolution on disease identification and diagnosis as well as economic importance will be published in 2026.

Another publication of relevance to sugar cane technology, not published by ISSCT, but widely used by its members, is *By-Products of the Cane Sugar Industry* by J.M. Paturau. It was first published in 1969 and republished many times. J.M. Paturau played an active role in this area at ISSCT and was Co-Products Commissioner for 1986-1989.

Also of relevance is the book by Emile Hugo *Handbook of Cane Sugar Engineering* (1986) and that by Peter Rein (Chair ISSCT Council and Executive Committee 1999-2001) *Cane Sugar Engineering* (2007). Although these were not published under the auspices of ISSCT, they are considered as authoritative in the field of cane sugar engineering.

Newsletters

In the 1950-80s, ISSCT published a Sugarcane Breeders' Newsletter, a Sugarcane Pathologists' Newsletter and a Sugarcane Entomologists' Newsletter. These issues were:

- ISSCT Sugarcane Breeders' Newsletter: No. 1, Dec. 1956 - No. 45, Dec. 1983
- ISSCT Sugarcane Pathologists' Newsletter: No. 1, Sep. 1968 - No. 29, Nov. 1982
- ISSCT Sugarcane Entomologists' Newsletter.

At the XXII Congress in Colombia the revival of technical newsletters was recommended, and the publication of a Sugarcane Biologists' Newsletter was planned. However, only one issue was published as there was no enthusiasm in pursuing this initiative.

Strategic Initiatives

Throughout its evolution, the ISSCT has always thought strategically to ensure the progress of the Society, although the term Strategic Initiatives came formally in the 1990s. From the 1950s the strategic approach consisted of the establishment of committees, including the Constitution Committee, the Standing Committee on Sugar Cane Diseases, the Standing Committee on Germplasm and Breeding, the Standing Committee on Sugar Cane Quality, and the Standing Committee on Agricultural Engineering. These Committees produced reports at congresses.

The Standing Committee on Germplasm and Breeding looked after quarantine, the two World Collections in the USA and India, and produced the Sugarcane Breeders' Newsletter until 1983. One important initiative were expeditions to Indonesia and Papua New Guinea to collect sugarcane germplasm; April-May 1977 in Papua New Guinea clones collected were *S. officinarum* (115), *S. robustum* (83), *S. spontaneum* (22), *S. edule* (9), *Miscanthus* (12) and *Imperata* (1); and April-July 1996 in Indonesia clones collected were *Saccharum robustum* (177), *S. officinarum* (124), *S. spontaneum* (51), *S. edule* (31), *Miscanthus* (40), *Ripidium* (152). These expeditions cost USD 11,000 and USD 26,582, respectively. The clones were quarantined at the CSR facilities in Brisbane and then sent to USDA facilities in Beltsville, Maryland from which they were transferred to the two World Collections in Canal Point, Florida and Cannanore, India. These initiatives allowed the significant broadening of the genetic base for sugar cane breeding programmes as the clones were made accessible to ISSCT members wishing to acquire them.

The Standing Committee on Sugar Cane Diseases updated the list of sugar cane diseases and occurrence in various countries and produced the Sugarcane Pathologists' Newsletter until 1982 and the International Cane Disease Index. Other activities were affiliation with international organisations such as the International Society for Plant Pathology, a Seminar on Problems, Progress and Prospects in Sugarcane Disease Control, and Publications.

The Standing Committee on Sugarcane Quality established a bibliography on sugar cane quality, organised a symposium on *Cane Deterioration* in 1987 and a survey in English and Spanish on problems in Sugarcane Quality worldwide as well as Mechanical Harvesting and its Effect on Sugarcane Quality.

The Standing Committee on Agricultural Engineering was involved in the preparations of approved or preferred methods of evaluating sugar cane harvesters and it defined appropriate terminology and recommended areas of research.

The Resolutions' Committee reported on the above and other issues at each Congress.

In the early 1990s, the major strategic decision was to create the ISSCT Secretariat.

The concept of Strategic Initiatives as such was first coined in 1999 in the report of the Chair of the Executive Committee. It was believed that at time when the world was entering in a new millennium the sugar cane industry was faced with increased competition with the ISSCT members having new

concerns, new needs and new challenges compelling ISSCT to adapt to fulfil these aspirations. It was considered that while pursuing its efforts in promoting technical matters, there is a need to make fuller use of new tools of communication and information technology.

In addition, a survey was carried out for the establishment of an ISSCT database encompassing an Index of all ISSCT Proceedings and publications in sugar technology. The role of the Permanent Secretariat was considered vital to the development of communication through its constantly updated website and other means like emails using the internet for active networking, especially between congresses.

Three Sub-Committees of the Executive were thus set up on Communications, Survey of Members' Expectation and the Future Management of Congress. Among the subsequent actions taken was the circulation of a questionnaire to all office bearers and a sample of the Individual members. 227 questionnaires were sent and 77 were received for analysis by a consultancy firm, two reports were produced on Members' Satisfaction Survey and Future Management of Congress. Amendments were proposed for relevant sections of the Constitution and the Policy and Procedures documents for the future management of Congress and for the appointment of Councillors to ensure better communication with Affiliated Societies and their more efficient participation in the affairs of ISSCT. Amendments were also proposed for improving the nomination of Honorary Life Members and of candidates for election to Executive as well as the appointment of Office Bearers of the Society. New nomination forms were produced for those purposes.

In the early 2000s, among the Strategic Initiatives of the Society was the concept of publishing an ISSCT Journal. Following discussions on a background paper on an ISSCT Journal and e-publication, the Executive Committee decided not to go ahead with the concept but to discuss the issue further with sugar journals promoting a better way to ensure the publication of Members' technical communications including selected ones from congress. Agreement was eventually reached for republication, initially by four Journals. It was also decided to develop an ISSCT Portal on the web which should give access to technical information and communication of importance in sugar cane technology.

A document entitled *Guideline for Councillors* was prepared with the aim of enhancing the participation of the Councillors and the Affiliated Societies in the activities of the Society. An operations manual was also developed to guide the Technical Program Committee.

Following the interesting information obtained from a survey at the XXIV Congress, further surveys of members' satisfaction/expectations were circulated at the XXV and XXX Congresses. The questionnaire analysed by a specialised professional firm. The survey report was placed on the open area of the website and a synopsis in English and Spanish were also included. Many actions ensuing from the survey were initiated as from the XXXI Congress.

Most respondents (89%) had attended a previous congress, 87% rated overall arrangements at the past congress as either excellent or very good, for pre- and post- congress tours 55% of respondents found them excellent or very good, and 11 of 12 areas describing congress scored above 50% in terms of either excellent or very good (the highest score of 76% was for the quality of the Trade Exhibition and the quantity of participants). Most preferred that oral presentation be limited to 20 minutes and on posters respondents were favourable with 64% wanting them to have a 5% presentation in each section.

In general, respondents favoured ISSCT continuing to hold workshops which they found important for their professional activities. Under communication and website which was covered in seven components, most (96%) wanted a regular circular from ISSCT, workshop organisation and participation (96%) and congress organisation and participation (90%). The ISSCT website was occasionally visited by 47% of the members, whilst 30% did so regularly or very frequently.

The Secretariat was rated as excellent with communication with members. There were a series of some suggestions for improving communication with members, but the general consensus was that the communication at ISSCT was satisfactory. Most (89%) expressed satisfaction with congress

proceedings, while 96% were in favour of ISSCT continuing to publish papers in international journals. A high percentage 75% was in favour of ISSCT having its own journal.

A significant strategic initiative was the presentation of Congress Proceedings on CDs at the XXVI and XXVII Congresses, thereby doing away with hard copies, usually difficult to carry by delegates owing to their weight. As from the XXVIII Congress in Brazil, there was a further evolution with the Proceedings being presented on USB external hard drives. Delegates at these congresses were, however, presented with a booklet containing abstracts of all papers and posters in English, French and Spanish. At the XXXI Congress, it was decided to have the booklet with the abstracts of the papers and posters only in English for the Centennial Congress. The Booklet also contained the reports of the Chair of the Council and Executive Committee, the General Secretary, the Chair Technical Programme Committee and the Editor and the complete lists of Office Bearers of Council, Executive Committee, Technical Programme Committee, ISSCT Standing Committees and ISSCT Commissions and Sections, Honorary Life Members past and present and the Congress Organising Committee.

Additional Strategic Initiatives concerned the creation of the Technical Programme Committee (TPC) in 2010 to replace the Technical Coordination Committee, and better relationships with important sugar cane producers, and with the Better Sugarcane Initiative (later Bonsucro). Membership registration and dues were facilitated through an online payment system from 2009.

A strategic initiative concerned the registration of ISSCT as a legal entity. After exploration of different countries' legislation, ISSCT was registered as a private company limited by guarantee in Mauritius in August 2019. I was decided to have ISSCT Ltd removed from the Register of Companies at the congress in India in 2023 since there was no real advantage for the Society with this status which came at a cost. The removal took effect in December 2024.

During its 100 years of existence, ISSCT has tried most often successfully to have its membership reflect on important issues at agricultural, industrial and societal levels as evident in the above-mentioned initiatives. The range of topics shows how the Society is forward-looking to the benefit of its membership.

International Consortium for Sugarcane Biotechnology (ICSB)

The International Consortium for Sugarcane Biotechnology (ICSB) originated from a collaborative initiative in 1988, when sugar cane scientists from Hawaii and Brazil partnered with Cornell University, USA, to assess the feasibility of mapping the sugar cane genome. This effort led to the first international workshop on Sugarcane Genome Analysis, held in 1991 in Beltsville, USA. A key outcome of the workshop was the drafting of a Memorandum of Understanding (MOU) among leading sugarcane research institutions to promote the sharing of information and costs related to sugar cane genome analysis. The MOU was signed by the following founding institutions: American Sugar Cane League; Bureau of Sugar Experiment Stations; Centro de Tecnologia Copersucar; Hawaiian Sugar Planters' Association; South African Sugar Experiment Station; Texas A&M Agricultural Experiment Station at Weslaco; and USDA represented by units in Florida, Hawaii, Louisiana, and Beltsville.

In 1992, a second international workshop was held in Albany, California, during which the group formalized its identity and adopted the name 'International Consortium for Sugarcane Biotechnology (ICSB)'. Three new institutions joined the Consortium at this time: Cenicaña; Florida Sugar Cane League; Mauritius Sugar Industry Research Institute. Over time, the ICSB continued to expand. By 2014, it comprised 18 member institutions from around the world: Argentina: Chacra Experimental and EEAOC; Australia: Sugar Research Australia; Brazil: Centro de Tecnologia Canavieira; Colombia: Cenicaña; Ecuador: Centro de Investigación de la Caña de Azúcar del Ecuador; France/Réunion: CIRAD; Guatemala: Cengicaña; India: VSI and, EID Parry; Mauritius: MSIRI; South Africa: SASRI; Thailand): Mitr Phol; West Indies: WICSBS; USA: Sugar Cane Growers Cooperative of Florida, Hawaii Agriculture Research Center, American Sugar Cane League and Texas AgriLife Research Center. In 2025, the Ecuadorians, EID Parry, the Hawaiians and the Texans withdrew.

ICSB was developed as a non-profit scientific research and development consortium that aimed to: encourage and promote the growth of sugar cane biotechnology including molecular genetics, genomics, and genetic transformation as pure and applied sciences; facilitate the sharing of information and technologies among its members; provide a forum for cooperatively identifying, evaluating, and funding research and development in sugar cane biotechnology that is beyond the scope of the individual members; and promote the general welfare and good fellowship of sugar cane researchers. It has strong links with the ISSCT and has been holding its Business Meetings in countries hosting ISSCT Congresses or Workshops.

The Consortium is coordinated by a Secretary, who manages its operations, and meets annually, usually in conjunction with the International Plant and Animal Genome Conference in San Diego, USA, or in a host country of one of its members. Each member pays an annual membership fee.

ICSB research projects are funded directly by its members. A proposal becomes an official Consortium project only after it is discussed and approved by a majority of voting members and that Members pledge sufficient financial support. Each contributing member signs a standard ICSB contract with the institution conducting the research. The minimum pledge is based on the member's annual sugar production volume. Only members who financially support a project have access to its results and tools.

The ICSB has over the years significantly advanced the field of sugar cane molecular genetics, supporting projects that have led to:

- Mapping of the sugar cane genome
- Development of genetic markers for use in marker-assisted selection
- Gene identification and functional analysis
- Progress in genetic transformation technologies.

Through its collaborative model, the ICSB continues to serve as a central platform for communication, coordination, and innovation, with the goal of improving sugar cane breeding and biotechnology through shared scientific effort.

International Sugarcane Biomass Utilisation Consortium (ISBUC)

Based on the positive experience and the benefits stemming from the creation of the International Consortium for Sugarcane Biotechnology (ICSB), it was decided to set up the International Sugarcane Biomass Utilisation Consortium (ISBUC), the fundamental difference being that ISBUC would include not only research organisations but also commercial companies and other interested institutions. After preliminary meetings in July 2006 in South Africa and in November 2006 in Brazil, a Memorandum of Understanding governing the activities of ISBUC was produced in view of the heightened interest in using sugar cane biomass for the production of fuel, chemicals and value added products and the prospect of collaborative research needed to be considered given the wide range of research opportunities and options that were involved and collaboration could help to bring commercial opportunities to fruition more rapidly.

The aims and objectives of the Consortium were to:

- Promote research into the processing of sugar cane biomass into useful value-added products.
- Establish collaboration among research providers to enhance progress towards commercialisation of useful products.
- Use the input of sugar companies and other industry stakeholders to direct research priorities for maximum benefit.

The rationale for ISSCT to be involved in this venture followed ISSCT's objectives of encouraging interchange of technical information and promoting cooperative research and development. Aims relate to promoting progress through collaboration and pooling of ideas and information, avoiding duplication, leveraging joint activities to increase the research funds available and serving as a central organization

for administrative and communication purposes. ISSCT was seen to also have a role in keeping a technical focus rather than a commercial bias.

The ISSCT Secretariat was instrumental in the organisation of the third meeting of ISBUC in Mauritius in June-July 2009 that was attended by 34 delegates from Australia, Brazil, Mauritius, Réunion and USA.

Following the meeting held at the XXVII Congress in 2010, a Steering Committee comprising Philip Hobson (Queensland University of Technology, Australia), Suleiman Hassuani (Centro de Tecnologia Canavieira, Brazil), Manoel Regis Lima Verde Leal (Centro de Energias Alternatives e Meio Ambiente, Brazil) and the ISSCT General Secretary as the coordinator, finalized a project proposal to develop gasification for high efficiency power and biofuel production in the sugar cane industry: Stage I – Development of enabling technologies and feasibility. A Call for Expressions of Interest (EOI) to which was attached a Non-Disclosure Agreement (NDA) and a Non-Confidential Summary of the proposal was circulated to all ISBUC members. Eleven members signed the EOI and the NDA, following which the full project proposal was sent to them. One member made a formal commitment to provide cash funding to the project.

Given the convergence between the objectives of ISBUC and the Brazilian Gasification Project, discussions were held between its Coordinator Fernando Landgraf of Instituto de Pesquisas Tecnológicas do Estado de Sao Paulo - SA (IPT) and the Steering Committee of ISBUC with a view to reaching an agreement to undertake a common project. However, after protracted discussions and in spite of potential synergies between ISBUC and the Brazilian gasification projects, no agreement was reached for a common undertaking.

After a meeting of ISBUC at the ISSCT Co-Products Workshop in Mauritius er 2015 four groups were established:

- Trash recovery, trash quantification, storage of biomass – Raoul Lionnet
- Cane cleaning, Impact of trash on cane processing (extraction/process) – Steve Davis
- High fibre cane – Salem Saumtally
- Conversion of biomass (impact on boilers/gasification) – Manoel Regis Lima Verde Leal

The Coordinators agreed to set up a network team to help them conduct the activities and to prepare a plan and expected results which were presented at the XXIX Congress in Thailand December 2016. The Working Groups pursued their activities and presented their reports at the XXX Congress in Argentina in 2019. However, owing to lack of resources and interest from many parties, the projects did not materialise and the ISSCT Executive Committee decided to discontinue ISBUC.

Trade Exhibition

A tradition of ISSCT Congresses has been an associated Trade Exhibition. At the VII Congress, mention was made of a Trade Cocktail Party and at the XIV Congress there was a *Partners in Progress Exposition*. At the XVIII Congress in Cuba, 47 commercial firms from 16 countries took part. The exhibitors included producers and exporters of industrial and agricultural machinery. In Indonesia in 1986 the activities of XIX Congress included the Sugar-tech exhibition.

At the XXII Congress in Colombia COC mentioned that the traditional Commercial Exhibition was organized in parallel with the Congress with 66 Corporate members from 15 countries taking part. At the XXIV Congress in Brisbane, the trade exhibition was quite successful with 33 Corporate members including two sponsors CASE IH and CAMECO. The tradition has continued in each successive Congress.

As per the ISSCT Constitution, exhibitors had to be Corporate members of ISSCT. Table 6 gives the number of corporate members at each of the last seven Congresses. Given that Corporate members

subscribe dues to ISSCT which were USD 750 in the early 1980s and now stand at USD 2000 they contribute significantly to the income of the Society.

Table 6. Corporate members.

Congress	Number	Year	Members
Guatemala City, GUATEMALA	XXV	2005	63
Durban, SOUTH AFRICA	XXVI	2007	58
Veracruz, MEXICO	XXVII	2010	77
São Paulo, BRAZIL	XXVIII	2013	115
Chiang Mai, THAILAND	XXIX	2016	75
Tucumán, ARGENTINA	XXX	2019	62
Hyderabad, INDIA	XXXI	2023	68

Finance

ISSCT has generally drawn its income from the dues of the various categories of members: Affiliated, Associate, Institutional, Corporate and Individual. In 1989 Individual membership dues were USD 50, Affiliated and Associated USD 150; Institutional USD 150 and Corporate members USD 1000. Over time there have been increases in the dues which stood in 2023 as Individual membership at USD 140, Affiliated, Associated, and Institutional at USD 300 and Corporate at USD 2000.

Due to the growth in the size of the proceedings from one Congress to another, many host countries received government assistance to help defray costs in the first 50 years of ISSCT. Such aid was not available to the Congress in Louisiana in 1971, and alternative sources of funding had to be found. Consequently, the organising committee for the XIV Congress requested contributions from companies and businesses that heavily depended on the sugar industry or actively participated in it. Some 81 firms made contributions, ranging from $10 to $2,000, substantially supplementing funds otherwise made available for the Congress.

At each congress the financial situation of the Society was considered and presented by the Custodian. In 1995, HSPA which had acted as ISSCT Custodian for almost 60 years resigned following the swift downturn of the Hawaii sugar industry. The Society conveyed its gratitude to the HSPA for its assistance and commitment to the financial affairs of the Society over the years. Accumulated funds (USD 92,000) were transferred to the newly created Permanent Secretariat for its operation and organisation of activities such as workshops.

At the following congress in 1999 in India, it was recorded that with the establishment of the Permanent Secretariat, and the increase in inter-congress activities of the Society, the management of the Society's funds had to be closely monitored. A more precise budget was prepared, with a cash flow to ensure maximum return from the investment of assets, without affecting the necessary liquidity for disbursements. At each congress the Secretariat presented a Statement on Income and Expenditure of the Society and audited Interim Financial Accounts. The reports were scrutinised by the Finance Committee, approved by the Executive Committee and endorsed by Council. The final accounts on the last day of Congress were also audited, scrutinised by the Finance Committee, and approved by Executive Committee at the Mid-Term Meeting before being endorsed by the Council at the following congress. The Secretariat prepared a budget for the following inter-congress period which was considered and approved by the Executive Committee after scrutiny by the Finance Committee and which was then endorsed by Council at Congress.

The reserves of the Society after the XXIII Congress in India were USD 193,790. Table 7 provides the income and expenditure since the turn of the century. In many instances, expenditure exceeded income and was financed from reserves.

Table 7. Income and Expenditure for 1999-2023 in USD.

Congress	Income	Expenditure	Surplus/(Deficit)
1999, XXIII, New Delhi, India	139,419	144,771	(5,352)
2001, XXIV, Brisbane, Queensland, Australia	177,778	136,004	41,774
2005, XXV, Guatemala City, Guatemala	244,328	202,602	41,726
2007, XXVI, Durban, South Africa	253,683	208,032	45,651
2010, XXVII, Veracruz, Mexico	283,741	290,443	(6,702)
2013, XXVIII, São Paulo, Brazil	380,056	401,612	(21,556)
2016, XXIX, Chiang Mai, Thailand	358,997	374,308	(15,311)
2019, XXX, Tucumán, Argentina	306,668	345,468	(38,800)
2023, XXXI, Hyderabad, India	264,401	262,145	2256

CONCLUSIONS

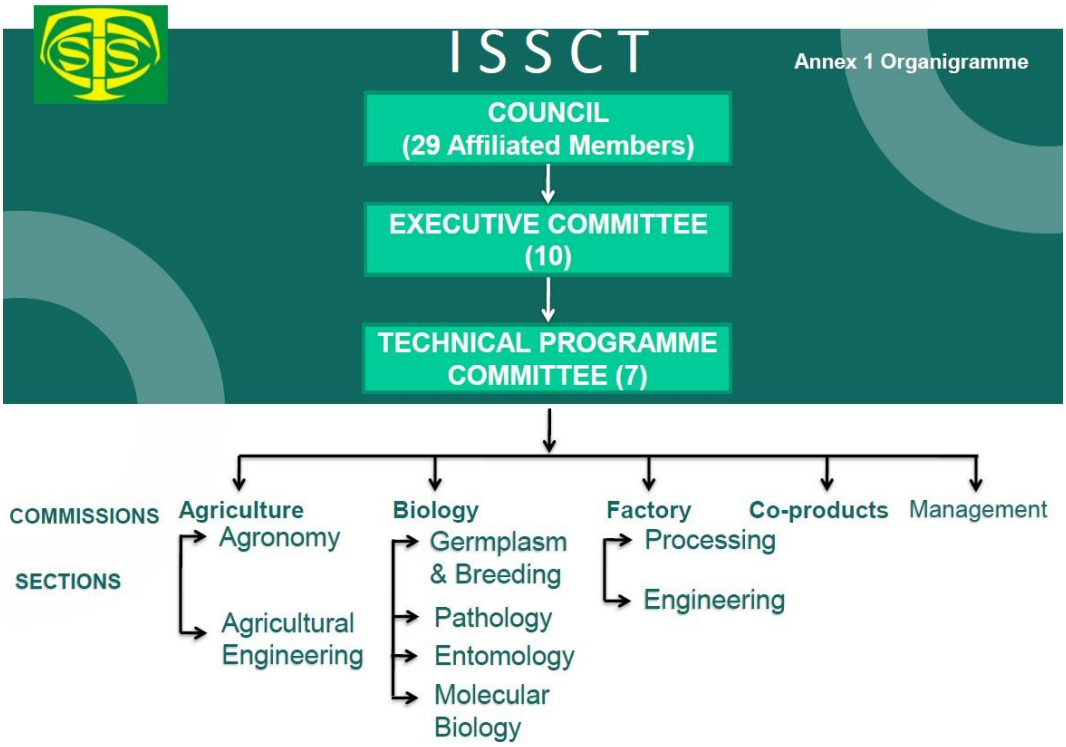
The centenary of the International Society of Sugar Cane Technologists (ISSCT) stands as a profound testament to the enduring value of international scientific collaboration, the resilience of agricultural innovation, and the shared global commitment to the development of the sugar cane industry. Since its inception in 1924 in Honolulu, ISSCT has evolved from a modest gathering of 47 delegates into a global Society representing thousands of scientists, technologists, administrators, and industry stakeholders from major sugar cane-producing regions in the world.

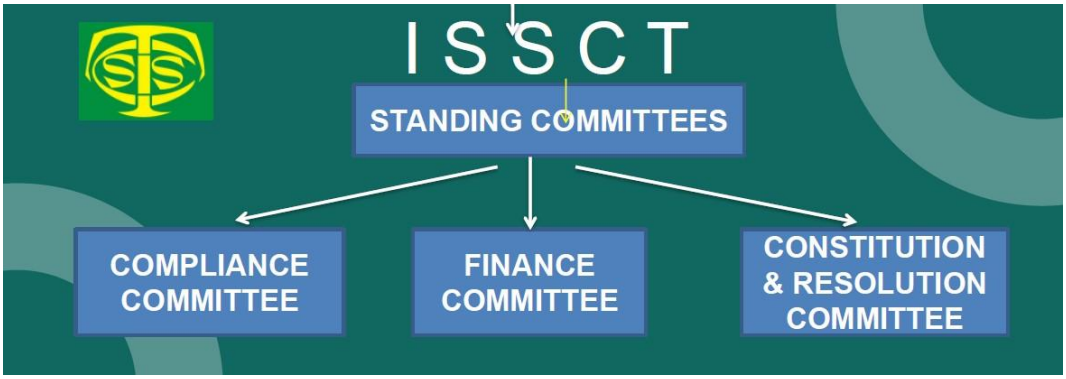
Throughout its 100-year journey, ISSCT has consistently upheld its founding vision to foster the exchange of technical and scientific information for the advancement of the sugar cane industry. Each congress, every workshop, and all institutional interactions have reinforced this mission. From the early focus on quarantine, disease management, and breeding, the Society has expanded its scope to embrace molecular biology, sustainability, energy, co-products, and more recently digital agriculture. The establishment of Standing and Special Committees, the formation of thematic Commissions, the dynamic Congress structure, and the active Secretariat have ensured organizational adaptability in a fast-changing world. Through its strategic initiatives it has been able to address the challenges that lied ahead of it. ISSCT is a unique organisation. No other crop worldwide has such an organisation and ISSCT is the apex one for sugar cane.

ISSCT's legacy lies not only in its rich archive of scientific proceedings and publications but also in the collaborative spirit it has fostered across disciplines, languages, and continents. It has the duty not only to consolidate its foundations but to cross new frontiers to make its membership attractive and meaningful and to be a source of inspiration for other organisations.

As the Society enters its second century, the global challenges it faces are the effects and mitigation of climate change, sustainability in all sugar cane, sugar and co-products production, circular economy, renewable energy, decarbonisation, social and environmental issues, artificial intelligence, technological disruption, sugar markets, etc. These call for even deeper collaboration and innovation. ISSCT must continue to evolve while preserving its foundational strengths: inclusivity, scientific rigor and exchange, and the pursuit of solutions beneficial to growers, researchers, technologists, and communities. Its next century will undoubtedly demand renewed commitments and innovative leadership and one can therefore be optimistic about the future of ISSCT.

APPENDIX 1 – CURRENT STRUCTURE OF ISSCT





APPENDIX 2 – EXECUTIVE MEMBERS FROM 1983

Country	Congress													
	1983-1986* Jakarta	1986-1989 Brazil	1989-1992 Thailand	1992-1995 Colombia	1995-1999 India	1999-2001 Australia	2001-2005 Guatemala	2005-2007 South Africa	2007-2010 Mexico	2010-2013 Brazil	2013-2016 Thailand	2016-2019 Argentina	2019-2023 India	2023-2025 Colombia
Argentina								J. Scandaliaris	J. Scandaliaris	J. Scandaliaris	J. Scandaliaris	J.C. Mirande	J.C. Mirande	J.C. Mirande
Australia	O.W. Sturgess	O.W. Sturgess (Ch)	B.T. Egan	B.T. Egan (Ch)	C.C. Ryan	C.C. Ryan	V. Mason (VCh)	V. Mason (Ch)	P. Allsopp (Ch TPC)			F C. Botha	F C. Botha (VCh)	R. Steindl
Belize	J.G.S. Ometto	J.G.S. Ometto	J.G.S. Ometto	L.E. Maranhao										
Brazil					P. Nogueira	P. Nogueira	P. Nogueira.	P. Nogueira	W.L. Burnquist	W.L. Burnquist (VCh)		W.L. Burnquist	M.S. Carneiro	M.S. Carneiro
Colombia			A. Samper	C. Cassalett	C. Cassalett	J.H. Cock	A. Amaya Estevez	A. Amaya Estevez	A. Amaya Estevez	A. Amaya Estevez	N.J. Gil Zapata	N.J. Gil Zapata	N.J. Gil Zapata	N.J. Gil Zapata (VCh)
Cuba	O. Almazan	O. Almazan	O. Almazan	O. Almazan	G. Galvez Rodriguez	G. Galvez Rodriguez								
Ecuador											R. O. Castillo Torres	R. O. Castillo Torres (VCh)	R. O. Castillo Torres (Ch)	
France									P. Rott	P. Rott	P. Rott (V Ch)	P. Rott (Ch)	FR. Goebel (Ch TPC)	FR. Goebel (Ch TPC)
Guatemala							M. Melgar	M. Melgar (VCh)	M. Melgar	M. Melgar				
Hawaii	K. Shoji	K. Shoji												
India			D.M. Sawhney	D.M. Sawhney	D.M. Sawhney (Ch)	D.M. Sawhney		V. Kumar	V. Kumar	V. Kumar	V. Kumar	S. Awasthi	S. Awasthi	S. Awasthi (Ch)
Indonesia	M. Hadipoero	M. Hadipoero	M. Hadipoero			H. Sjamsir	H.Sjamsir							
Mauritius	R. Antoine	R. Antoine	R. Antoine (Ch)	C. Ricaud	J.C. Autrey C. Ricaud (PS)	J.C. Autrey (VCh) C. Ricaud (PS)	J.C. Autrey (Ch) C. Ricaud (PS)	J.C. Autrey C. Ricaud (PS)	J.C. Autrey (GS)**	J.C. Autrey (GS)	J.C. Autrey (GS)	J.C. Autrey (GS) A.S. Saumtally	J.C. Autrey (GS) A.S. Saumtally	J.C. Autrey (GS) A.S. Saumtally
Mexico								R. Reissner	R. Reissner	R. Reissner	R. Reissner			
Pakistan				A. M. Saleem	A. M. Saleem	A. M. Saleem	A. M. Saleem							
Réunion													B. Siegmund	B. Siegmund
South Africa	G.D. Thompson	G.D. Thompson	G.D. Thompson	P. Rein	P. Rein	P. Rein (Ch)	T. Murray	T. Murray	T. Murray (VCh)	T. Murray (Ch)	T. Murray (Ch)			
Thailand				K. Sooksathan	G. Sukarso							S. Uraichuen	S. Uraichuen	S. Uraichuen
UK	A.J. Vlitos	A.J. Vlitos	A.J. Vlitos											
USA	D.T. Loupe	D.T. Loupe	D.T. Loupe	B. Legendre	B. Legendre	B. Legendre	B. Legendre P. Rein	F. Martin	F. Martin (Ch)	F. Martin	F. Martin R. Gilbert (Ch TPC)	R. Gilbert (Ch TPC)		
Venezuela	F. Cordovez	F. Cordovez												

*Then called the Board of Trustees.
The Executive Committee was first set up at the XIX Congress, Jakarta, Indonesia in 1986, when it replaced the Board of Trustees. The inaugural meeting was held on 30th August 1986.
**The General Secretary is an ex-officio member of the Executive Committee (Permanent Secretary to 2007).

APPENDIX 3 – TCC/TPC MEMBERS, COMMISSIONERS AND SECTION CHAIRS FROM 1983

	Congress												
Position	1983-1986 Jakarta	1986-1989 Brazil	1989-1992 Thailand	1992-1995 Colombia	1995-1999 India	1999-2001 Australia	2001-2005 Guatemala	2005-2007 South Africa	2007-2010 Mexico	2010-2013 Brazil	2013-2016 Thailand	2016-2019 Argentina	2019-2023 India	2023-2025 Colombia
Chair		G.D. Thompson	B. Egan	C. Ricaud	P. Rein	J. C. Autrey	V. Mason	M. Melgar	P. Allsopp	P. Allsopp	R. Gilbert	R. Gilbert	F.R. Goebel	F.R. Goebel
Secretary			B. Purchase	B. Purchase	B. Purchase		D.M. Hogarth	D.M. Hogarth						
Commissioners														
Agriculture	P.K. Moberly	P.K. Moberly	P.K. Moberly	G. de Beer	G. C. Soopramanien	E.P. Richard	E.P. Richard	R. Ng Kee Kwong	R. Ng Kee Kwong	R. Gilbert	B. Schroeder	B. Schroeder	B. Schroeder	H. S. Sandhu
Biology	D.J. Heinz	B.T. Egan	J.C. Autrey	J.C. Autrey	F. Martin	F. Martin	P. Allsopp	P. Rott	W. White	W. White	A. Dookun-Saumtally	A. Dookun-Saumtally	A. D'Hont	A. D'Hont
Factory	L. Lincoln	L. Lincoln	B. Purchase	B. Purchase	B. Purchase	V. Mason	L. Wong Sak Hoi	J. Lewinski	J. Lewinski	R. Steindl	R. Steindl	R. Steindl	R. Steindl	G. Eggleston
Co-Products	J.G. Stupiello	J.M. Paturau	P. Nogueira	P. Nogueira	O. Almazan	O. Almazan	M.R L.V. Leal	M..L.V. Leal	P. Avram-Waganoff	P. Avram-Waganoff	S.J. Hassuani	M.R.L.V. Leal	B.P. Lavarack	B.P. Lavarack
Management								R. Rivalland	A. T. Wynne	F.C. Botha	C. M. Baker	C. M. Baker	K. Redshaw	F.F. Garces Obando
Section Chairs														
Agriculture Commission														
Agronomy	P.K. Moberly	P.K. Moberly	P.K. Moberly	G.C. Soopramanien	G.C. Soopramanien	E. P. Richard	E. P. Richard	R. Ng Kee Kwong	R. Ng Kee Kwong	R.Gilbert	B. Schroeder	B. Schroeder	B. Schroeder	H.S. Sandhu
Agricultural Engineering.	J. C Hudson	J. C Hudson	J. C Hudson	G. de Beer	G. de Beer	E. Meyer	E. Meyer	C. Norris	C. Norris	K. Choonhawong	N.L. Lecler	N.L. Lecler	P. Todoroff	T. Jensen
Physiology	J.E. Irvine	J.E. Irvine	P. Moore											
Biology Commission														
Germplasm and Breeding	D.J. Heinz	T. L. Tew	B. Egan	F. Martin	F. Martin	W. Burnquist	N. Berding	N. Berding	R.O. Castillo	R.O. Castillo	P. Jackson	G. Badaloo	G. Badaloo	G. Piperidis
Pathology	A.G. Gillaspie	B.T. Egan	J. C. Autrey	J. C. Autrey	R. Bailey	R. Bailey	P. Rott	J. Comstock	J. Comstock	S. Saumtally	S. Saumtally	F. F. Garces Obando	N. Thompson	J.H. Daugrois
Entomology	B.E. Hitchcock	P.S.M. Botelho	P. Cochereau	T. Falloon	O. Sosa	P. Allsopp	P. Allsopp	W. White	W. White	R. Goebel	R. Goebel	R. Goebel	J. Beuzelin	J. Beuzelin
Molecular Biology				P. Moore	P. Moore	F. Botha	F. Botha	E.C. Ulian	A. Dookun-Saumtally	A. Dookun-Saumtally	A. D'Hont	A. D'Hont	D. Watt	M.K. Butterfield
Factory Commission														
Engineering	L. Lincoln	L. Lincoln	W. Gellie	W. Gellie	F. Zarpelon	V. Mason	L. Wong Sak Hoi	J. Lewinski	G. Kent	G. Kent	B. Morgenroth	B. Morgenroth	B. Morgenroth	H.S. Bola
Processing	J.T. Lodos	J.T. Lodos	B. Purchase	B. Purchase	B. Purchase	G.R.E. Lionnet	L. Edye	V. Sens	R. Steindl	R. Steindl	R. Steindl	M. Saska	G. Eggleston	G. Eggleston
Co-Products Commission														
Co-Products	Yao-Tung Liu	J.M. Paturau	J. Lois	J. Lois	O. Almazan	O. Almazan	M.R.L.V. Leal	M.R.L.V. Leal	P. Avram-Waganoff	P. Avram-Waganoff	S. J. Hassuani	M.R.L.V. Leal	B.P. Lavarack	B.P. Lavarack
Energy	J.P. Stupiello	I. de Macedo	P. Nogueira	P. Nogueira										
Management Commission														
Management								R. Rivalland	A.T.Wynne	F. C. Botha	C.M. Baker	C.M. Baker	K. Redshaw	F.F. Garces Obando

APPENDIX 4 – NUMBERS OF PAPERS PUBLISHED AT EACH CONGRESS SINCE 1950

Year	Congress	Editor	Agronomy/ Agriculture/ Soils/Field	Agricultural Engineering/ Irrigation	Breeding/ Physiology	Entomology	Pathology	Manufacturing	Engineering	By-products/ Chemical Analysis	Extension/ General	Processing	Symposia
1950	VII, Brisbane, AUSTRALIA	C.G. Hughes	29		6	13	10	27					
1953	VIII, Bridgetown, BARBADOS	K. McCowan	46		22	12	16	24					
1956	IX, New Delhi, INDIA	T. Prasad	46		20	14	18	23	17	13			30
1959	X, Honolulu, USA	Not stated	31		31	21	26	34					
1962	XI, Réduit, MAURITIUS	J.R. Williams	72		25	16	20	34		7	3		
1965	XII, San Juan, PUERTO RICO	J. Bagué	52		48	24	32		12	10		25	
1968	XIII, Taipei, TAIWAN	K.C. Liu		8	27	22	27		14	12		16	15
1971	XIV, New Orleans, USA	M.T. Herdenson	26	20	50	25	26		16	3	6	25	

			Agronomy	Agricultural Engineering	Plant Physiology	Plant Breeding & Germplasm	Entomology	Plant Pahology	Molecular Biology	Factory Engineering/ Energy	Factory Processing	By-Products/ Co-Products	Management/ Workshops reports
1974	XV, Durban, SOUTH AFRICA	J. Dick & D.J. Collingwood	46	10	13	20	21	30		17	40	11	
1977	XVI, Sao Paulo, BRAZIL	F.S. Reis & J. Dick	66	17	29	29	35	20		24	51	12	
1980	XVII, Manila, PHILIPPINES	M. Lopez & C. M. Madrazo	35	27	33	30	23	36		10	35	25	
1983	XVIII, Havana, CUBA	D. M. Rivero & M. Tagle	17	12	10	15	10	15		17	18	15	
1986	XIX, Jakarta, INDONESIA	J.L. Clayton & H. Handojo	16	9	10	14	10	15		16	16	13	
1989	XX, São Paulo, BRAZIL	G. Thompson	15	10	10	15	8	12		22	21	19	
1992	XXI, Bangkok, THAILAND	B. Napompeth & P. Wisarath	12	9	6	12	6	10		17	14	13	
1995	XXII, Carthagena, COLOMBIA	J. H. Cock & T. Brekelbaum	37			18	12	13	19		41	20	
1999	XXIII, New Delhi, INDIA	V. Singh & V. Kumar	13	10		10	7	9	7		30	10	
2001	XXIV, Brisbane, AUSTRALIA	D. M. Hogarth	21	12		8	8	8	7	12	13	11	37
2005	XXV, Guatemala City, GUATEMALA	D. M. Hogarth	23	12		14	8	10	7	12	16	17	6
2007	XXVI, Durban, SOUTH AFRICA	D. M. Hogarth	22	10		11	9	7	8	17	21	23	13
2010	XXVII, Veracruz, MEXICO	D. M. Hogarth	32	6		15	11	10	12	14	25	22	16
2013	XXVIII, São Paulo, BRAZIL	D. M. Hogarth	42	5		20	15	16	13	14	21	25	9
2016	XXIX, Chiang Mai, THAILAND	P. G. Allsopp	18	10		13	12	13	7	11	25	22	17
2019	XXX, Tucumán, Argentina	P. G. Allsopp	27	4		17	9	14	16	18	24	25	8
2023	XXXI, Hyderabad, INDIA	P. G. Allsopp	21	8		15	8	11	6	15	11	14	7

APPENDIX 5 – WORKSHOPS HELD SINCE 1995 AND NUMBERS OF PARTICIPANTS

PERIOD 1995-1999					
Workshop	Theme	Host / Venue	Country	Date	Participants
Engineering and Energy	Engineering and energy workshop on factory design,	Shakarganj Sugar Research Institute, Faisalabad	PAKISTAN	24 - 28 February 1997	120
Agronomy	Irrigation	Bureau of Sugar Experiment Stations, Townsville (BSES)	AUSTRALIA	September 15 to 19 1997	56
Pathology and Molecular Biology		South Africa Sugar Association Experiment Station (SASEX)	SOUTH AFRICA	12-16 May 1997	62
Agricultural Engineering and Factory Processing	Effect of field mechanization on factory performance	Centro de Investigacion y Asistencia Técnica del Estado de Querétaro. A.C.(Ciateq), Veracruz	MEXICO	24 - 28 November 1999	76
Germplasm and Breeding	Efficiency of sugar cane breeding	Mauritius Sugar Industry Research Institute. Réduit	MAURITIUS	18 - 22 May 1998	60

PERIOD 1999-2001					
Workshop	Theme	Host / Venue	Country	Date	Participants
Entomology		Khon Kaen	THAILAND	7-10 February 2000	30
Pathology		CHA-AM	THAILAND	17-23 July 2000	
Agricultural Engineering		Malelane	SOUTH AFRICA	23 - 28 July, 2000	55
Agronomy		Florida	USA	2 - 6 December 2000	61
Breeding	Innovative solutions for future progress - sugarcane breeding and germplasm management strategies	Barbados	BARBADOS	13 - 17 November 2000	56
Energy and Factory Engineering	Cogeneration	Mauritius	MAURITIUS	23 - 27 October 2000	90
Molecular Biology		Brisbane (during congress)	AUSTRALIA	17 - 18 September 2001	
Factory Processing	Sugar losses from mixed juice to market sugar	Brisbane (during congress)	AUSTRALIA	19-20 September 2001	

PERIOD 2001-2005					
Workshop	Theme	Host / Venue	Country	Date	Participants
Factory Engineering	Energy management in raw cane sugar factories	Berlin Sugar Institute in collaboration with MSIRI	GERMANY	7 - 12 October 2002	65
Molecular Biology	Genome analysis and molecular physiology	Centre de Coopération Internationale en recherche agronomique pour le développement (CIRAD)	FRANCE	7 -11 April 2003	25
Germplasm and Breeding	Sugar cane breeding: basic elements and practical applications	South African Sugar Association Experiment Station (SASEX)	SOUTH AFRICA	4 - 9 May 2003	49
Pathology	Advances and challenges in sugarcane pathology	ASSCT in collaboration with Louisiana State University Agricultural Centre and USA Dept of Agriculture Sugarcane Research Unit	USA	11 - 16 May 2003	32
Co-Products	Ethanol production and use	Copersucar Technology Center	BRAZIL	14 - 18 July 2003	58
Agronomy	Opportunities in sugar cane cultivation to confront the new realities in the 21st century	Mauritius Sugar Industry Research Institute (MSIRI)	MAURITIUS	21 - 25 July 2003	47
Agricultural Engineering	Burnt cane v/s green cane mechanization: Agricultural engineering challenges	American Sugar Cane League (ASCL) & American Society of Sugar Cane Technologists (ASSCT)	USA	12 -17 October 2003	49
Factory Processing	New technologies for manufacture of quality sugar	The Sugar Technologists Association of India (STAI)	INDIA	8 - 12 November 2003	45
Entomology	Pest management- new techniques	Sugar Industry Research Institute of the Sugar Industry Authority of Jamaica	JAMAICA	23 - 29 November 2003	32

PERIOD 2005-2007					
Workshop	Theme	Host / Venue	Country	Date	Participants
Pathology	Advances and challenges in sugarcane pathology	Centre de coopération Internationale en Recherche Agronomique pour le Dévelopment (CIRAD) and post-workshop to West Indies Central Sugar Cane Breeding Station (WICSCBS) BARBADOS	GUADELOUPE	23 – 27 January 200 Barbados 30 – 31 January 2006	34
Factory Engineering	Miling and diffusion – theory and practice	Mexican Association of Sugar Cane Technologists (ATAM) under the auspices of University of Veracruz	MEXICO	7 – 10 March 2006	42
Molecular Biology	Molecular biology: the means for driving the sugar industry forward	Mauritius Sugar IndustryResearch Institute (MSIRI)	MAURITIUS	3-7 April 2006	18
Breeding	Pushing the boundaries: innovation in crop improvement	Fundacion para la Investigacion Azucarera del Ecuador andCentro de Investigacion de la Cana de Azucar del Ecuador (CINAE)	ECUADOR	1-5 May2006	36
Entomology	Advances and challenges in sugarcane pest management	BSES Ltd Cairns and post workshop to Ramu Sugar PAPUA NEW GUINEA	AUSTRALIA	14-24 May 2006	24
Agronomy	Integrated agronomic practices to improve/sustain cane productivity	Thailand society of Sugar Cane TechnologistsKhon Kaen	THAILAND	23-26 May 2006	52
Factory Processing	Cane juice purification	The Audubon Sugar InstituteUnder the auspices of the American Society of Sugar Cane Technologists (ASSCT)Louisiana	USA	29 May– 1 June2006	83
Management	Managing change in mature sugar cane industries	South African Cane Growers Association KwaShukela Building, Mt. Edgecombe, Durban, SOUTH AFRICA	SOUTH AFRICA	12 – 14 July 2006	37
Agricultural Engineering	Improving productivity under green cane harvesting	Sociedad Argentina de Technicos de la Cana de Azucar (SATCA)	ARGENTINA	3 – 7 September2006	51
Co-Products	Co-Products as renewable feedstocks for energy, fuels, plastics and other applications	STAB LESTEThe Eastern regional division of the Sociedade dos Técnicos Açucareiros e Alcooleiros do Brasil (STAB)	BRAZIL	12 1- 16 November 2006	29

PERIOD 2007-2010					
Workshop	Theme	Host / Venue	Country	Date	Participants
Management	Advancing sugarcane leading and managing change	Australian Cane Growers Council Ltd. Townsville	AUSTRALIA	27 April - 2 May 2008	34
Pathology and Molecular Biology	Advances and challenges in sugarcane biotechnology and plant pathology	CENGICAÑA	COLOMBIA	23-27 June 2008	44
Factory Engineering	Design, manufacturing and maintenance of sugar mill equipment	COSAN S/A Industria e Comercio	BRAZIL	30 June-4 July 2008	59
Factory Processing	Green cane impact on sugar processing	CERF	RÉUNION	20-23 October 2008	36
Agricultural Engineering	Sugarcane mechanization for profitability and sustainability under environmental conservation	Thailand Society of Sugar Cane Technologists Kasetsart University Kamphaengsaen Nakornpathom	THAILAND	1-6 March 2009	40
Co-Products	After the oil has gone: utilization of sugar cane co-products	STAI, Spray Engineering Devices	INDIA	15-19 March 2009	27
Entomology	Impact of globalization on sugarcane pests, biodiversity and the environment	Estacion Experimental Agroindustrial Obispo Colombres	ARGENTINA	20-25 April 2009	19
Agronomy	Sugarcane production: integration among sugar, alcohol, residue cycling and sustainability	Universidade Federal de Uberlandia	BRAZIL	24-29 May 2009	77
Breeding	Sugarcane crop improvement – opportunities and challenges	Brisbane	AUSTRALIA	17-21 August 2009	70
ISBUC		ISSCT	MAURITIUS	28 June - 4 July 2009	34

PERIOD 2010-2013					
Workshop	Theme	Host / Venue	Country	Date	Participants
Entomology	Recent advances and new challenges in sugar cane pest management	Réduit	MAURITIUS	27 March - 1 April 2011	42
Factory Engineering and Processing	Technologies for profitable cogeneration	Gold Coast	AUSTRALIA	8 - 12 May 2011	57
Germplasm and Breeding and Molecular Biology	Breaking breeding and biotechnology paradigms - towards a complementary approach in sugar cane research	Maceio	BRAZIL	15 - 20 May 2011	148
Management	Effective research analysis and technology transfer using a multidisciplinary approach	Tami Nadu	INDIA	24-24 August 2011	43
Co-Products	Successful utilization of co-products in the sugar industry	Bangkok	THAILAND	19-22 March 2012	70
Pathology	Understanding sugar cane diseases for their efficient management	Nanning	CHINA	7-11 May 2012	66
Agronomy and Agricultural Engineering	Sustainable sugarcane production	Townsville	AUSTRALIA	9-14 September 2012	105

PERIOD 2013-2016					
Workshop	Theme	Host / Venue	Country	Date	Participants
Factory Engineering and Processing		Protea Hluhluwe Hotel	SOUTH AFRICA	24 to 28 August 2014	82
Germplasm and Breeding and Molecular Biology	Pushing the frontiers of sugar cane improvement	Saint-Gilles	RÉUNION	1 to 5 June 2015	69
Entomology and Pathology	Enhancing innovative pest and disease management strategies in the sugar cane agrosystem	Guayaquil	ECUADOR	14 - 18 September 2015	57
Agronomy and Agricultural Engineering	Sustainable solutions to production constraints	Durban	SOUTH AFRICA	24 to 28 August 2015	124
Co-Products	Development of co-products from sugar mill streams and sugar cane biomass	Mauritius Airport	MAURITIUS	30 November - 4 December 2015	69
Management	Boosting sugar industry R&D: current constraints, future opportunities and global trends	Chang Mai (during congress)	THAILAND	8 December 2016	

PERIOD 2016-2019					
Workshop	Theme	Host / Venue	Country	Date	Participants
Co-Products	Full use of sugar cane, residues and wastes – maximizing efficiency and profits	Campinas, São Paulo	BRAZIL	21-24 August 2018	19
Pathology	Challenges and advances in sugarcane pathology – a key to resolve emerging issues and to formulate innovative disease management strategies	Coimbatore	INDIA	3-7 September 2018	56
Agricultural Engineering, Agronomy and Extension	Farming for the future: improving productivity and ecological resilience in sugarcane production systems	Réunion	RÉUNION	23-28 September 2018	98
Factory Engineering and Processing	Processing and engineering options towards more competitive factory operations	Cali	COLOMBIA	1 to 3 October 2018	70
Germplasm and Breeding and Molecular Biology	Improvement of sugarcane for stress environments	Okinawa	JAPAN	22-26 October 2018	113
Entomology	Solving regional arthropod management challenges in a global world	Belle Glade	USA	3-7 December 2018	23
Management	Solving regional arthropod management challenges in a global world	Tucumán (during congress)	ARGENTINA	2-5 September 2019	

PERIOD 2023-2025					
Workshop	Theme	Country		Date	Participants
Germplasm and Breeding and Molecular Biology	The smart sugarcane biorefinery. full valorization of co-products for a sustainable future	Coimbatore	INDIA	8-12 July 2024	81
Agricultural Engineering, Agronomy and Extension	Towards BCG (bio-circular-green) economy: smart farm to drive economic recovery and sustainable sugarcane industries	Pattaya, Chonburi	THAILAND	19-22 August 2024	112
Co-Products	The smart sugarcane biorefinery. full valorization of co-products for a sustainable future	Saint-Gilles	RÉUNION	15-20 September 2024	27
Factory Engineering and Processing	Innovations in the sugar cane industry– enhancing sustainability, quality and efficiency	Berlin	GERMANY	6-10 October 2024	112
Pathology and Entomology	Dealing with sugar cane pests and diseases in the context of regenerative agriculture	Salta and Jujuy	ARGENTINA	25-29 November 2024	78
Management	Anticipating actions and innovations for sugarcane agro-industry sustainability	Cali (during congress)	COLOMBIA	26-27 August 2025	

PART 2

Research Advances and Impact

Agronomy 1924-1938

L Ronald Ng Cheong and Adess Gooljar

ronald.ngcheong@msiri.mu

INTRODUCTION

Research in agronomy during the first six congresses (1924-1938) primarily focused on cultivation, field operations, field experimentation, and soils and fertilization. Indeed, numerous presentations concerned soil-related studies, with crop management emerging as an important topic as from 1938. Field experimentation, in the form of applied statistics, was an equally important theme throughout that period.

RESEARCH ADVANCES

1924 Congress

Discussions were mainly in the form of presentations on regional sugarcane cultivation, with methods of cultivation being outlined for Cuba, India, Fiji, Mexico, Formosa (Taiwan), Louisiana, and Australia. Conditions differed among these countries in terms of green manuring, cover crops, crop rotation and irrigation. Field preparation for planting was also discussed for these countries, encompassing both manual and mechanical methods, as well as type and source of seed canes.

There was a great diversity of soils, fertilizers and agricultural practices outlined among the regions represented. In Australia, cane soils showed wide variation, while the best fertilizer practice was green leguminous cover crops. Cuba and Fiji produced cane on two different types of land with no fertilization, but coral sand and chemical fertilizers were needed in the poorer zones of Fiji. Formosa reported that several field experiments had been conducted on fertilizer requirements and green manuring was considered a valuable practice. In India, cane was grown on different types of soils, which were generally low in organic matter and nitrogen. Use of fertilizers in Philippines was recent, and experiments had shown the yield benefits of nitrogenous fertilizers. Finally, in Hawaii, field experiments had established the profitable limits of fertilization in different regions.

These discussions provide an interesting insight into the cane industry of the time. The cane crop was not usually a monocrop/monoculture since rotation was a common practice. It was also apparent that fewer ratoons were obtained, with the number of ratoon crops ranging between one and four. Inorganic fertilization was still in its infancy in a few countries, and indeed green manuring was widely practiced. The absence of fertilization in some countries is testimony to the fact that soils still had a high level of natural fertility in those early days of cane production.

1927 Congress

Presentations on agronomy aspects were made under the section cultivation and field operations, including soil management and fertilizer use. Different topics had been assigned to specific presenters. The main subjects included soil classification, land preparation and fertilizers.

Soil classification was still a relatively new topic, irrespective of the crop. The relationship between soils and cane yield was emphasized and thus the need for knowledge of soil properties (both physical and chemical) was justified. Soil classification had become a strong and enduring concept, and it was discussed that notable progress had been made in preparation of soil surveys in countries where agricultural experimentation was being undertaken.

Generalization of soil preparation practices was considered a difficult issue as choices would depend on local conditions. The benefits of deep ploughing (to a depth of 3 feet) were questioned, and it was felt that the necessity for proper seedbed preparation through harrowing tended to be overlooked. Trash management was extensively discussed, including practices such as trash incorporation or conservation for moisture retention, as well as the value of trash as a source of nutrients.

The subject which led to most discussion was fertilizers. Interestingly, it was noted that work on fertilizers had its origin through plant diseases, initially probing the relationship between nutrient deficiency and disease outbreak. The chemical nature of the constituents of soil organic matter, which can be useful or harmful to the plant was discussed. Principles for fertilizer experimentation were presented, with NPK applied in the forms of ammonia, phosphoric acid and potash, based on a triangular approach. This methodology was used under sugarcane in different regions of Puerto Rico, where the question of the most appropriate soil test for fertilizer recommendation had also been raised. In Hawaii, experimentation was being undertaken on timing of fertilizer application, as well as plant root growth in relation to nutrients and soil moisture. The need for a scientific approach in cane fertilizer experimentation as well as appropriate soil tests for fertilizer recommendations were thus clearly recognized in this congress.

1929 Congress

Both formal and informal meetings were held during this congress. On the formal side, there were regional reports (in standardized format) on the different stages of field operations and cultivation, presentations on commercial varieties, and a meeting on soil survey. The conclusions concerning commercial varieties were that all countries had the quest for high yields and resistance to drought. However, due to differences in major diseases present in each country, local varieties did not perform well in other countries as they had been selected for local conditions.

Presentations were given on tillage, use of tractors, planting material, and fertilization. The presentation on use of tractor for cultivation predicted the advent of mechanized practices in cane farming, stating that “The modern tractor is on the verge of revolutionizing cane agriculture”, in replacement of farm animals. Ensuing discussions from the different presentations centered on row spacing, weeding, tillage and hilling up, irrigation and green manuring. This was the first congress where research papers were presented in a format resembling current papers, including statistical design and analysis for field experiments. Two papers dealt with plot arrangements for experimentation, as well as variety testing and fertilization trials.

An informal meeting was held to discuss field experiment techniques. It was observed that, in every country represented, some system of plot arrangement of the checker-board type was used. There was a consensus that a regular arrangement was preferable to a random one. Considerable differences existed with respect to plot size, even though 0.05 acre (0.02 ha) seemed to be the size most generally used. The number of replications varied from 5 to 12. Buffer rows between plots were generally not used but the outside rows of the fields were as a rule not included in the experiments, and plot shapes varied from square ones to long and narrow ones.

Compared to the previous congresses, the main innovations in this congress were in the form of papers in standardized formats and the presentation of formal experimental work, including randomized designs and statistical analyses of results. Use of mechanized equipment was also a new topic discussed.

1932 Congress

Three themes were considered under “Agronomics of sugar cane”, each under the responsibility of its own standing committee, namely (1) cultivation and field operations, (2) soils, and (3) techniques of field experiments. All papers had been preprinted and given to attendees, who read them beforehand. At the congress meeting, only the paper title (or a short summary) was read by its author, followed by discussions.

Under the first theme, presentations were made on the sugar industry in the host country, with emphasis on balanced fertilization. The benefits of fertilizer mixtures containing NPK in different relative proportions were discussed, and it was recognized that the mixture leading to highest yield gain was different from the one giving highest economical returns. Some differences of opinion were expressed on trash management and burning, particularly the importance of trash as a source of nutrients and organic matter. Other papers dealt mostly with experimental work on fertilizers (including molasses) and tillage experiments.

The soils section had a component of literature review, with a bibliography on sugarcane soils investigations (1920-1930). Results from fertilizer trials were presented, with the application of Schreiner’s triangle method to determine the most appropriate NPK ratio, while response of soils to fertilizers in relation to length of time under cane cultivation was discussed. The importance of silica as an amendment to increase phosphate availability was reported. Presentations were given on characteristics for soil classification using physico-chemical and other properties. The objectives of soil surveys and classification for the cane crop were questioned by some participants, who thought their purpose should be for soil fertility study to reduce production cost.

Techniques of field experiments were a relatively new subject. Data from trials were subjected to different methods of statistical analysis to determine the most appropriate one. One experiment was reported where trial plots were arranged in a “regular and systematic” way, with other participants recommending applying a randomized layout. Presentations were also made on the use of appropriate experimental methods, field sampling and border effects in field experiments.

In this congress, the importance of amendments with silica was recognized for soils with low silica to iron/aluminium oxide ratio. Experimental results were presented in a more extensive way and the application of statistical techniques was emphasized, with several participants advising their colleagues to apply Fisher’s methods.

1935 Congress

Novelties introduced during this congress included the holding of two symposia on methods of maturity determination and on laboratory methods for soil fertility determination. A joint session was held with Pathology and Entomology sections concerning field experimentation. Three committee reports were presented on labour-saving devices, field experimentation and soils. A meeting was devoted specifically to irrigation and drainage.

A labour-saving device was defined as any method that would perform a certain operation at a lower cost than it had been accomplished previously. These operations were mainly related to planting, crop management, harvesting and transport, and the devices of interest were mechanical implements at a time when animal power was increasingly being replaced by machines. The development of new soil tillage implements and the adaptation of existing ones to suit conditions for cane were also discussed.

The symposium on methods of maturity determination looked at ways to determine peak maturity period of cane, seemingly a very complex problem at the time. Experimental work and methodologies were discussed on issues such as identifying representative portion of the stalk to sample, required number of stalks and use of portable refractometers.

The objectives of the symposium on laboratory methods for soil fertility determination were essentially to determine crop fertilizer requirements. Issues considered were related to field experiments, chemical laboratory methods and physiological methods such as testing of cane juice. The need to conduct both

field experiments and soil tests for nutrient availability was stressed. The absence of universally applicable standard tests for different nutrients was noted because of major differences in soil types.

This congress introduced participants to issues of labour cost and mechanized solutions for cultural operations. The two symposia allowed extensive discussions on two essentials topics: how to determine peak cane maturity to maximize sugar content at harvest and what methodology to adopt to determine the required amounts of fertilizer to apply.

1938 Congress

Presentations were grouped under two main themes, namely field and soil research, and technique of field experiments, with a joint session being also held with the pathology section. Most papers were under field and soil section, broadly grouped as cultural practices, soils and fertilizers, mechanization, and field and laboratory methods.

Cultural practices included a comparison of single versus dual row planting, as well as intercropping in plant cane, in this case paddy rice. Ratooning ability as influenced by stubble deterioration, detoxification of soils through flood-fallowing and windrowing of cane under freezing conditions was also discussed.

As per usual practice, a report was presented by the committee on soils, whereas a chemico-physiological study demonstrated the influence of phosphorus deficiency on growth, sucrose accumulation, nitrogen content and ash constituents. Schreiner's triangle method continued to be used to test response of varieties to different rates of NPK fertilizers.

Mechanization received particular interest, with presentations on cultivation with rubber-tired tractors, fine tuning works on mechanical loading and fully mechanized harvest, land preparation for replanting using new mechanical means, as well as different new implements that could reduce labour requirements in several field operations.

Presentations on laboratory techniques included a comparison of soil analyses with the response of sugarcane fertilization as well as innovative laboratory methods to determine phosphate, ammonia/nitrate, potash, etc. The different methods to determine fertilizer requirements were compared. The authors concluded that it would be best to use a combination of the different laboratory, pot and field techniques available.

Owing to a great diversity in growing conditions, it was not expected that a standard method for field experiments could be devised. Great attention in field experimentation was given to plot arrangement, with disagreements still ongoing between the random and systematic approaches. Concerning plot sizes, it was noted that large plots were needed because of gaps in the cane row, and even though size tended previously to be limited by practical considerations, the invention of field scales could eliminate this problem. Border effect was also discussed, with mathematical adjustment as a possible solution. Finally, issues of representative sampling and proper statistical analysis were discussed.

Even at the time of this sixth congress, the need for predictive capacity (modelling?) was preempted in the report of the committee on field experimentation as "… much less attention has been given to the much more important question of developing a measure of the limitation of past relative yields as a basis for predicting future ones".

PROMINENT CONTRIBUTORS

Henry William (Bill) Kerr (11 papers) was Director of the Queensland Bureau of Sugar Experiment Stations (1933-1945) and first Director of the Sugar Research Institute (1946-1961). He was mainly interested in conducting research in soil chemistry. He introduced field fertility trials and soil experiments at the Bureau, with emphasis on rigorous statistical analysis of experiment results. He sought to improve yield industry-wide through an outreach program to growers on cultivation methods and benefits of fertilizers, with, amongst others, the publication of the "*Cane growers' quarterly bulletin"* (1933). His

other publications included "*The Queensland cane growers' handbook*" (1939, with A.F. Bell). He was a co-founder (and later President) of the Queensland Society of Sugar Cane Technologists. During the Second World War, he supervised the production of foodstuffs for the armed forces. After his retirement, Bill Kerr worked as a sugar industry consultant, providing services to overseas sugar production programs in countries such as Iran, Malaysia, Sri Lanka and Jamaica.

Oswald Schreiner (7 papers) was employed at the USDA for more than 40 years, having initially been appointed as expert in physical chemistry in 1902 at the former Division of Soil Fertility Investigations, and later put in charge of this Division. His work on soils contributed greatly to advances in this field at the USDA. Thus, his team has been recognized for introducing the 'triangle' method of expressing the ratios of nitrogen, phosphorus, and potash in fertilizers. His work also led to the development of a colorimeter (the Schreiner colorimeter) as well as other methods for determining water-soluble plant-food constituents. It is also worth noting that he and his team discovered basic facts on the relationship between rarer elements and plant health. They discovered the effects of soil organic matter in promoting or inhibiting plant growth, as well as the existence of more than 50 new organic compounds in soils, resulting in changes in some fundamental conceptions of the part played by organic matter in crop production.

George Arceneaux (6 papers) was a native from Louisiana, USA where he grew up in the heart of the sugar district. From 1928 to 1950, he was responsible for sugar and agronomic investigations at the Bureau of Plant Industry, Soils and Agricultural Engineering before becoming the Superintendent of the US Sugar Plant Station at Houma, Louisiana. As the Project Leader for USDA research on sugarcane, George Arceneaux headed the Department of Agriculture's sugarcane breeding program and was acknowledged as being a pioneer in the development of new varieties of sugarcane. As such, he helped restore the Louisiana sugar industry by developing improved varieties of cane. After his career with USDA, he founded and directed the International Research Service, a private sugarcane research organization. These consultancy activities took him to several countries, especially Egypt and Dominican Republic.

IMPACT OF RESEARCH

Insights from the I Congress included crop rotation and low inorganic fertilization in a few countries, with green manuring widely practiced. Trash management and fertilization received extensive attention during the II Congress. Fertilizer experimentation using a balanced NPK approach, timing of fertilizer application and the scientific basis for fertilizer recommendations were recognized. The III Congress saw the introduction of a standard format for research papers, including statistical design and analysis for field experiments. Novelties included soil tillage, particularly the use of tractors instead of farm animals, as a precursor to the advent of mechanized practices in cane farming. In the IV Congress, three themes were discussed, each under its own Standing Committee, namely cultivation and field operations; soils; and techniques of field experiments. Further innovations were introduced during the V Congress, namely two symposia on methods of maturity determination and laboratory methods for soil fertility determination, and a joint session with the Pathology and Entomology sections concerning field experimentation. During the VI Congress, two main themes, namely field and soil research, and technique of field experiments, were explored. There was increased interest in mechanization including cultivation, mechanical loading, mechanized harvest, land preparation and new implements. Methods to determine fertilizer requirements were compared and greater attention was paid to plot arrangement and border effect in field experimentation, as well as issues of representative sampling and proper statistical analysis.


The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Agronomy 1950-1974

Abraham Singels and Jan Meyer

abraham.singels@gmail.com

INTRODUCTION

This paper reviews the main topics studied and key advances reported at the congresses held during the period 1950-1974 and considers the impacts thereof on global sugarcane production. Agronomy papers presented during this era dealt with various crop production aspects such as land preparation, planting, soil management and crop nutrition, crop water use and irrigation, weed control, growth regulation and cane quality management, and related disciplines supporting these aspects such as crop physiology, agrometeorology and soil science.

RESEARCH ADVANCES

General agronomy

The initial (1950-1962) focus was on general agronomy, with papers comparing various practices in the different parts of the world (South Africa, Hawaii, Haiti, Jamaica, India, Puerto Rico, etc.). For example, Evans (1962) reviewed sugarcane agronomy extensively, covering topics such as planting, weed control, soil cultivation, fertilization and crop nutrition, irrigation, harvesting, as well as sugar metabolism research.

Crop establishment

Early papers also focussed on efficient crop establishment. The form of seed used (budded setts, shoot sets and seedlings) was assessed, as well as planting time, planting density and row spacing (for example Hebert 1956). Positive yield responses to higher bud densities and narrower row spacings had to be balanced against increased costs and other practical limitations. Research on the effect of soil temperature on germination rate and shoot emergence (Clements and Nakata 1965) enabled the determination of optimal planting times in different parts of the world.

Crop nutrition

There was a strong focus on gaining a better understanding of nutrient requirements of crops to achieve high yields, good cane quality and efficient fertilizer use. Research revolved around analysis and interpretation of soil and foliar chemical information, and on fertilizer products and application methods.

Soil testing

The advances made post war in chemical analysis using electronic laboratory equipment such as flame photometry and ultraviolet and visible radiation spectrophotometers. Compared with the slow classical

methods based on gravimetric and titrimetric analysis, have enabled soil chemists to improve the basis of soil testing for improving fertilizer advice and economic returns to the grower.

For example, Du Toit (1953) reported that fertilizer advice in South Africa was based on results from a series of NPK trials conducted over a wide range of soils. The approach was the prevention of soil nutritional deficiencies using soil tests, rather than blindly building up soil nutrient reserves. A Fertilizer Advisory Service for growers was established in 1956 using a range of soil test techniques that were calibrated from observed yield responses to phosphate and potash applications. In a follow up paper (du Toit 1968), it was reported that the service played a major role in reducing excessive fertilizer usage, thereby reducing production costs and often increasing yields.

Crop logging and foliar diagnosis

A paper presented by Halais (1950) is a good example of the early work he started in 1936 in Mauritius to prove the usefulness of foliar diagnosis for predicting the nutrient status of sugarcane by correlating the nutrient content of leaves with field response to fertilizers, in order to establish some of the first optimum nutrient threshold values for determining the N (nitrogen), P (phosphorous) and K (potassium) requirements of sugarcane.

The system of “crop logging” received much attention during this period. Clements (1953, 1959, 1971), Humbert (1953), Samuels *et al.* (1953) and Moir (1956) analysed tissue of various parts of the plant periodically to determine the nutritional and moisture status of the crop and how this related to yield and cane quality. A better understanding was gained of the influence of crop age, time of year, rainfall and temperature on the nutrient and moisture contents of the different plant parts. Indices were developed to quantify N, P and K (and other nutrients) requirements to aid fertilizer management of the crop.

Samuels (1956) reviewed the use of foliar diagnosis in Puerto Rico, identifying benefits and challenges. He demonstrated that different laboratory methodologies caused significant variation in test results (e.g. up to 23% for K tests) and that these factors should also be considered when assessing plant analyses.

Evans (1965) in a later review concluded that the foliar diagnostic technique was suitable to determine nutritional status for essential macro and micro elements. The crop logging system can be considered the precursor of modern foliar diagnosis, which is a crucial element of contemporary crop nutrition management.

Fertilizer use efficiency

Excellent review papers at the 1953 congress covered crop nutrition aspects of sugarcane production in Hawaii and Jamaica. Research in Hawaii covered aspects such as N and P dynamics in the plant, and fertilizer application methods (Humbert 1953). Reference was made to fertigation for irrigated cane, as well as flying on late dressings of potash on K deficient fields. Mention was also made of the increasing need for checking micro-nutrient levels in sugarcane.

In Jamaica, sugarcane was produced on a complex range of soils with varying climate. Fertilizer policy was determined by the accumulated results from NPK field experiments, and by relative leaf analysis. N was found to depress juice quality, but this effect was secondary to the beneficial effects on yield response. The former could be partly countered by the application of potash in K deficient areas.

Against a backdrop of rising fertilizer prices as well as limited availability of N, Humbert and Ayers (1956) reported a rapid conversion to the use of aqua ammonia in Hawaii, because of substantial savings in material costs, methods of handling, and more effective application of nitrogen fertilizer in the field. The bulk of aqua ammonia purchased in 1954 and 1955, was applied in irrigation water on the irrigated plantations by injection equipment on both irrigated and rainfed plantations.

The growing popularity of anhydrous ammonia as a source of N nutrition for crops in the United States, prompted Govinda Rajan (1956) from India to undertake a series of small-scale trials to investigate the efficacy of anhydrous N on a range of soil types. He concluded that anhydrous N nitrified more rapidly than ammonium sulphate, especially in light textured soils where its application should be limited as the potential for N loss through leaching and volatilisation was also very high.

Schroo (1953) presented findings concerning the efficient application of phosphatic fertilizer on acid high P fixing latosols in Trinidad, that typically occur on soils underlain by basaltic parent material or in areas with high rainfall. Recommendations included application of single super phosphate in the planting furrow rather than broadcasting it, and incorporation of rock phosphate carriers in acid soils to raise soluble P concentrations.

Cane-root experiments showed that after harvest, the original root system soon ceases to function and dies and that there is no measurable nutrient and water uptake by these old roots (Baver 1962). New roots develop rapidly. Practical application of this knowledge has resulted in more rapid growth of ratoons when aqua ammonia and phosphate were placed as close to the stool as possible.

Soil management

Beater (1959) described how the South African Sugar Industry embarked on an aerial survey of the whole sugar industry. The resulting maps have been used to conduct a detailed soil survey of the industry at a 1:6000 scale based on 17 geological soil groups. Farm maps enabled growers to better conform cane field boundaries with soil boundaries, thereby minimising spatial variation within a field. Knowledge of soil type enables the user to interpret different soil properties that are helpful in agronomic decision-making, from land use planning to irrigation planning and control.

Hare (1962) investigated the effect of soil physical conditions on the nutrient uptake, crop growth and yield. It was shown how increasing water content in a well-aerated soil increased K uptake, but waterlogging decreased uptake of K as well as other nutrients. Reduced vegetative growth due to water stress and soil compaction was shown, and a negative correlation between compaction and yield performance was established.

Gosnell (1971) from Zimbabwe studied the effects of water table height on cane growth and development using lysimeters and found that a 25 cm deep water table inhibited germination at planting and ratooning, and caused large reductions in root mass, stalks number, stalk height and cane yield. Salinization of the soil occurred about 25 cm above the water table in all treatments due to the transmission and deposition of salts through capillary action.

Ramdial (1974) from Jamaica presented an interesting paper dealing with the possible mechanism for the leaching and redistribution of water and salts in heavy vertisols. His field studies showed that salts accumulated along crack edges and throughout the entire ped as the crack depth increased. However, irrigation with saline water leaches these salts, thus retaining continued good growth and productivity of sugarcane grown on these cracking clays.

Weed control

Weed control received attention throughout the period, with research focus gradually shifting from cultural methods of control to chemical interventions to combat problem weeds such as Johnson grass, *Cyperus* spp*., Cynodon* spp*., Digitaria* spp. and others. Papers from India, Louisiana, South Africa and Puerto Rico dealt with herbicide efficacy, phytotoxicity, and timing and method of application of products such as 2,4-Dichlorophenoxyacetic acid (2-4-D), trichloroacetic acid (TCA), atrazine, diuron and paraquat. Shaw (1968) provided an excellent review of weed control practices, highlighting the need for integrated control, herbicide efficacy, cost-effectiveness, and safety to humans and environment.

Water relations and irrigation

Irrigation is an important aspect of sugarcane production. Efficient use of irrigation water, a limited resource, requires knowledge about crop water use (evapotranspiration, ET) and its relation to yield, and this topic was researched thoroughly during this period. Some basic research projects studied aspects of the soil-plant-atmosphere system to improve understanding of crop water relations.

An important line of research was dedicated to developing methods for determining rates of actual (ETa) and potential ET (ETp) as affected by soil, plant and atmospheric factors. Cowan and Innes (1956) measured sugarcane ETa in Jamaica using lysimetry, and reviewed methods of estimating ETp from weather data. Hargreaves (1956) proposed a formula for calculating potential sugarcane ET from weather factors and related this to pan evaporation (Epan), to enable application worldwide. Chang and Wang (1968) found that stalk elongation rates were strongly correlated to ET rates, that cane yield was strongly correlated to growing season ET, that evaporation pan factors (the ratio of ETp to Epan) varied with growth stage, that ETp varied little with soil type, and that evaporation from soil for full canopy cover crop is about 10% of ET.

Thompson (1965) attempted to resolve variability in reported crop evaporation factors (the ratio of ET to open water evaporation Eo; Penman 1948) ranging from 0.57 in Jamaica to 1.71 in Australia. ETa was measured with weighing lysimeters and related to weather data. Full canopy ETp was found to roughly equal A-Pan evaporation, and to exceed Eo, due to effects of advection and the roughness of the crop. The inconsistent ratio of net radiation to incoming radiation was also highlighted. Early and Gregorio (1974) confirmed crop factors for Philippines, ranging from 0.48 to 1.23.

Thompson and Boyce (1971) evaluated various forms of the Penman equation (Penman 1948) for estimating ET from weather and crop parameters. Weekly ET was measured using weighing lysimeters at two sites in South Africa. Crop and weather parameters for the various equations were measured or derived. The Penman-Monteith (PM) equation (Monteith 1965) predicted measured ET the best. The authors noted that the PM equation is able to predict ETa for diverse situations because it accounts for the effects of crop surface characteristics, soil water supply and evaporative demand. However, the authors recommended that for practical irrigation management, the crop evaporation factors and A-pan evaporation measurements be used to estimate ETp.

Nowadays, the PM equation is the accepted standard for predict ETp and ETa for many crops, including sugarcane. It is employed in crop models that are widely used to support planning and management of sugarcane production.

This period also saw the progression from surface flood irrigation as the dominant means of irrigation to more efficient drip irrigation systems, enabling profitable sugarcane production on marginal soils and areas.

Other research focussed on the effects of water logging and high water tables on cane yield, and leaching of salts from the soil profile.

Plant physiology

Labelled isotope studies in 1953 and 1962 advanced our understanding of translocation of photosynthate and remobilization of nutrients in the plant. It was found that photosynthate moved rapidly to all parts of the stool and that nutrients also moved freely throughout the stool to where it was required. Effects of water and nutrient deficiencies and temperature on translocation were also studied.

Bull (1965) explored differences in morphology and temperature responses for different *Saccharum* species, providing new insights into genetic and environmental control of growth and development processes.

Glasziou and Bull (1965) advanced understanding of enzymatic control of internode extension and sucrose metabolism, encapsulating the knowledge in a model. Hartt and Burr (1965) presented a key paper on photosynthesis and effects of crop and leaf age, nutrient and water status, temperature, radiation and atmospheric carbon dioxide.

Shaw and Innes (1965) conducted comprehensive growth analysis experiments to investigate effects of planting time, irrigation and nitrogen on biomass accumulation and partitioning, for different varieties. Highest yields (and highest stalk density, length, diameter and weight) were achieved by crops experiencing favourable climate (occurring during the summer solstice) during the first 30 weeks of the crop cycle.

These studies advanced our understanding of growth and development, and biomass accumulation and partitioning at phytomer and crop level, and how these processes were influenced by external factors. This enabled the development of mathematical models of sugarcane growth and development, that eventually contributed significantly to improved planning and management of sugarcane production. Bull and Tovey (1974) presented the first process-based crop simulation model for sugarcane to integrate physiology knowledge with weather and soil data, to gain a better understanding of yield limiting factors.

Cane quality

High sugar yields require careful management of cane maturity (best quantified by cane sucrose content and/or juice purity) before harvest and the quality of the cane (enabling cost effective recovery of sucrose) thereafter. It was recognized that knowledge of the maturity status of standing cane was fundamental in managing the crop to achieve the desired maturity status at harvest. Garza (1968) analysed long term climate data and crop data to develop a maturity index based on accumulated daily temperature range, reflecting the influence of cool night temperatures on the sucrose accumulation process. Other studies explored various parameters for monitoring cane maturity in terms of accuracy and practicality. These included the glucose ratio brix content of the juice in different parts of the stalk, as well as moisture content in different parts of the stalk (Moir 1956). Two papers in 1974 found juice brix readings to be the most practical estimate of cane maturity status. This approach is still used e.g. in South Africa to determine cane maturity for assisting with decision-making around ripening and harvesting. Green leaf number was also identified as a practical indicator of cane maturity.

Cane maturity can be enhanced by suppressing cane growth through deficit irrigation or by application of chemical ripeners. Gosnell and Lonsdale (1974) investigated the effect of deficit irrigation of different severities and durations on cane maturity and sugar yields. The optimum duration and severity varied with time of year (which determined initial maturity status). Chemical ripening first received attention in 1962 (Evans, 1962) and again later in the era (Yates 1971; Rostron 1974). Variety responses to various chemicals were tested with some promising results.

Quality of harvested cane also depends on harvesting methods and time from harvest to crush. The ideal topping height (for maximum recoverable sugar) depended on time of year and the maturity of the crop (Wood, 1974). The detrimental effect of the inclusion of crop residue (leaf material) in harvested cane on cane quality was also reported in several papers.

Research further provided insights on cane deterioration after harvest, and the importance of limiting the time from harvest to crushing. Hes (1950) studied changes in cane composition after harvest to gain a better understanding of cane deterioration processes. Coleman (1953) found that respiration rates in harvested cane differed between bottom and top parts of stalks, and that it was strongly related to temperature. Turner (1959) found that weight loss in harvested stalks increased with increasing crop age and that juice purity declined slowly at first, and then rapidly after 5 days.

Yield decline

The phenomenon of “varietal” yield decline was perceived as a major problem worldwide during this era, and research was initiated to identify causes and remedies. Findings from reviews and experiments were reported in a symposium held in Honolulu in 1959. Soil physical (compaction), soil chemical (loss of organic matter) and soil biological factors (soil fauna), as well as diseases (ratoon stunt disease), were proposed as potential causes. Results from a long-term field experiment in Louisiana demonstrated the benefits of incorporating harvest residue into the soil, and of crop rotation with legumes. Long-term effects of harvest residue retention were also demonstrated in South Africa, but not in Australia.

Stokes and Ashley (1956) found that yields of ratoon crops depended on harvest age and harvest time of the preceding crop. The hypothesis offered was that high-yielding crops stored more reserves in the stubble, which enabled a better regrowth in the subsequent ratoon. Research by Shoji and Samuels (1965) found that a long-term decline in sucrose yields observed in Puerto Rico could be explained by climate trends, an increasing length of the harvesting period, and increasing amounts of crop residue in cane deliveries over this period.

The initial research around yield decline revealed the complex nature of the problem. Although several potential causes were put forward, it became clear that further research was needed to gain clarity and develop remedies for this growing threat.

PROMINENT CONTRIBUTORS

George Samuels of Puerto Rico presented 12 papers, mostly on crop nutrition. He and his co-workers conducted excellent research to gain a better understanding of the nutrient dynamics in the plant and how this knowledge can be used to improve fertilizer practices.

Harry Clements of Hawaii presented several papers on the development of a “crop logging” system to track crop status. Weather conditions, crop parameters and levels of macro- and micro-nutrients were recorded and used to guide crop management. This ultimately led to improved understanding of how climate and nutrient levels controlled crop growth and status.

H. Evans did valuable work to fine-tune methods for sampling and analysing plant tissue for macro- and micro-nutrient levels to determine crop nutrition status and fertilizer requirements.

IMPACT OF THE RESEARCH

In conclusion, the period between 1950 and 1974 witnessed significant strides in sugarcane agronomy research. Studies in crop establishment, weed control, irrigation optimization, yield decline, cane quality and crop physiology contributed significantly to shaping contemporary sugarcane cultivation practices.

Results from the many NPK fertilizer trials and the development of crop logging improved understanding of crop nutritional response, and helped to calibrate soil and leaf test procedures, laying the foundation for improved fertilizer advice with more balanced fertilizer usage, better choice of fertilizer carriers, timing of application and placement.

Notable advances were also achieved in the knowledge of crop water relations and the physiology of biomass accumulation and partitioning. This enabled significant improvements in irrigation efficiency, and improved management of cane maturity and cane quality. The groundwork was also laid for future modelling of crop growth processes, an area that held great promise for aiding the planning and management of sugarcane production.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Agronomy 1975-1999

Hardev Sandhu and Amandeep Sharma

hsandhu@ufl.edu

INTRODUCTION

In celebrating the 100th anniversary of the ISSCT at the 2025 congress in Colombia, this paper provides an overview of agronomic research on various aspects of sugarcane cultivation that was presented in the ISSCT Congresses, and workshops held from 1977 to 1999.

Eight congresses were held during this period: in São Paulo, Brazil (1977), Manila, Philippines (1980), Ciudad de La Habana, Cuba (1983), Jakarta, Indonesia (1986), São Paulo, Brazil (1989), Bangkok, Thailand (1992), Cartagena, Colombia (1995), and New Delhi, India (1999). The major Agronomy research areas identified from presentations in these congresses were crop nutrient management, irrigation management, weed management, planting practices, sugarcane harvesting, and ratoon management.

RESEARCH ADVANCES

Nutrient management

Researchers during this period focused on understanding nutrient requirements, optimizing fertilizer application, and improving crop yields.

In the 1970s and 1980s, studies explored the role of essential nutrients such as nitrogen, phosphorus, and potassium in sugarcane growth. Researchers aimed to establish balanced fertilization practices to enhance both yield and sucrose content. Field trials and soil analyses were common methodologies used to refine nutrient management strategies. As the 1990s unfolded, there was an increasing emphasis on sustainable and environmentally friendly approaches. Integrated nutrient management gained attention, incorporating organic amendments and biofertilizers. This decade marked advancements in precision agriculture technologies, allowing for more precise nutrient applications tailored to specific crop needs. Additionally, there was growing awareness of micronutrient importance, with studies delving into the role of elements like zinc and boron in sugarcane nutrition. The aim was to address micronutrient deficiencies that could limit crop productivity.

During 1977-1999 congresses and workshops, studies were presented on N fertilizer use efficiency in plant cane and ratoon crops (Chui and Samuels 1977), the effect of N dose and application timing on sugarcane yields (Fasihi and Malik 1980; Fogliata and Gargiulo 1977; Ng Kee Kwong and Deville 1992), N fertilization response to soil physical and chemical properties (Zambello *et al.* 1986), and N losses in the soil (Wood *et al.* 1989, Ng Kee Kwong *et al.* 1999). Researchers also looked at different methods of N application (e.g. top dressing versus buried, fertigation) for their effect on N losses through leaching or volatilization (Pinna and Valdivia 1977; Tsai *et al.* 1992).

Research on phosphorus was mainly focused on its availability in the soil (Wang *et al.* 1977), calibration of its extraction methods (Marinho and Albuquerque 1977), diagnostic criteria to estimate P fertilizer

requirement (Villegas *et al.* 1986), and the effect of P fertilizer application on sucrose content (Perumal 1992) and residual levels in the soil in long term (Wang and Fang 1986). Potassium research was focused on K fixation or availability in the soil (Naamatalla 1989; Naidu *et al.* 1992; Wood 1992), improvement in K crop requirement (Duvenhage and King 1996), and sugarcane response to K application (Perumal 1992).

Micronutrient research was primarily focused on manganese and zinc. Studies from the United States and India reported manganese availability in sugarcane soils (Gascho *et al.* 1977) and its effect on sugarcane growth (Gupta and Rao 1980). In China, Juang *et al.* (1977) reported the effect of zinc application on plant uptake and yield in sugarcane.

In the 1990s, the studies were focused on overall sugarcane nutrition programs including advances in leaf analysis techniques (Schroeder *et al.* 1992), sugarcane nutritional analysis program (SNAP) (Lentini *et al.* 1996), and indicators of nutrient assimilation and sucrose content (Perumal 1996).

There were few studies on vinasse application in which researchers looked at its effect on soil pH and exchangeable aluminum content (Rodella *et al.* 1983), soil properties (Mazza *et al.* 1986), and nitrogen water table pollution (Orlando *et al.* 1996).

Overall, the research landscape in plant nutrition for sugarcane during the 1980s and 1990s witnessed a transition from basic nutrient studies to more holistic and sustainable approaches, contributing to improved agricultural practices in the cultivation of sugarcane.

Irrigation management

Research on sugarcane irrigation management presented at the ISSCT congresses and workshops from 1977 to 1999 focused on optimizing water use and improving irrigation efficiency. The period saw significant advancements in both surface and drip irrigation systems, with a strong emphasis on optimizing water management to address the challenges of irregular rainfall and the high water requirements of sugarcane.

Topics included the development of scheduling systems for irrigation (Sheu and Yang 1986; Vázquez *et al.* 1983), the effects of different irrigation methods on sugarcane yield (Susa and Scardua 1977; Batchelor *et al.* 1989), identification of varieties for different moisture conditions (Hellman 1977; Yang and Chen 1980; Singh and Reddy 1980; Naidu *et al.* 1983; Viqueira *et al.* 1983), and strategies to manage water under drought conditions (Shih *et al.* 1977). Additional factors such as green versus burnt cane harvest and their interactions with irrigation level were studied in a long-term study in Zimbabwe (Gosnell and Lonsdale 1977). Advanced technologies such as neutron probing were evaluated in irrigation control/scheduling by Sheu and Yang (1986).

These studies were crucial in addressing the challenges of water scarcity and improving crop productivity in various regions, contributing significantly to sustainable sugarcane cultivation practices.

Weed management

Research on weed management in sugarcane presented from 1977 to 1999 highlighted various strategies and advancements in the field. Most of the research was conducted on nut sedge and Johnsongrass, but there were some other problematic weeds in sugarcane cultivation. During this period, studies focused on the efficacy of different herbicides, integrated weed management through the integration of cultural practices and the impact of weed management on sugarcane yield.

Different doses of asulam were tested to control Johnsongrass (Millhollon 1983) and itch grass (Millhollon 1986) in Louisiana. Different rates of Roundup® (glyphosate) were tested against multiple problematic weeds in standing sugarcane fields in Mauritius that showed no significant effect on cane yields if sprayed when plant height was 120 cm or more (McIntyre *et al.* 1983). A mixture of different

herbicides including Roundup were tested to control *Cyperus esculentus* in fallow and young sugarcane fields (McIntyre *et al.* 1986). Preemergence and postemergence herbicides were tested against grasses and broadleaf weeds in Texas (Reeves 1977). Low-dose herbicide, isoxaflutole was found effective against a range of grass and broadleaved weeds in some Caribbean countries (Dasrat *et al.* 1999).

In an integrated weed management approach, the effect of planting density, nitrogen fertilization, and different sugarcane varieties was studied on multiple weed species and sugarcane yields in a multi-year study in Argentina (Arévalo *et al.* 1977). Sugarcane trash blanket suppressed 83-92% of the weed infestation in Brazil (Lorenzi *et al.* 1989). Minimum tillage also improved weed control in sugarcane (McIntyre and Barbe 1989). In a 3-year crop cycle, the effect of Bermuda grass interference reduced cane and sugar yield by 5% per year (Richard 1992).

The ISSCT congresses served as a crucial platform for sharing these findings, contributing to the advancement of sugarcane cultivation through improved weed management practices.

Planting

Research on planting practices was focused on optimizing land preparation, planting method, seedcane quality, seedcane treatment, planting date, row spacing, and inter-cropping.

In land preparation, different tillage methods were evaluated for their effect on soil properties and sugarcane yield (Casagrande and Godoy 1977; Fernandes *et al.* 1977; Yang and Quintero 1986). Minimum tillage was compared with conventional tillage in different studies for its effect on sugarcane yields. For example, Moberly and Turner (1977) reported sugarcane yield improvement with minimum tillage in light soils, but little negative effect on yield in heavy, poorly drained soil. Compared to conventional tillage, minimum tillage was also reported to improve soil structure with a neutral effect on sugarcane yield over a five-year crop cycle (McIntyre and Barbe 1989).

The effect of seedcane age and planting dates were reported from Kenya (Mutanda *et al.* 1980) and Fiji (Gawander *et al.* 1996). Different planting methods were compared for their effect on sugarcane yield in Louisiana (Ricaud and Cochran 1980) and the Philippines (Tianco 1992). Few studies were reported on intercropping (Kandasami *et al.* 1977; Pillay 1980) and the effects of seedcane treatment (Diaz *et al.* 1996) on sugarcane yield.

Row spacing is a crucial factor in sugarcane cultivation, impacting plant growth, yield, and overall crop management. The appropriate row spacing can significantly influence sunlight penetration, nutrient distribution, and weed control, ultimately affecting the overall productivity of sugarcane fields.

Researchers during this period explored various row spacing configurations to optimize sugarcane yield and efficiency.

In the late 1970s, studies focused on traditional row spacing and its impact on plant growth. As the 1980s progressed, there was an increased emphasis on narrow row spacing, aiming to enhance sunlight interception and maximize photosynthesis.

During the 1990s, research delved into the interaction between row spacing and plant density, seeking an optimal balance to promote healthier cane development. Some findings suggested that narrower row spacing could result in higher yields under certain conditions, but the overall effectiveness varied across different environments also due to different planting and harvesting methods.

Compared to conventional row spacing, wider row spacing produced similar or higher yields in Taiwan (Tang 1977) and Brazil (Fernandes *et al.* 1980). However, later in the 1980s, El Fattah *et al.* (1986) found that narrow inter-row spacing increased sugarcane yield parameters and sugar yield compared to conventional spacing in Egypt. Three papers from Louisiana in the 1980 congress summarized sugarcane row spacing's historical and theoretical aspects (Irvine and Benda 1980), effects of spacing

on sugarcane plants (Irvine and Benda 1980), and development of production techniques for narrow rows (Irvine *et al.* 1980).

Overall, the research during this period laid the foundation for understanding the relationship between row spacing and sugarcane productivity. It highlighted the need for site-specific recommendations, acknowledging that the ideal spacing could depend on factors such as soil type, climate, and cultivation practices.

Harvesting

Sugarcane harvesting during the period from the 1970s to 2000 witnessed significant advancements, driven by technological innovations and changes in agricultural practices. In the early 1970s, manual harvesting dominated sugarcane fields. Skilled laborers, often equipped with machetes, manually cut, and gathered the sugarcane stalks. This labor-intensive method was time-consuming and required a large workforce. As the demand for sugar increased, the industry sought ways to improve efficiency. The 1980s saw the introduction of mechanized sugarcane harvesting. Harvesters, equipped with rotating blades, were employed to cut and collect sugarcane, reducing the reliance on manual labor.

The 1990s marked a significant shift with the widespread adoption of mechanical harvesters in sugarcane farming. These harvesters integrated cutting, collecting, and processing capabilities, streamlining the harvesting process. The use of mechanical harvesters led to increased productivity and reduced labor costs.

The evolution of sugarcane harvesting from the 1970s to 2000 reflects a dynamic interplay between traditional practices, mechanization, and technological advancements. The industry's transition from manual labor to advanced machinery has not only increased efficiency but also posed new challenges that continue to shape the future of sugarcane harvesting. Mechanical harvesting affected the soil physical properties and the growth of ratoon cane. Yang (1977) reported an increase in soil bulk density and penetration resistance, and a decrease in soil porosity with the increase in traffic passes. This soil compaction decreased ratoon yields.

Ratoon management

The focus on ratoon management research was evident from the papers presented in the 1980s and 1990s. In the 1980s, the main focus was to determine the effects of crop management factors such as fertilization, trash management, varieties, subsoiling, number of cultivations, and date of harvest on ratoon yield and longevity (Gotera *et al.* 1980; Moberly and McIntyre 1983; Ricaud and Arceneaux 1986). In the 1990s, the focus was primarily on soil properties (physical, chemical, and biological properties) and soil management for their effect on sustainable ratoon cane production (Henry and Ellis 1996; Meyer 1996).

PROMINENT CONTRIBUTORS

G. McIntyre, whose research was focused on evaluating various herbicides for controlling emerging weeds in sugarcane in Mauritius. His work contributed greatly towards a better understanding of herbicide efficacy in pre- and post-emergence weed control in plant cane, ratoon cane, and fallow lands. Additionally, he contributed in compiling a global list of sugarcane diseases and their causal agents, playing a key role in updating this list by including diseases without known causal agents. His work during 1975-1999 was important for improving weed and disease management in sugarcane cultivation worldwide.

Ray Ricaud, whose work was focused on optimizing sugarcane yield through various agronomic practices, such as different planting methods, soil compaction management, fertilizer application rates and placement, cultivation frequency, and stubble protection in different sugarcane varieties. His

research has significantly increased sugar yield in both plant cane and ratoon crops in Louisiana. These agronomic practices have since been widely adopted, contributing to sugarcane yield improvement in Louisiana and beyond. His work during 1975-1999 was important to update management practices in sugarcane.

K.F. Ng Kee Kwong, whose research focused primarily on nutrient management in sugarcane cultivation in Mauritius. He evaluated the Diagnosis and Recommendation Integrated System (DRIS) for assessing the nutrient status of sugarcane in response to nitrogen fertilizer application, establishing critical threshold values for nutrients required by the crop. His work also explored the use of nitrogen fertilizers under sprinkler irrigation and the application of different nitrogen rates to optimize sugarcane yields. In addition, he studied nitrogen losses from sugarcane soils in Mauritius, highlighting the importance of optimizing nitrogen use to achieve maximum yields while reducing greenhouse gas emissions from sugarcane fields. His work in 1975-1999 played an important role in improving nutrient management in sugarcane.

IMPACT OF THE RESEARCH

The International Society of Sugar Cane Technologists (ISSCT) is the oldest and largest international organization of sugarcane technologists that organizes a congress every three years and multiple workshops on different disciplines during the inter-congress period.

Studies explored the roles of essential nutrients such as nitrogen, phosphorus, and potassium, transitioning towards sustainable practices with integrated nutrient management and a focus on micronutrients. Irrigation management research aimed at optimizing water use and improving efficiency through advancements in surface and drip irrigation systems, scheduling techniques, and strategies to manage water under drought conditions. Weed management studies highlighted various strategies and advancements, including herbicide efficacy, integrated weed management approaches, and the impact of weed management on sugarcane yield. Sugarcane harvesting witnessed significant advancements, transitioning from manual labor to mechanized harvesters, leading to increased efficiency and reduced labor costs. Planting practices research focused on optimizing land preparation, planting methods, seedcane quality, and row spacing configurations to enhance sugarcane productivity. Ratoon management research emphasized factors influencing ratoon yield and longevity, including fertilization, trash management, soil properties, and soil management practices.

Overall, the research presented in the ISSCT congresses and workshops during this period significantly contributed to the advancement of sugarcane cultivation practices, addressing key challenges and enhancing productivity in the industry. The findings facilitated the adoption of more efficient and sustainable practices, laying the groundwork for continued innovation and improvement in sugarcane cultivation globally. As we commemorate the 100th anniversary of the ISSCT, reflecting on the achievements and progress made in agronomic research underscores the vital role of international collaboration in shaping the future of sugarcane cultivation.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Agronomy 2000-2023

Bernard L Schroeder

bernard.schroeder@unisq.edu.au

INTRODUCTION

This paper provides a summary of papers presented in the Agronomy Sections within the ISSCT Agricultural Commission during the time of eight congresses that were held from 2001 to 2023. During this period, 429 agronomy-related papers included 214 full papers presented orally, 194 posters and 21 plenary papers. These papers often elaborated on initial ideas and preliminary results, outputs and outcomes previously presented and discussed at ISSCT Agronomy or combined Agronomy, Agricultural Engineering and Extension workshops that were held during the periods between congresses. These workshops included those held in Miami, USA (2000), Reduit, Mauritius (2003), Khon Kaen, Thailand (2006), Uberlândia, Brazil (2009), Townsville, Australia (2012), Salt Rock, South Africa (2015), St Giles, Réunion (2018) and a webinar in 2022. Summary reports of the workshops (or webinar) were included in the appropriate congress proceedings as documented by Richard *et al.* (2001), Richard *et al*. (2005), Ng Kee Kwong (2007), Ng Kee Kwong (2010), Gilbert *et al*. (2013), Schroeder *et al.* (2016), Schroeder *et al*. (2019), and Schroeder and Todoroff (2023), respectively. A total of 22 agronomy-related plenary papers were presented at the congresses during 2001-2023.

Despite the congresses spanning a period of almost 25 years and the large numbers of papers, several themes were identified that linked to an overall objective of sustainable sugarcane production. Sustainability was, in fact, highlighted in several congress plenary presentations during 2001 to 2023 period and was the underlying theme of most of the workshops. A plenary paper presented at the Congress in Chiang Mai (Poggio *et al.* 2016) suggested that sustainability and its supporting best management practices (BMPs) should be considered in terms of agronomic, social, economic, and environmental considerations. This combination and interaction of concepts essentially underpinned advances in sugarcane agronomy since the early 2000s. It also provided the background for the development and adoption of best management practices across industries (Kealley and Quirk 2006; Kingston *et al*. 2007).

The main themes that were identified during the review process included sugarcane farming systems and practices; crop nutrition and nutrient management; soil management and crop residues; sugarcane growth and crop management; advances in technologies; and ecology, climate and cultivar assessments. The majority of these themes included several sub-themes.

RESEARCH ADVANCES

Sugarcane farming systems and practices

Prior to the 1990s, the sugarcane production system was generally characterised by sugarcane being replanted shortly after destruction of the last ratoon crop of the previous crop cycle (Schroeder *et al.* 2009). This was often accompanied by aggressive tillages practices prior to planting. Row-spacings were usually less than 1.6 m. Although mechanical harvesting had been introduced in some countries, cane was still often manually harvested following burning of the standing crop. The congresses

proceedings (2001-2023) tracked the change from these 'traditional' practices to 'new farming systems' that aimed at alleviating sugarcane yield decline (Garside *et al*. 2001; Seeruttun *et al*. 2013), and the development of BMPs for sugarcane production (Kingston *et al*. 2007; Quirk *et al*. 2007). These 'new' systems encouraged utilising principles to underpin on-farm activities rather than using sets of instructions or 'recipes' to guide practices and inputs (Schroeder *et al*. 2019). These modified approaches included aspects of fallow management, crop establishment and reduced tillage.

Wide interest in alternative fallow management strategies and benefits of legumes/green manure break crops was evident among a number of international sugarcane industries. These included positive N contributions and biological advantages of such systems. Examples were the findings and experiences described by Munoz *et al*. (2016) in Colombia, and Castillo *et al*. (2019) and Palomeque *et al*. (2019) in Ecuador.

Improvements in cane productivity associated with advances in crop establishment, especially tillage practices and planting layouts/row spacings, were reported from Mauritius (Ismael *et al*. 2007), Thailand (Klomsa-Ard *et al*. 2007), Colombia (Torres *et al*. 2010), Brazil (Martinho *et al*. 2010), Florida, USA (Sandhu 2023) and Australia (Bull *et al*. (2001). Dual-row planting appeared to be one of the preferred options.

Longer-term assessment of conventional tillage (Gonzalez *et al*. 2019) and experiences of minimum tillage options (Prammanee *et al*. 2007) highlighted the advantages of improving soil health and reducing the adverse effects of excessive soil disturbance.

Crop nutrition and nutrient management

Nutrition-related papers covered the primary nutrients [nitrogen (N), phosphorus (P) and potassium (K)] and sulphur (S). As there was an emphasis on N in agriculture worldwide, the majority of these papers also dealt predominantly with a range of N-related topics. While some of these papers covered systems, strategic and program-based approaches (Perez *et al*. 2010; Schroeder *et al*. 2010; Thorburn *et al*. 2010), others focused on specific aspects of understanding and managing N within sugarcane crops. They often concentrated on sustainability, particularly environmentally-orientated considerations, rather than the productivity-driven aspects that characterised N-related RD&E prior to the 1990s.

Attention was also directed towards better understanding of components of the N-cycle (Valdiva-Vega *et al*. 2019) including crop uptake (Franco *et al*. 2010) and mineralisation of N in soil (Miles *et al*. 2019). Importantly, cane yield effects associated with N losses were investigated and reported by Castro *et al*. (2019), as were N losses due to runoff (Webster *et al*. 2010), leaching (Portocarrero *et al*. 2013) and gaseous emissions (Thorburn *et al*. 2010, 2013). Sources of N other than 'inorganic' fertilisers were investigated especially organically-bases alternatives (Ng Kee Kwong *et al*. 2005; Balana *et al*. 2010; Poultney *et al*. 2019). Continued reports of biological N-fixation within the sugarcane cropping system were provided in papers from South America (Perez *et al*. 2005; Roa *et al*. 2016) and China (Yang-Rui *et al*. 2013). Recent advances in improving nitrogen use efficiency (NUE) were described by Meyer *et al*. (2007), and the important relationship between NUE and water-use efficiency (WUE) was highlighted by Dinh *et al*. (2019).

Enhanced efficiency fertilisers (EEFs), a term that has emerged in the past 10 years, relates to fertilisers (especially urea) that are supplied as specific formulations with the underling intent of improving crop uptake efficiency. As such, EEFs have received attention at several of the congresses since 2007 and included several from Brazil (Cantarella *et al*. 2007; Vilas et al. 2019; Rossetto *et al*. 2023) with apparent mixed results in productivity responses due to the EEF formulations. Cantarella *et al*. (2019) found that a positive environmental outcome of using EEFs was due to a reduced carbon footprint associated with the sugarcane production system that they studied in Brazil. Soares *et al*. (2013) reported that the use of EEFs containing nitrification inhibitors reduced N_2O emissions compared to standard urea and poly-coated urea.

Phosphorus-related papers covered crop responses to P fertiliser applied to the diverse soils found on Réunion, Oxisols in Brazil, alluvial soils of volcanic origin in Nicaragua, and calcareous soils in Iran (Nobile *et al*. 2023; Rein and de Souza 2013; Caldera Dominguez and Schroeder 2019; Noori *et al.* (2019), respectively). The positive influence of P-solubilising bacteria on sugarcane production was highlighted by Sundara *et al*. (2001) and Safirzadeh *et al*. (2023). Phosphorus-use efficiency associated with different sugarcane cultivars was reported by Sreewarome *et al.* (2003) and Khajavi-Shojaei (2023). Influence of rainfall intensity on P losses were described in Mauritius by Mardamootoo *et al*. (2013).

Aspects of other nutrients included nutrient interactions, nutrient management guidelines, formulations, and specific practices.

Advances in K nutrition were reported from Mexico, South Africa and Japan by Salgado Garcia *et al*. (2005), van Antwerpen *et al*. (2019) and Watanabe *et al*. (2013), respectively. McCray and Rice (2013) reported sugarcane yield responses to elemental S applied to high pH organic soils. While Meyer and Keeping (2005), and Camargo and Korndorfer (2013) described the uptake, productivity and impacts of silicon (Si) in alleviating biotic stresses in sugarcane, Dias *et al*. (2010) provided as assessment of Si in relation to a range of sugarcane cultivars in Brazil. Reports of field responses to nutrient combinations and nutrients in organic forms were also included in a range of papers. These included research on a combination of N_2 fixing and P solubilising bacteria (Shankariah and Hunsigi, 2001), soil and plant nutrient interactions (Fortes *et al*. 2013), and long-term effects of inorganic fertilisers on soil microbial activity (van Antwerpen *et al*. 2013). Shinde (2019) described the relevance of fertigation via drip irrigation to a particular sugarcane cultivar in India.

Soil/site-specific nutrient management programs/packages or supporting technologies as developed in Thailand, Mexico, Ecuador, Florida, Réunion and Australian were described by Prammanee *et al*. (2005), Salgado Garcia *et al*. (2010), Spaans and Nuñez (2010), Sandhu *et al*. (2016), Ramos *et al*. (2019) and Schroeder *et al*. (2010), respectively.

Soil management and crop residues

Topics within this theme covered soil properties and management, amendments and conditioners derived from sugarcane and other sources, and sugarcane trash and harvest residues.

Although several papers dealt with changes in soils and soil degradation due to sugarcane production (McGarry and Bristow 2001; Meyer and van Antwerpen 2001; Morrison *et al*. 2005; Ram *et al*. 2007; Umrit *et al*. 2010; Vargas *et al*. 2013), others highlighted positive aspects and factors associated with healthy soils (van Antwerpen *et al*. 2007; Carvalha *et al*. 2013). Kingston and Anink (2005) described a capability of in-field soil salinity measurements and refined salinity tolerance for different sugarcane cultivars.

A paper that highlighted the use of renewable sugar-industry wastes towards a circular bioeconomy in sugarcane production was presented by Singh *et al*. (2023) in India. Descriptions and assessments of various amendments/conditioners derived from sugarcane were included in several papers on vinasse (effluent from sugarcane-based distilleries). These covered contributions from Brazil, China, Japan, Mauritius, Guatemala, Brazil and Colombia (Casagrande *et al*. 2007; Yang-Rui *et al*. 2007; Tominaga *et al*. 2010; Soobadar and Ng Kee Kwong 2013; Perez *et al*. 2013; Rossetto *et al*. 2013; Tejada 2010, respectively). Bhadha *et al*. (2023) reported on using bagasse as an amendment in mineral soils in Florida, Quirk *et al*. (2010) described the potential role of biochar in sugarcane production, and Lima and White (2019) presented an impressive paper at the Tucumán Congress on both bagasse and biochar as soil amendments to increase sugar and cane yields.

As green-cane trash blanketing (GCTB) is a practice that increased considerably in many sugarcane-growing countries over the past three decades, several papers dealt with various aspects of crop residues. Overall advantages and impacts of GCTB on soils and crops, as previously reported by others

in various forms, were re-affirmed and documented by Kingston *et al*. (2005). Particular experiences relevant to Colombia were highlighted by Munoz-Arboleda and Quinteroduran (2010). Based on acquired data, simulations of some of these effects within Brazilian circumstances were provided by Marin *et al*. (2013) and Oliveira *et al*. (2013). Although GCTB posed some challenges in particular environments such as Louisiana (Viator *et al*. 2005), concerns about soil temperature and moisture under trash blankets in Argentina were allayed by Morandini *et al.* (2005). Impacts and interactions of trash blankets and N were provided by Thorburn *et al*. (2001) and Vitti *et al.* (2010). Allelopathic effects of sugarcane postharvest residue were described by Villegas *et al*. (2007). Several papers dealt with microbial aspects of crop residues, particularly in terms of decomposition of trash (Johnson *et al*. 2007; Digonzelli *et al*. 2013) and the effects of the trash on soil microbes and C (Tortora *et al*. 2013; Hatyani *et al*. 2013). Gaseous losses from decomposing trash blankets were quantified in terms of CO_2, and N_2O and CO_2 emissions by Ramos *et al*. (2016) and Vargas *et al*. (2013), respectively. At the 2019 Congress in Tucumán, Munoz (2019) proposed using labile C as an indicator of the impact of trash removal on soil health, and Chalco *et al.* (2019) indicated the positive effect of trash retention compared to loss of soil C when trash is burnt.

Crop growth and management

'Crop growth' included a range of papers dealing with different growth phases and processes. Romero *et al*. (2005) provided information about emergence and early growth of plant and ratoon crops under different temperature regimes in Argentina (Romero *et al*. 2005). Sugarcane root systems were found to grow to a depth of up to 4 m irrespective of the commercial cultivar in Côte d'Ivoire, Brazil and Réunion, France (Chopart *et al*. 2010). However, there was no direct relationship between root length and sugarcane biomass (Chopart *et al*. 2010). Chopart *et al*. (2013) evaluated possible relationship between dry above-ground biomass and the energy yield of sugarcane. The effects of soil water content, intercepted radiation and temperature on sugar cane sucrose balance and partition were described by Martiné *et al*. (2001). Chlorophyll and leaf relative water content as indicators of drought tolerance on initial sugarcane growth were assessed in Brazil on several commercial cultivars (Silva *et al*. 2010). Information on chemical ripeners for sugarcane grown in South Africa, USA and Khuzestan province (Iran) was presented by van Heerden (2013), Orgeron *et al.* (2013) and Karmollachaab *et al*. (2016), respectively. Van Heerden *et al*. (2023) presented results of a participatory on-farm demonstration project aimed at advancing cane-quality by targeted ripener usage in the South African smallholder-farmer sector.

Growth-promoting micro-organisms were the topic of several papers presented at various congresses and included the occurrence and apparent benefits of diazotrophic and growth-promoting rhizobacteria in Mauritius (Moutia *et al*. 2005), and the isolation and characterization of potential plant growth-promoting bacteria from sugarcane grown in Argentina (Michavila *et al*. 2019). Screening of phosphate-solubilizing bacteria from sugarcane rhizospheres (Thongponkaew *et al*. 2016), and the efficiency of arbuscular mycorrhiza fungal inoculation with rock phosphate on soil-available P (Juntahum and Boonlue 2016) were reported from Thailand. In both cases the effects on growth and yield of sugarcane were assessed.

Two sub-themes were identified under crop management: water-use efficiency and irrigation, and weed control.

Reminders about the need for improved water-use efficiency were important, given climate change scenarios (Singh *et al*. 2016) and specific requirements within semi-arid environments (Wiedenfield 2007). Papers reported on advances in achieving such efficiencies by coupling of irrigation requirements with transpiration through 'scaling-up' from leaf to field (Nassif and Marin 2013), and using updated irrigation techniques. Such improvements included new applications of drip-technology aimed at improved environmental consequences (Krontal 2013), use of low furrow inflow rates in Colombia (Campos and Cruz 2013), and drip and rain-gun sprinklers in India (Shinde 2013). Advances in irrigation scheduling to improve yield and decrease inputs, particularly in small-scale grower environments in Eswatini, were reported by Mkhaliphi and Dlamini (2016). Progress in using demonstration trials to

enable adoption of appropriate irrigation in the South African sugarcane industry change was presented by Adendorff *et al*. (2023).

Weed control continued to receive attention across the congresses during the 2001-2023 period. At a higher level, this included an automated system for integrated weed management as proposed by Diaz *et al*. (2001), control of weeds occurring in trash-blanked cane (Manechine *et al*. 2005), and predicting weed infestations using multi-label learning algorithms (Fabre Ferber *et al*. 2023). Specific aspects of weed control included potential dispersion of weed seeds by cane harvesters (Vargas *et al*. 2019), weed seedling being introduced when sugarcane seedlings are transplanted (Baucum *et al*. 2023), interactive effects of seed depth, trash thickness and herbicide treatments of vine weeds in GCTB systems (Gaungoo *et al*. 2010), and appropriate herbicide spray volumes in Brazil conditions (Ramos *et al*. 2010). Reports on the efficacies and successful use of herbicides were provided in several papers including Seeruttun *et al*. (2005, 2007, 2010), Orgeron *et al*. (2019), Odero and Negrisoli (2023) and Rodriguez *et al*. (2023). Kealley and Milford (2013) put a case for preserving diuron usage in sugarcane grown adjacent to the environmentally sensitive Great Barrier Reef. The concept of airborne-sourced images to construct weed maps for site-specific control was explored by Olea *et al*. (2001)

New technologies

Reports of advances in technology covered aspects of modelling, decision-support, data-analyses, spatial variability, sensing, automation, and robotics.

Agricultural crop-modelling received much attention worldwide over the past few decades. In the early 2000s, Muchow *et al.* (2001) promoted the concept of sustainable sugarcane production using a whole-system perspective. This approach was supported using state of the art crop models (Inman-Bamber *et al*. 2001) such as APSIM and CANEGROW. Singels (2007) described a novel approach of implementing computer-based support for growers and extension officers. At the Congress in São Paulo, Marin *et al*. (2013) provided an evaluation of these particular models to simulate a Brazilian sugarcane cultivar grown under Brazilian conditions. Refinements and more focused aspects of crop models were reported at the congresses. Cheeroo-Nayamuth *et al*. (2005) suggested that real-time dewpoint temperature could improve estimated evapotranspiration and enhance crop model performance. Romero *et al*. (2001) indicated that plant cane emergence could be predicted using biothermal models. More recently, crop models were used to predict annual sugarcane yield variability (Christina *et al*. 2019) and the effects impacts of climate variability on sugarcane production (Singels *et al*. 2013). The potential of sugarcane for sugar and ethanol production under current and future climates in South Africa was described by Singels *et al*. (2019).

General spatial identification, determination and analyses included the use of geographic information systems (GIS) (Segrera *et al*. 2001), combined applications of near-infrared (NIR) remote sensing (RS) and NIR (Ueno *et al*. 2005), and farm, land-use road networks using Indian remote sensing satellite 1D (IRS-1D) imagery and GIS (Saravanan *et al*. 2005). The use of electrical resistivity (Viremouneix *et al*. 2007) and NIR (Chapanya *et al*. 2016) were reported as useful rapid techniques for field soil characterisation in Cameroon and Thailand, respectively. Non-destructive techniques for measuring various plant parameters included chlorophyll meters for monitoring a crop's N status (Ng Kee Kwong *et al*. 2001), and portable NIR spectrophotometers to determine sucrose content of cane stalks in the field (Taira *et al*. 2013; Nootas *et al*. 2016). Developments in remote sensing received attention in several papers inclusive of reports of hyperspectral data to estimate canopy chlorophyll content of sugarcane (Murillo *et al*. 2013), monitoring of sugarcane growth using UAV-sourced high-resolution imagery (Veerachitt *et al*. 2016), and use of RS and GIS to differentiate sugarcane crop classes in according to age (Fandos *et al*. 2019). Specific weed management technologies included remote identification of weed infestation (Simoes *et al*. 2005), and proximal or remote sensing used in combination with drone-based weed control spray options (Olea *et al*. 2005; Jensen *et al*. 2019).

Ecology, climate and cultivar assessments

This identified theme consisted of ecological and climatic perspectives, and assessments of sugarcane cultivars for specific circumstances. During the Brisbane Congress, several environment-focused papers were presented. They included strategies to minimise risks from metals, pesticides, wastes and acid sulphate soils in the Australian sugar industry (Rayment 2001), sustainability as affected by soil erosion and agrochemical movement in Mauritius (Ng Cheong *et al*. 2001), and losses of nitrate in groundwaters (Thorburn *et al*. 2001). This was put into context by an environmental monitoring framework for benchmarking best practices as proposed by Hanlon *et al*. (2001), and an example of achieving self-regulation of drain maintenance in New South Wales (Beattie *et al*. 2005). Reghenzani et al. (2001) highlighted the importance of sustainable management of agrochemicals by limiting losses and optimising profitability. Selim and Zhu (2001) described the effect of sugarcane trash systems on herbicide retention.

Climate variability received attention particularly in the later congresses. This included an index for estimating the effect of climate on cane crops (Moreno *et al*. 2001) and impacts of the El Niño/Southern Oscillation (ENSO) on sugarcane yields in Thailand (Seechan *et al*. 2016). Predicted implications of climate change were presented for sugar production in Mauritius (Cheeroo-Nayamuth and Nayamuth 2001) and Fiji (Bano 2023), and risks for sugarcane within agroclimatic zones in Mexico (Brunini *et al*. 2010). Bezuidenhout *et al*. (2007) presented agroclimatic and hydrological responses for sugarcane production in South Africa. In terms of specific climatic conditions, Giardina *et al*. (2013), Legendre *et al*. (2013), and Okada *et al*. (2016) described the effects of cold temperatures and frost damage on sugarcane and possible management for these conditions. Poser *et al*. (2019) highlighted the effect of temperature on the geographic spread of a particular cultivar on Réunion, and Pissolato *et al*. (2023) suggested that cane could possibly 'acclimatise' to drought through pre-exposure. Expansion of cane production into drier areas in Thailand and Argentina was described by Kamiya *et al*. (2016) and Fandos (2023), respectively.

Although information about sugarcane cultivars was generally included in the ISSCT Breeding Section within the Biological Commission, some papers covering this topic were included in the Agronomy Section because of their practical nature and relevance on-farm. These included the effects of lodging on growth, yield and quality of specific varieties (Silva and Caputo 2005; Noori 2013), and consequences of location and time of harvest on particular cultivars grown in Mexico (Milanés-Ramos *et al*. 2010). The effects of saline/sodic soils (Ali *et al*. 2019), and irrigation water with raised electrical conductivities (Karami *et al*. 2013) were described for different sugarcane cultivars. Diversification of sugarcane as animal feed was suggested by Ishikawa *et al*. (2007) and Jorge *et al*. (2010). Although planting mixed cultivars in a field is usually not encouraged, Takaragawa *et al*. (2016, 2019) reported increased growth and yield, and improved root growth and water-use efficiency under drought conditions in Japan.

PROMINENT CONTRIBUTORS

Rian van Antwerpen (South Africa) for pursuing and furthering knowledge of soil health and its impact in sustaining sugarcane production especially in challenging environments.

Graham Kingston (Australia) for his broad commitment and understanding of sugarcane agronomy particularly as it relates to productivity, productivity and the environment.

K.F. Ng Kee Kwong (Mauritius) for his contribution to the international sugarcane industry through novel and integrated approaches to support sugarcane sustainability.

IMPACT OF THE RESEARCH

The period from and including the XXIV to the XXXI ISSCT Congresses saw a substantial change from 'traditional' sugarcane farming practices to the so-called 'new' farming systems that generally incorporated combinations of in-field break-cropping, reduced tillage, and controlled traffic. These changes were prompted by an overall need for sustainability inclusive of profitable sugarcane and sugar production, environmental considerations, and social and cultural prerequisites.

The identified themes (detailed above) indicated that agronomic RD&E activities were quite diverse with progress on various fronts across the international sugarcane industries. The advances in farming systems included the development of integrated nutrient management programs, weed control strategies, crop modelling, and introduction of new in-field technologies. Despite the initial thrust of these 'bigger-picture' initiatives, many of the subsequent ideas, concepts and reports seemed to be aimed predominantly at fine-tuning existing information and practices, rather than delivering innovations to 'propel' the sugarcane into the future. I suggest this may need to change as diversification of sugarcane continues to be considered and implemented more widely in the future. Sugarcane is so much more than a feedstock for raw sugar production linked to world commodity markets! Its potential needs to be more fully recognised and supported by dynamic and forward-thinking RD&E. Advances in sugarcane agronomy will be fundamental to such considerations, particularly as growers will need to address and manage their particular regional and on-farm circumstances with specific objectives in mind. Fundamental understanding of soil, their positions in the landscape and properties; agrometeorology and aspects climate variability; and sugarcane crops and their management inclusive of productivity, profitability and environmental considerations; will remain essential, especially with anticipated advances in artificial intelligence (IA), automation and robotics.

I suggest that the ISSCT Agronomy Section papers, poster and appropriate plenary presentations will continue to provide an important and useful resource for recording and sharing progress in sugarcane agronomy and agricultural developments worldwide!


The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Agricultural Engineering 1924-1938

Carmina Fandos, Pablo Scandaliaris, Somwang Leekar, Nonthawat Chainarong and Sombat Khawprateep

carminaf@eeaoc.org.ar

INTRODUCTION

Until the early 20th century, all stages of sugarcane agricultural production, from planting to harvesting and transportation of raw materials, had been carried out using intensive labor. These were times of low global sugar production volumes, but there were significant prospects for growth due to product demand, while labor availability decreased and became more expensive. Therefore, substantially improving labor productivity was the only feasible option to increasing efficiency and productivity.

Agricultural engineering played a crucial role in generating a plethora of mechanization alternatives for each stage of the production system and for each environmental condition worldwide. This was achieved through high levels of innovation and many years of development. Agricultural engineering was decisive in achieving two fundamental objectives required by the sugarcane agroindustry: increasing sugar production with significantly fewer workers. Thus, the notable surge in mechanization that took place between 1920 and 1940 is a historical technological milestone, showing the remarkable effort and great achievements made for the sugarcane agroindustry.

RESEARCH ADVANCES

1924 to 1929

Soil preparation

In many cases before soil preparation, crop rotation was carried out, particularly with legumes, mainly to replenish soil organic matter and weed control in the new cane field. Another alternative was trash conservation, which in some production areas like Fiji, is accumulated between rows and incorporated into soil preparation upon renewal.

The innovation of large producers was to carry out soil preparation work to replace animal traction with steam plowing and low-power tractors (around 45 HP). Mechanical traction was a significant advancement in reducing costs, as in some situations, up to 12 passes were made to prepare a good bed, especially to control perennial weeds. In Australia, new tractors were incorporated daily for various operations.

The depth of soil preparation varied, being 10 cm in India and ideally 30 cm in Australia. In Cuba, Caterpillar tractors, along with suitable equipment for substituting animal power and human labor, were considered the machinery of the future, and were already widely used in Hawaii.

Planting

In Louisiana, subject to constant water logging, planting rows were made on ridges. Conversely, in India, seed stakes were manually placed in the mud after irrigation. Other areas partially used irrigation, either occasionally or specifically in some available areas. Technical aspects considered were: seed origin and care, whole or chopped cane, planting distance, distribution method, amount of seed, use of the apical part of the stem, etc., which varied according to the producing areas. Ahead of its time was the development of a planter under experiment in Australia, which consisted of a "*box on wheels with a funnel through which the seed is chopped into the furrow while the feet on the rear of the machine cover over the pieces*," according to Mr. Freeman, who believed that the developed equipment had to be incorporated in the short term, due to the scarcity and high cost of labor.

In subtropical production areas with severe winters due to low temperatures, such as Louisiana and Argentina, whole stems were distributed at the bottom of the furrow and covered with a thick layer of soil to prevent seed decomposition. They had to withstand winter cold and dry conditions before sprouting in the spring. In those cases, wagons with seed cane were driven into the fields and dropped cane in the furrow. In spring, the cane row was off-barred, and excess dirt was removed to allow germination. In Cuba, the ELSO planter performed the task of opening the furrow, dropping the piece, fertilizing, and then closing the furrow, all in one operation.

Cultivation

Faris made a few remakes about the trend of cane cultivation in Cuba. "*The beautiful cane in Java shown by the slides of Dr Jeswiet, was grown by a Cuban system of cultivation. Dr Reynoso system was applicable to the conditions of slave labor then existing in some countries but with the abolition of slavery and the increase in the cost of labor, new adjustments became necessary*". *Various cultivation systems were developed but the most generally used in ratoon and which seems well adapted, both from the standpoint of cost and sustaining yields, is the transfer of trash to alternate middle and the cultivation of the exposed middle. The tendency now is to find methods of carrying out these operations mechanically at low unit cost*".

In the 1920s, constant progress was made in agricultural experimentation in practically all sugar cane countries. The relationship between soil type and cane plant development was studied, highlighting the need to restore soil organic matter and the deficiency of nitrogen and other elements. Alongside good knowledge of soil and nutrition, three management alternatives emerged: rotation with legume crops and their subsequent incorporation at the appropriate time; trash conservation techniques (Cuba, Fiji, and South Africa, among others); and finally, fertilizer application. Additionally, Hawaii has made valuable contributions at this stage of sugar cane technological evolution to identify the various nutrient needs of sugar cane, depending on the conditions in which the cane fields developed.

To carry out various cultivation tasks, equipment adapted to soil tillage needs, weed control, and pesticide application were developed, which were either animal-powered or tractor-powered, depending on the producer's size and mainly the conditions of each production area. Basil Hone believed that tractors introduced us to mechanical cultivation to reduce costs significantly.

Harvesting

Increasing human efficiency in harvesting was a challenge for innovative technologists, who through successive contributions over the years, made it possible to have high-efficiency harvesting systems to achieve high working capacities, and an acceptable quality of the raw material. This persistent effort developed over more than a century has been much more remarkable than in any other crops because the significant difference lies in the high tonnage characterizing sugarcane production compared to other cultivated species.

The first attempts were focused on developing equipment for cutting cane and dated back to the early 20th century. Indeed, in 1902, an automatic device for cutting cane was patented in England, but it did not become very popular. Shortly thereafter, the Gonserand Cane Cutter was developed and used to a limited extent in Louisiana. Drawn by animals, it consisted of a wooden structure holding two circular blades that cut the stems and deposited them at the rear along the furrow. For 20 years, work was done on the Luce Cane Harvester, which finally reached the market in 1921. It operated for some years in Cuba, although it did not achieve good performance.

According to Atkinson, the development of mechanical harvesting in the sugar industry in Australia has been a gradual process since 1920. In 1930, an evaluation was made of a harvester-loader, the Howard Cane Harvester; then, a cleaning system was added thereto. At the same time, another Australian, Ralph Falkiner, created a machine that has been developed over 20 years mainly in Cuba and Florida (USA), where it was improved and finally launched for commercial operation, harvesting over 20,000 t of cane in Clewiston in 1930. For the first time in the history of sugarcane, a cane field was mechanically harvested.

Another significant challenge for technologists was finding a solution for mechanizing the harvesting of sugar cane produced in Hawaii, where yields could reach 250 t/ha. Although the first self-propelled cutter was evaluated in 1906, and subsequently 26 models of machines with diverse characteristics were tested, it was not possible to mechanize harvesting until 1940.

Transport of raw materials

During the early 20th century, technologists placed significant importance on replacing animal-drawn carts with innovation that mechanized and increased the capacity of equipment, while simultaneously reducing the costs of transporting raw materials. As sugar factories expanded their milling capacity, distance among sugar cane production areas also increased. To make the most of available options, railway transport was utilized when tracks were relatively close, or the Decauville system of portable tracks was employed to facilitate railway access to sugar cane fields.

In 1924, D.R. Thomas described his experience of using trucks to transport sugar cane directly from the fields to sugar factories. On this occasion, detachable boxes were tested so that the truck would not have to wait for manual loading time. Trucks were used both to transport cane directly from the fields to the factory, and from collection centers. Various types of mechanical loaders were used to load the cane.

1930-1938

The period 1930-1938 was characterized by changes in the labour force, there has been significant development of equipment for various sugarcane field activities, including clearing, land preparation, planting, cultivation, harvesting, and ratooning.

In 1932, two articles related to agricultural engineering were notable. The first article discussed the cultivation of ratoon in Hawaii, presenting principles for long-term ratooning under various limiting factors. The second article detailed cultivation experiments with sugarcane, showcasing the design and layout of two successful preliminary tillage trials conducted in Trinidad. The article on ratoon cultivation in Hawaii highlighted several limiting factors, including the need for fertilizers, the influence of weather on sugarcane at unsuitable times, and the availability of labour. These factors contributed to a focus on ratooning practices in Hawaii for many years, with diverse practices even within different parts of a single plantation. The article reported on both irrigated and unirrigated areas.

For irrigated areas, six principles were outlined: (1) Irrigating as soon as possible after harvesting to ensure strong stools, especially after cutting off water for ripening; (2) Building up the furrow bank using loosened soil from the bottom of the furrow to allow water and fertilizer to reach the root zone; (3) Improving soil productivity with early applications of nitrogen and phosphates where phosphates were

lacking, followed by nitrogen and potash; (4) Timely execution of fieldwork, including weed control before seeding, and maintaining schedules for irrigation, fertilization, and planting; (5) Harvesting at the proper time, using appropriate methods, and ensuring the correct age of the crop; (6) Implementing practical measures and fertilization to prevent pests, considering the diversity of practices.

For unirrigated areas, six principles were also presented, with the third, fourth, fifth, and sixth principles being the same as those for irrigated areas. The differences were: (1) Clearing all trash from stools, trimming high stools, and allowing sunlight to reach the stools; (2) Loosening the soil as soon as possible after field clearing, before new roots develop from the stools.

Rapid practices with tractor-drawn equipment enabled cost-effective operations, transforming unprofitable land into highly productive areas. However, proper layout of the area was essential. Additionally, the transition from steam ploughing to “Caterpillar” tractor ploughing for land preparation made the work cheaper and more efficient.

Another article compared the effects of two different types of soil preparation in sugarcane cultivation experiments. The study included a diverse range of treatments, comparing tractor ploughing with hand-forking, and chiselling with hand-forking, as well as variations in layout design, plot size and shape, and the number of replicates. The results indicated that the yield of plant canes from tractor-ploughed and chiselled plots was significantly better than from hand-forked plots. Randomised blocks arranged in a row in the field were considered a suitable model for cultivation experiments. The plot size had a length-to-width ratio of 30 to 1, and the estimated number of replicates for each treatment was determined to achieve statistically significant differences.

Land and soil preparation

In 1935, changes in the workforce significantly impacted cane production. It was observed that second and third-generation growers were less willing to engage in hard labour compared to their predecessors. Consequently, labour-saving devices became increasingly important. Various machines and implements were described for each production activity in sugarcane cultivation. For fresh areas containing bushes, stones, or wood, these obstacles had to be cleared before other activities could commence, including the removal of trash from previous crops. In Hawaii, a crawler crane fitted with a rock grab was used for clearing rocks in the fields. Trash clearing methods varied by country; some growers used a Howard Rotary Hoe or a large disc harrow with cutaway discs to mix trash with the soil.

In terms of land preparation, single and double-disc types drawn by three horses were used in Australia, while larger two-disc equipment was mounted on tractors. Although multi-disc ploughs were available, they were not favoured at the time. The typical disc diameter was 28 inches, allowing for a plough depth of 10 inches. After three or four ploughings, clay soil became compacted, necessitating the use of a subsoiler during the first or second ploughing, or as an alternative. Subsoilers could be drawn to a depth of 14-16 inches, with the number of times depending on tractor power. The rotary hoe, attached to wheel-type tractors, was popular for land preparation, useful for destroying old stools and chopping trash before ploughing. Harrows were used to break up clods and firm the soil, with disc types carrying 28 or 32 discs of 18-20 inches in diameter. Spike-tooth and roller types were also in operation.

The introduction of large diesel tractors changed ploughing and harrowing methods, leading to increased use of implements in Hawaii. Growers preferred deeper ploughing for planting, resulting in the development of 24-inch cut two-bottom mouldboard ploughs with hydraulic lifts. These could be used in conjunction with subsoilers working at depths of 28 inches when mounted on 75 HP tractors. Additionally, 32-inch three-to-six-disc ploughs were offered by manufacturers from Europe, Australia, and America. For harrowing, there was a preference for double-action types with 28-inch discs, ranging in width from 12 to 17 feet.

For planting, in Louisiana, cane stalks were piled on carts with wheels spaced to match the width of cane inter- rows spacing. During operation, the wheels ran in the bottom of the furrow, and the cane

stalks were pulled from the cart and placed in the furrow bottoms, then covered by a disc plough. In Hawaii, planters mounted on crawler-type tractors were developed. These planters could make a furrow, drop the cane seed, fertilize it, and cover it in one pass, requiring a small headland. In Australia, growers used double-mouldboard ploughs for preparing cane seed furrows, drawn by 2 to 4 horses or light tractors. Other planter designs included a large box for carrying cane stalks, a chute for cane seeds, and a fertilizer applicator, also drawn by horses and light tractors.

Weed control and fertilisation

For cultivation, in Australia, it was promoted to remove weeds when they were small, before flowering, commonly using scrapers to destroy weeds in inter-rows. For weeds within cane rows, growers had to wait for the young cane to grow, which might not be timely for weed flowering. This led to the design of straddling disc implements for ploughing the sides of cane rows, turning some soil away, and using a spring tooth rake to pull young weeds from cane rows. Another design, called a “spinner,” removed weeds in rows and excess soil surface, usable when the cane was still small. Additional devices used two mouldboards or four narrow tines for cultivating and moving light soil, often mounted with spring tooth rakes. Some plantations used small rotary hoes driven by 3 or 8 HP petrol engines for weeding interspaces. In Hawaii, pneumatic tire tractors were used but had limitations in areas with high soil moisture or slopes, leading to the use of high-clearance crawler-type tractors for cultivation. Disc-type cultivators designed for rocky fields allowed each disc to jump over obstacles without interfering with others. In unsuitable conditions or when cane was too high for tractors, small narrow tractors were used to run between cane rows, cultivating one row at a time with the operator walking behind.

Fertilizing machines had not developed as quickly as other equipment due to some fertilizers’ high moisture-absorbing characteristics. Growers typically used vibrating types suitable for any weather conditions. These implements consisted of two vibrating hoppers fitted on high-clearance tractors, driven by connections to tractor wheels or driving gears. In Louisiana, some growers applied filter press mud, a by-product of the sugar process, to fields by diluting it with water and pumping it through galvanized pipes into the cane fields. In Hawaii, trucks transported and distributed diluted mud to the fields.

Harvesting

For harvesting, countries with available labour still relied on manual labour. However, there was interest in developing cane harvesters and loaders. Australia and the Continental U.S.A. led these investigations. Louisiana experimented with harvesters, which were expensive and time-consuming. Australia later developed cane harvesters that could operate under field conditions, but development was limited by the global economic downturn. Eventually, successful harvesters were developed, with 16 Faulkiner harvesters sent to Florida and two to Cuba. These harvesters could separate trash and top parts by chopping the whole stalk into 5-inch lengths, then raising it into a rotating drum with a fan passing strong air through it. However, green tops were not always removed by air separation. Other machines, such as loaders, were highly successful due to their low cost and simple construction, handling at least 500 t/day with an 8 HP engine in Louisiana and 2000 lbs per grab with a 50 HP engine in Hawaii.

For ratooning, in Australia, stronger spring steel was used for “rolling” fresh tops into interspaces, then burning them. Tandem disc harrows were used to mulch the soil surface and destroy upper buds, ensuring the ratoon crop came from underground buds. In Hawaii, growers used the Stubble-Shaver for this task, hilling up the row before harvesting. Some growers used traditional methods, such as ploughs or tines, to plough soil away from stubble to provide sufficient soil moisture. Cutting discs were mounted ahead of inner ploughs or tines to cut off old roots and avoid disturbing the stubble.

In field experiments and sampling, the short harvesting season in Louisiana made weighing time-consuming, especially with many treatments and replicates. A portable scale for weighing cane stalks

in the field was investigated, capable of weighing 100 to 124 plots per day with plot sizes of 24 feet wide and 30 feet long. In Florida, a system for weighing small samples mechanically moved from plot to plot was developed, including a portable fixed mill providing 60 samples per day with 2 lbs of juice per sample.

Land preparation, planting and harvesting equipment

In 1938, reports indicated significant population and economic changes in Louisiana. As a result, growers were compelled to adopt more efficient methods and machinery or cease sugarcane planting. Restrictions on labour wages and sugarcane prices necessitated greater attention to each production step. For land clearing, 75-100 HP diesel tractors equipped with push blades or “bulldozers” were used to uproot and push trees up to 10 inches in diameter. Trash was ploughed into the field using mouldboard ploughs, heavy 24-to-28-inch disc harrows, and Howard rotary hoes.

For land preparation, there was a focus on removing old stubbles from previous crops. In the USA, heavy tandem disks were used to chop up stubble, followed by a 22-inch double mouldboard plough in front, separate 22- to 28-inch left and right-hand ploughs, and a pair of 14-inch mouldboards in the rear to destroy the old row. In Cuba, cross-ploughing with a heavy disc plough was followed by harrowing with a heavy 28-inch disc harrow. In Australia, stubble was removed with a 28-inch disc plough, and a special hoe with a diesel crawler tractor was employed for heavy soil preparations. In Louisiana, studies on deep tillage using the gyrolette mounted on a Caterpillar diesel 35 tractor showed that it could plough to a depth of 12 to 14 inches, compared to the 6 to 8 inches of other implements. This allowed for quicker absorption of heavy rain and reduced soil erosion, while promoting deeper root systems to mitigate drought effects. However, growers had to be cautious of the potential negative impact of mixing subsoil with topsoil, which could reduce sugarcane production.

For planting, Louisiana developed a wagon model in 1935 for use in large operations, capable of planting three or five rows. Rollers were used to compact the soil around seed canes during dry season planting. In many countries, planting machines reported in 1935 in Hawaii proved extremely satisfactory and were widely used. Hawaii also developed a two-row planter requiring narrow headlands, with individually adjustable furrows, and easy installation and removal from tractors.

For cultivation, high-clearance tractors evolved from crawler models in 1935 to rubber tires with treads designed for soft, muddy, or loose soil. These tractors were equipped with two-row frames and four sets of three discs each, or right and left-hand 10-inch mouldboard ploughs, successfully used for weeding in Louisiana. Australia created the first successful rotary weed extractor, modified several times in Hawaii for weeding in cane furrows. In Cuba, growers used John Deere No.4 cultivators with 2 discs and a middle breaker, right and left-hand 10 or 12-inch mouldboards, or reversible discs (18 to 24-inch discs) with gangs spaced 12 to 16 inches. In areas not requiring drainage, growers used 5-inch shovels, and animal power was still used for between-row walking cultivators. Chemical weed control was employed in various countries using knapsack, packsaddle, sled, truck, and tractor sprayers, especially in Hawaii. The overhead boom sprayer, with a 400-gallon capacity and 24-foot width, was reported at the Sixth Congress.

For harvesting, increasing labour problems and rising wages led to greater interest in developing modern harvesters. Two types of harvesters were developed: (1) windrowing machines and (2) complete machines that remove leaves and cut cane tops. The first type was popular in Louisiana, mounted on high-clearance tractors with power-driven revolving disks or saws to cut sugarcane at ground level. Two rows of sugarcane were thrown into a single centre row and pressed down by the front axle of the tractor. A three-wheel model on rubber tires was also developed, with two parallel horizontal rotating screws to guide the cane to an upright position, cutting stalks at or below ground level.

Rubber tires offered several advantages over steel wheels, including easier riding, less dust, reduced time, and lower fuel consumption. They were developed for use in soft or wet soils. Loaders were

improved with turntables on an axis, allowing 10 to 12 loads per move. However, loaders or grabbers introduced contamination issues with trash, rocks, and dirt. Some factories developed machines to separate these contaminants, and efforts were made to design machines to clean cane stalks before processing. In Louisiana, large plot size experiments required weighing yield data multiple times per plot. A bigger portable scale developed in 1935 could weigh 200 to 400 pounds of sugarcane at a time, using an extended hook grab and single beam scale driven by engine power. Another design in Louisiana had a capacity of 600 pounds, with both designs appearing similar.

PROMINENT CONTRIBUTORS

One notable figure was John Bovell, a plant breeder who maintained that the success of genetic improvement depended on combining superior varieties with appropriate cultivation practices. His studies on soil were particularly significant, as they helped identify the most suitable soils for sugarcane cultivation and establish fertilization and soil amendment practices to enhance fertility. He also contributed to the development of planting techniques and weed control strategies.

P.J. Wester studied the relationship between environmental factors (such as climate and soil) and sugarcane production. His research identified the key environmental factors affecting crop yield and led to the development of management strategies aimed at minimizing negative effects while maximizing positive ones.

Another significant contributor was N. Deerr, who, in 1915, published "Conditions of the Sugar Industry in Cuba." His work provided a technical and scientific foundation for improving sugarcane cultivation and production processes.

IMPACT OF THE RESEARCH

The expansion of productive areas and the sustained reduction of costs in all tasks made the activity more competitive overall. Thus, the notable surge in mechanization that took place between 1920 and 1940, is a historical technological milestone, showing the remarkable effort and great achievements made for the sugar cane agroindustry.

The period 1924-1928 was characterised by advances in soil preparation, crop establishment, cultivation, harvesting, and transport. There was movement from traditional and somewhat rudimentary animal-drawn implements to larger and more purpose-built units drawn by steam and low-power tractors. Progress towards mechanized systems also occurred in planting techniques that aimed to ensure better distribution of seedcane and integration of the various components of crop establishment. These included opening of planting furrows, placing of seedcane cane within these furrows, fertiliser application, and closing of furrows. Improved tillage practices aimed to loosen soil, enable fertiliser placement and control weeds particularly in ratoon crops. Developments in cane-cutting machines were the first attempts at mechanical harvesting. Trucks and rail-systems gradually replaced animal-drawn carts. Many of these developments were summarized by Sturrock (1929) who provided descriptions of the use of mechanical tractors that were ‘on the verge of revolutionizing cane agriculture’.

Papers delivered at the ISSCT Congresses during 1932–1938 provide evidence of further development of the above-mentioned on-farm practices. Implements grew in terms of size, width, multi-row options and depth of tillage. An age of increased frequency and depth of soil disturbance was initiated and driven by advances in mechanical options. Of major importance was the progress made in mechanical harvesting and associated activities.

The fundamental areas of agricultural engineering in sugarcane agriculture that were covered in the 1920s and 1930s provided substantial amounts of experience and engagement. These ultimately led to further development and innovation in future decades. Modern and routine on-farm practices benefitted greatly from the early efforts that sought to improve sugarcane production systems.

In summary the period 1930-1938 is characterized by changes in in the labour force, there has been significant development of equipment for various sugarcane field activities, including clearing, land preparation, planting, cultivation, harvesting, and ratooning. Studies on sugarcane equipment have been conducted in most sugarcane-producing countries. Even in countries with an available labour supply, there has been a focus on developing labour-saving devices to improve multiple field operations. These developments also assist researchers in managing time-consuming activities, especially when dealing with numerous treatments and replicates in experimental fields. However, some countries have been reluctant to mention machinery development for sugarcane production fields.

Prototypes of developed equipment have been applied in sugarcane fields, but they still presented some problems and require feedback for improvements or adjustments. Additionally, exploring equipment use across different countries with varying field conditions and weather is necessary for enhancing efficiency. Therefore, the continuous development of agricultural machinery and technology in sugarcane production is essential.



The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Agricultural Engineering 1950-1974

Bernard L Schroeder

bernard.schroeder@unisq.edu.au

INTRODUCTION

The Agricultural Engineering (Ag Eng) Section of the International Society of Sugar Cane Technologists (ISSCT) has traditionally formed part of the ISSCT Agricultural Commission. The triennial ISSCT congresses have continued to provide opportunities for delegates to present, discuss and record details of advances in research, development and extension (RD&E) covering all aspects of sugarcane production from breeding of cultivars to harvesting. Papers delivered within the Agricultural Engineering Section have specifically covered areas of engineering in agriculture and the interface with sugarcane agronomy. This paper provides a summary of topics that were covered by papers presented at the nine congresses held between 1950 and 1974. A total of 95 agricultural engineering papers covered several broad themes including in-field mechanisation, irrigation and water management, weed control, and harvesting and transport. These papers were either presented in agricultural engineering sessions, amongst related agronomy-focused papers, or within sessions that were identified according to appropriate and/or specific themes.

RESEARCH ADVANCES

In-field mechanisation

A substantial surge in developments in farm mechanisation followed the end of the World War II. This trend continued into the 1950s and beyond. Animal-drawn implements and modes of transport were gradually replaced with tractors, and larger and more robust implements. This initial change occurred mostly on large corporate-owned sugarcane mill-cum-planter estates and larger commercial enterprises in the United States of America and previous colonies of Britain, France and Spain. Examples were provided by Jex (1950) and Pearson (1953a) in South Africa, and Ramos Nuñez (1953) in Colombia. Jex (1950) recognised that although sugarcane production in South Africa was well progressed to full mechanisation, a relatively large number of factors influenced adoption. He concluded that mechanisation came with distinct advantages but also several challenges. He suggested that the latter would need to be recognised, assessed and dealt with through experience. The blending of advances in agronomic and agricultural engineering techniques with traditional practices in sugarcane production systems were also described for countries such as Jamaica (Innes 1953) and Puerto Rico (Samuels and Capo 1953).

During the 1960s and early 1970s several general agriculture-related papers described advances in various countries to improve yields using updated practices across the sugarcane production systems (Evans 1962; Wilson 1968). These papers included aspects of in-field operations such as land preparation, cultivation practices, planting, fertiliser applications, weed control, and harvesting and transport. Land preparation and tillage practices inclusive of relatively deep disturbance using various implements, harrowing and knifings were identified and evaluated as means to alleviate unfavourable soil compaction (Chinloy 1962) that existed ‘naturally’ and/or due to in-field operations. Specialised

forms of tillage included strip-tillage (Menon 1965) and vertical mulching (Evans 1962). While strip-tillage aimed to reduce widescale soil disturbance across large areas and the time need for soil preparation (Menon 1965), vertical mulching was introduced and assessed as a means of improving root exploitation of subsoils, especially those affected by adverse chemical and/or physical constraints.

The advent and increased availability of mechanical options for performing agricultural activities resulted in a surge in interest in systems involving various combinations of tractors and implements (Cykler 1971). Due to the associated relative ease of undertaking in-field activities and decreased dependency on labour, the focus was generally on maximising sugarcane production via so-called 'cane on cane' strategies. This involved limiting fallow periods between crop cycles, investigating different row spacings, both narrower and wider (Hebert *et al.* 1965), as there was no longer a restriction to accommodate the width of horses' rumps between rows. Multiple tillage operations to produce fine tilths during land preparation and cultivation practices could also be readily achieved and viewed as effective strategies for controlling weeds even during ratoon crops. The age of multiple tillage operations had indeed arrived! Reports of cultivation practices continued from various countries (Hsu 1968; Panje 1971; Ricaud 1971; Symes 1971; Mathur 1974). Interestingly, soil compaction (Taylor 1974) and yield decline research (Coleman 1974) were raised as issues in the mid-1970s. The latter may possibly have been associated with increased in-field practices and trafficking but not identified as such at that time.

The use of aircraft for herbicide, pesticide and supplementary fertiliser applications were first reported at an ISSCT conference in the mid-1960s (Riollano and du Pre 1965). This was considered a distinct increase in efficiency in Puerto Rico especially in terms of pesticide application. More than 20,000 ha were sprayed in a relatively short period in 1964 to control an outbreak of yellow aphid. This development was complemented by reports from South Africa of a tractor-mounted loader capable of substantially reducing the loading time of aircraft involved in crop dusting operations (Wilkins and Barnard 1965). Aviation in sugarcane agriculture was also now a reality!

Irrigation and water management

During the early 1950s, the need for irrigation and development of infrastructure and irrigation systems to ensure more reliable and consistent sugarcane yields were reported from South Africa (Hill-Lewis 1950; Pearson 1953b), Hawaii (Baver and Humbert 1953), Haiti (Hargreaves 1953) and Jamaica (Thompson 1953). They included the advantages, challenges and lessons learnt during this important change in practices. Methods of application, amounts of water, and cognisance of the properties of soils being irrigated were considered. This was followed logically by fine-tuning of decision-making about when and where to irrigate using in-field instrumentation such as tensiometers, gypsum blocks and evaporation tanks (Thompson 1953; Cowan and Innes 1956), and computation of irrigation requirements using climatic data (Hargreaves 1956; Rogers 1959).

n subsequent congresses there was an emphasis on water requirements and utilisation (Reynolds and Gibson 1968) and the uses, opportunities and benefits of different irrigation methods for specific circumstances such as surface/furrow irrigation (Chinloy *et al*. 1962; Gosnell and Pearse 1971). This also included information, experiences and financial considerations associated with overhead sprinkler irrigation systems (Macari and Fors 1959; Cleasby and Hill 1968; Norum 1968). The characteristics and linkages of irrigation systems to other practices (Hill 1971) were recognised as essential for ensuring compatibility with soil characteristics (Chinloy and Kelly 1971; Uehara *et al.* 1971), climatic conditions (Fogliata 1974), and in-field operations aimed at overall gains in productivity (Humbert 1971; Leverington 1971). Identification of subsurface and drip irrigation options, their uses, advantages and relevance in particular circumstances were highlighted by Gibson (1974) and Martin (1974).

Weed management

Ag Eng is an important aspect of weed control due the need for associated engineering intervention techniques. The practicalities of replacing hand and/or mechanical methods of cutting and/or removing

weeds with chemical weedicides [such as 2,4-Dichlorophenoxyacetic acid (2,4-D)] in sugarcane fields were described by Domangue (1953). The reported post-planting and pre-emergence methodology of spraying newly-tilled soil with weedicide reduced incidences of Johnson grass and other weeds, increased sugarcane yields and reduced labour costs in Louisiana.

Perceived incidences of tolerances of certain weed species to 2,4-D (Hanson 1959) and the need for other chemicals to control weeds prompted efficacy studies such as those reported by Lawrie and Vlitos (1962) and Mongelard (1971). Those studies included some recognition, at the time, for application (spray) methods to be evaluated. Shoji and Sund (1962) indicated that optimum weed control with chemicals needed uniform applications using appropriate equipment. This included aeroplanes, tractor-mounted boom sprayers, small-scale-type sprayers and knapsacks (Gilfillan 1971). Development of shielded sprayers enabled grass weed control without injury to the sugarcane crop (Orsenigo and Casselman 1965).

Harvesting and transport

Hand harvesting of cane continued to be the standard on sugarcane farms around the world following World War II. However, interests in developing mechanical harvesters had apparently been prompted by the mechanical developments in other types of farm machinery and a need to find alternatives to often unpleasant conditions experienced by cane cutters. The development of the Fairymead harvester in Australia was described at the 1950 congress and included details of prototypes, challenges and opportunities (Young 1950). Pressures on industry to expediate such developments led to successful outcomes in mechanised harvesting and in-field loading and transport in places such as Hawaii (Duncan 1959, 1962).

Despite adequate access to labour, the South African industry chose to assess three commercial harvesters for their circumstances (Bartlett 1965). Harvesting on steep slopes and conforming to existing row-spacings were identified as being particularly problematic. However, it was recognised that green harvesting with the ability to leave trash residue in harvested fields would be a distinct advantage, as would whole-stick harvesters to enable compatibility with existing transloading, stockpiling and transport procedures. Assessments of commercially-available harvesters and loading and transport systems occurred progressively in various countries over the next decade. Developments were reported by Churchward (1965), Gaunt (1965), Partridge (1965), Baxter (1968), Deacon (1968), Gaunt and Zagorski (1968), Panol and Escober (1968), Price and Blyth (1968), Toft (1968), Clayton (1971), Clayton and Whittemore (1971), van Groenigen (1971).

The strengths and weaknesses of different transport systems [i.e. road (Prince 1980) and light-gauge rail (Murry 1968)] were assessed for suitability in different circumstances in different countries and to meet different needs (Koopman 1974). These initial assessments and developments were the precursors to more in-depth investigations that were aimed at improving harvesting efficiencies by optimising parameters within machines (e.g. Rivas Novais 1974; Clayton *et al.* 1974) and the possibilities of harvesting without burning (Allison 1974).

PROMINENT CONTRIBUTORS

H. Evans (Booker Sugar Estates Ltd, Georgetown, British Guiana) who reviewed recent developments and trends in sugar cane agriculture (1962). This paper provided an important review of how integrated developments in agricultural engineering and agronomy contributed to ensuring advances in sugarcane production.

H.A. Thompson (West Indies Sugar Company Limited, Jamaica) who outlined irrigation studies at Monymusk, Jamaica (1953). This paper provided a forward-thinking approach for fine-tuning of decision-making in irrigation practices using in-field instrumentation.

C.A.N. Young (Fairymead Sugar Company Ltd, Bundaberg, Australia) for the development of the Fairymead cane harvester (1950). This paper described the details of development of a mechanical harvester including prototypes, challenges and opportunities. It set an important basis and bench-mark for future harvester innovation.

IMPACT OF THE RESEARCH

The period from the VII to the XV ISSCT Congress saw a substantial change in agricultural engineering concepts and applications within the international sugarcane community. These included:

- Manual and animal-orientated sugarcane farming practices being replaced with mechanised systems that aimed to maximise sugarcane production via intensive tillage and production options.
- Development of irrigated systems to enable sustainable sugarcane production in drier areas.
- Hand and mechanical weed control being replaced with spray-technologies using knapsacks, small-scale spray units, tractor mounted booms and aeroplanes.
- Development, improvement and increasing use of mechanical harvesters to replace manual cane cutting.

A substantial surge in developments in farm mechanisation followed the end of the Second World War. Replacing animal-drawn implements and modes of transport with tractors and larger implements provided great opportunities but also distinct challenges. The relative ease of undertaking in-field activities and decreased dependency on labour enabled a focus on maximising sugarcane production via so-called ‘cane on cane’ strategies. Multiple tillage operations to produce fine tilths during land preparation and cultivation practices could also be readily achieved. Although compaction and yield decline issues were raised as issues in the mid-1970s, links to the increased in-field practices and trafficking were not yet recognised. The use of aircraft for herbicide, pesticide and supplementary fertiliser applications was first reported in the mid-1960s.

During the early 1950s, the need for irrigation and development of infrastructure and irrigation systems to ensure more reliable and consistent sugarcane yields were reported from various countries. These included the advantages, challenges and lesson learnt from experience with irrigation, as well as methods and amounts of water applied. Decision-making about irrigation was improved using in-field instrumentation and computation of irrigation requirements based on climatic data. Opportunities and benefits of different irrigation methods for specific circumstances were highlight and included surface/furrow irrigation, overhead sprinkler systems, and subsurface and drip irrigation options.

The practicalities of replacing hand and/or mechanical methods of cutting and/or removing weeds with chemical weedicides was recognised. Importantly efficacy studies prompted viewpoints that optimum weed control with chemicals needed uniform applications using appropriate equipment inclusive of aeroplanes, tractor-mounted boom sprayers, small-scale-type sprayers and knapsacks. Development of shielded sprayers enabled grass weed control without injury to the sugarcane crop.

Although hand harvesting of cane continued to be the standard on sugarcane farms around the world following WWII, there was much interest in developing mechanical harvesters as alternatives to often unpleasant conditions experienced by cane cutters. Pressures on industry to expediate such developments also led to advances in in-field loading and transport. Various assessments identified factors that would need to be considered in the future. These included harvesting on steep slopes, conforming to existing row-spacings, and finding ways to ensure compatibility with existing transloading, stockpiling and transport procedures. Assessments of commercially-available harvesters and loading and transport systems occurred progressively in various countries over the next decade. These initial assessments and developments were the precursors to more in-depth investigations that were aimed at improving harvesting efficiencies by optimising parameters within machines.

These important developments provided a logical and sound basis for further improvements and innovations across these four fields in the later 1970s, 1980s and beyond!



The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Agricultural Engineering 1975-1999

Troy A Jensen

troy.jensen@unisq.edu.au

INTRODUCTION

The Agricultural Engineering (Ag Eng) Section of ISSCT) has historically been an integral component of the ISSCT Agricultural Commission. The triennial ISSCT congresses have consistently served as a forum for delegates to present, discuss, and document advancements in research, development, and extension (RD&E) encompassing all facets of sugarcane production systems, from agronomic influences to cultivar breeding, milling refinements and harvesting. Papers presented within the Agricultural Engineering Section have specifically addressed engineering in agriculture and its intersection with sugarcane agronomy. This paper provides a summary of the topics covered by papers presented at the eight congresses held between 1975 and 1999. A total of 114 agricultural engineering papers (including six posters presented at the XXIII congress) were presented and covered a diverse range of topics. These topics have been group into several broad themes: harvesting and transport; in-field mechanisation; irrigation and water management; and systems optimisation.

RESEARCH ADVANCES

Harvesting and transport

With more than half of all papers presented in the Ag Eng Section at the congresses being on topics related to sugarcane harvesting and transport category, this shows the importance of this topic to the sugar industry worldwide. Sugarcane harvesting and transport is a crucial step in the production of sugar and involves numerous key processes that are achieved in a range of methods depending on what part of the world is considered. The period 1975–1999 was very informative in terms of the evolution of harvesting sugarcane. In some parts of the world, the sugarcane crop had been cut entirely by chopper harvesters since 1975. Yet in other parts of the world, the crop was still being cut by hand.

As cane production systems, patterns, yields, access to equipment / technologies and customs have varied across the world, there is not one unique system for sugarcane production. These drivers cannot always be changed to match existing machinery, so there is a continuous adaptation to suit local conditions. The range of system adaptations have included:

- hand cutting and loading, to machine cutting, followed by continuous loaders;
- trash burning and push raking, to precision chop and fan clearing;
- manpower or small walk-along cutters, to two tonne per minute giants
- single row or dual row harvesters,

and questions such as:

- is it better to convey billets or to throw them?
- whether to suck trash from the cane mat or to blow it ?
- whether to use wagons, canetainers or trucks?

As a result, the parallel paths of continual refinement and evaluation of both harvesting techniques (manual/semi-mechanical and machine harvesting), have been reported.

Manual and semi-mechanical harvesting

Traditionally, sugarcane fields were burned before harvesting to remove leaves and tops, making it easier to cut the stalks and reduce the volume of material that needs to be processed. Workers use machetes / knives or mechanical means to cut the cane stalks close to the ground. The cut stalks are bundled together and transported to the processing facility.

Investigating methods to economically reduce losses and refining the amount of soil, stones and other extraneous matter in push pile and grab loading of cane has been detailed. Single operation mechanical advancements such as de-thrashing equipment, a front basecutter, use of hydraulics for a continuous loader and the development of a whole stalk harvester were reported.

Invariably, there was also the comparison between mechanical, semi mechanical and manual harvesting methods with connections being drawn between standards of living, workforce availability and the need for mechanisation (Fauconnier 1983). An exhaustive study was undertaken comparing pol, fibre, juice %, reducing sugars, purity, t cane/ha, t pol/ha for semi mechanised verses manual harvesting (Allam 1980).

Chopper harvesting

The introduction of mechanical harvesters in the mid-20th century marked a significant shift in sugarcane farming. These machines could cut and process cane more efficiently than manual labour. However, early mechanical harvesters still relied on pre-harvest burning to function effectively. The environmental and health concerns associated with burning led to the development and adoption of green-cane harvesting. This method uses mechanical harvesters to cut the cane without burning the fields. The leaves and tops are left on the field as mulch (green-cane trash blanketing), which improves soil health, reduces evaporation, protects the soil from erosion and reduces air pollution.

Today, green-cane harvesting is widely practiced in many sugarcane-growing regions, including Brazil, Australia, and parts of the United States and Thailand. It is considered a more sustainable and environmentally friendly approach to sugarcane farming

The changeover to chopper harvesting was not without problems in the early stages with this timeframe spanning the congress years reviewed here. Refinements were being made in countries that were early adopters/developers of the technologies and other countries were grappling with the transition and changeover to mechanical harvesting.

To accommodate mechanical chopper harvesters, it is essential to consider cultural practices, field layout, and transport system design. One country was designing machinery for 80 cm row spacing whilst others were contemplating double rows at 2 m spacing (Hudson 1989). Improving field cultural practices can help reduce soil in chopped cane. The use of small green cane chopper harvesters was reported and machine modifications to enhance the cleaning system (Dick 1986) could improve the reliability and efficiency of chopper harvesters. Standards for cane quality from chopper harvesters were suggested (Fuelling 1983). Factors such as cane collection efficiency, extraneous matter removal, and billet quality are crucial. Sucrose losses from mechanically harvested cane were mathematically expressed (de Beer 1980). Additionally, working time, wait time, and travel time for mechanical harvesters were important considerations.

Various components of the chopper harvester operations were singled out as a focus area. Sensors on the extractor hood were heralded as a loss monitor with a fan-speed controller enabling billet losses through the primary extractor to be finetuned (Dick 1996). Mathematical modelling of use to toppers was undertaken to assess the different topper height setting and the subsequent impact on Pol at the

mills (Fernandez 1992). Geometry of the feed roller and chopper chamber were assessed to minimised extraneous mater being trapped in the cane mat geometry and to increase separation efficiency (Monetero 1977). The cutting of the cane was also explored with the cutting resistance of basecutters in various configurations being documented (Chang 1980) and the hardening of chopper blades to improve life (Sanchez 1986) being investigated.

Removing material from the field has been a priority with the size, shape and amount of turning all impacting on efficiencies (Dutartre 1977). Field cultural techniques were gradually adapted to make them more compatible with chopper harvesting with works examining row spacings, cultivation techniques and within block layout were modified to accommodate chopper harvesting (Freyou 1999). Other works detailed efficiency gains in optimising harvesting, loading, transloading and transport (Donawa 1977) with data acquisition systems being developed to optimise haulage logistics. Also in the transportation dynamic are the issues around volumetric weight, extraneous matter, yield, billet length and loading coefficient. Comparisons of rail verses road as the transportation medium was also reported (McWhinney 1983). Connections between heavy machinery / haulage vehicles and compaction and the resultant yield reductions in subsequent crops was also mentioned (Cheong 1999), with operators comparing tracks to tyres for flotation and compaction considerations (Brixius 1977).

Material throughput of the chopper harvest is a primary consideration, but the flipside of quantity is the efficacy of the machine and how well it extracts sugar from the field (Mason 1980). Field and quality losses, due to chopper harvesting, were explored with papers comparing outcomes with hand harvesting. Other studies investigated the impacts of billet quality (sound, damaged, mutilated) (de Beer 1980), cane losses and extraneous matter levels in green and burnt cane on recoverable sugar. The generally accepted loss quantification method for commercial cane at the time was assessed by picking up cane pieces and fragments left in the field after passage of the harvester (Mason 1980). This was a very time-consuming task, and the accuracy was limited by the destructions of small pieces of cane by the harvester extractors. It was during this time that the term ‘Invisible losses’ was first coined (de Beer 1980).

The environmental impact of burning cane receive attention with several comparisons between burnt and green-cane harvesting being reported (Neto 1989). The components focused on included the reduced cutting rates and increased fuel usage and maintenance / operating costs and the impact on harvester performance (Ridge 1989).

In-field mechanisation

Papers presented at the congresses that fall into this theme generally dealt with mechanisation components within the sugar farming system that is not related to harvesting and covers the areas of planting, cultivating and weed control.

Papers dealt with making better use of larger machine and improving machinery performance, utilisation and the economic benefits of tillage. In a framing system where larger machines are used, there is the inevitable comparison between the use of tyres and tracks to get the horsepower to the ground (Brixius 1977). With the use of larger machines comes the associated soil compaction problems arising during land preparation, planting, cultural practices and harvesting operations. High values of field efficiency are attained through the use of larger implements, tractors and wagons mounted on high-flotation tyres or track layers to reduce compaction damage to the soil. Compaction is normally accepted as an unavoidable consequence of mechanized agriculture. The paper by Torres (1996) gave a good description of compaction management.

Planting is also an important component of the sugar farming system. Papers have been dedicated to evaluating and comparing wholestalk planters versus billet planters. Studies were undertaken to investigate the impact of row profile on the planter to be and its impact on root growth (Salata 1986). There were also other papers reporting on the development of various planter configurations and the development of a self-propelled two-row billet planters (Huang 1999). Assessments were also

undertaken to assess row spacing profitability. The benefits and limitations of green-cane trash blanketing to conserve moisture, suppress weeds and minimise erosion were discussed (Ridge 1989).

Investigations into ratoon management leading to stool eradication once it is no longer profitable to continue the ratoon, by chemical and mechanical means, were also addressed by several papers (Jacquin 1996). The consequences of all field operations undertaken during the growing season were assessed for its impact on factory performance and the ability to recovery sugar (de Beer 1999).

In the developing world where there are a lot more smaller landholders, there were similar areas of interest to those listed above around the increasing use of mechanisation to overcome labour shortfalls (Perumal 1999).

Irrigation and water management

Sugarcane is known for its high water demand, which is crucial for its growth and yield. Water demand is met by rainfall or supplement by irrigation. Water stress during critical growth stages can significantly reduce both total yield and sucrose yield. Methods detailed in papers presented at the congresses involved measuring ETa and precipitation to assess water excess and deficits. These measurements are crucial for managing water resources, especially under conditions of water scarcity.

Several papers were dedicated to computer simulation of evapotranspiration and rainfall and frost modelling (Ayub 1980). Links were made between evapotranspiration, cane yield and sugar yield (Shik 1983). Sugar cane / water consumption models along with knowledge of the mathematical functions of water-soil relationship were used to predict soil moisture levels as a trigger for irrigation scheduling (Vazquez 1983).

The physical infrastructure to deal with water delivery and drainage was also evident. An underground pipeline irrigation system was developed for surge and continuous irrigation of furrows (Fang 1996). Comparisons of the drainage and leaching efficiency of drains in sugarcane plantation, the effect of sub-soiling in soils with excess water, or with a hard pan, on soil properties and sugarcane quality and yield were also reported (Jagtap 1992).

Making better use of the water resource was also a focus. Papers dealing with water balancing and alternate-furrow irrigation (Torres 1996) were compared with conventional methods.

System optimisation

Sugarcane producers can achieve higher yields, better quality, and more sustainable production practices by investigating system optimisations. Each stage of the value chain is interconnected, and improvements in one stage can positively impact the overall efficiency and profitability of sugarcane production. These concepts have been addressed at ISSCT congress.

Systems approach comparing hand and mechanical harvesters including consideration of such variables as interest, inflation, administration, salary, drivers, fuel. maintenance, overhaul, repairs, social obligations, insurance, depreciation, etc. are presented (Gentil 1977). Computer simulation models were developed to test alternative strategies and decisions in sugarcane transportation management from harvesting to the transloading in the mill, with considerations being made for weather, travel times, equipment capacity and equipment breakdown (Libunao 1977).

Additional insight provided by other papers addressed the interactions between mechanical harvesters, transport and capacity of factory to handle material, with good machine management and mechanization planning are prerequisites for cost effective operations (de Beer 1992). In addition, maintenance can no longer remain an isolated technical activity, but must become an integral part of the entire organisational management function (Braithwaite 1989)

Papers also address the technical and economic assessment of sugarcane cleaning station to reduce extraneous matter sent to mill, with the removed trash used to feed cattle (Eguiluz 1983). A simple deterministic model was also developed to describe and explain sugar losses detected due to harvest, cane maturity, infield cane losses, milling delay, trash content and frost effects, with the model use to simulate various scenarios with the intent of improving sucrose recovery (Romero 1996). Green-cane trash management options, including heavy trash loads, were evaluated to and showed promised to control weeds (Richard 1999).

PROMINENT CONTRIBUTORS

Over the period, much work undertaken focussed on chopper harvester incorporation and refinements. Hence two nominees are from the harvesting area.

R.G. Dick who contributed on Australian harvester research, adoption of green-cane harvesting and trash blanketing in Australia, and sensor and control technology in sugarcane harvesters. He chronicled the chopper harvester research and refinement in Australia, that impacted on subsequent research in other parts of the world.

A.G. de Beer who contributed on the performance of chopper harvesters, semi-mechanized sugar harvesting systems for a developing country, mechanical green cane harvesting, refinements to semi-mechanised systems as countries progress to the chopper harvester. and losses incurred when chopper harvesting sugarcane. He reviewed mechanical harvesting and its effect on sugarcane quality.

J.S. Torres who contributed on soil compaction and sugarcane stool damage due to semi-mechanized harvesting in the wet season, differentiation of soil compaction and cane stool damage, and alternate-furrow irrigation of sugarcane. He addressed farming systems issues of sugarcane production covering broad topics for compaction to irrigation.

IMPACT OF THE RESEARCH

Much innovative work in agricultural engineering, that was conducted between the years of 1977-1999, has been presented at ISSCT congresses. As detailed above, a large proportion of the papers delivered addressed mechanical harvesting developments and the introduction of a new techniques and technologies. Papers also dealt with other farming operations including planting, tillage, irrigation, transport logistics and weed control.

The issues that were front and centre to the world sugar industry in the last decades of the 20th century are still pertinent in 2025. Yes, technologies have made some tasks easier. Data collection and storage is much easier and guidance of tractors and harvesting machines is now commonplace in some countries. Sensors are available to facilitate automation and mechanisation. Diesel engines now have increased power outputs allowing much larger machines to cover larger areas and to reduce work times

However, questions relating to the underpinning fundamental principles of sugarcane production are still as current today as they were more than 25 years ago. The limitations or research questions being address back then, are still front and centre and remain relevant and/or unresolved today.

As the developing world moves towards further integrations of mechanisation into their sugarcane farming system, this compendium of research outcomes, produced by countries that had embraced mechanisations in the late 20th century, should be a valuable resource for partitioners in parts of the world who are currently making the transition mechanised and green-cane harvesting.


The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Agricultural Engineering 2000-2023

Pierre Todoroff

Pierre.TODOROFF@ec.europa.eu

INTRODUCTION

The period from 2001 to the present includes congresses in Brisbane (2001), Guatemala City (2005), Durban (2007), Veracruz (2010), São Paulo (2013), Chiang Mai (2016), Tucumán (2019), and Hyderabad (2023).

The Agricultural Engineering section, created in 2001, has seen 121 contributions to ISSCT congresses, including papers and posters, i.e. an average of 15 contributions per congress. More than half of these contributions deal with research issues related to mechanization, making it the section's preferred theme. Digital agriculture ranks second, with the number of presentations varying between three and seven at each congress. Irrigation is in third place, ahead of the environmental impacts of sugarcane production that appeared in 2010.

RESEARCH ADVANCES

Mechanization

Although the theme of mechanization occupies an important and more or less constant place in the presentations of the Agricultural Engineering section, its content has evolved over the last 20 years.

Initially it focused on the development of harvesting mechanization in industrialized countries to overcome the growing shortage of harvesting labour. Many presentations approached this theme from the angle of increasing productivity in countries where sugarcane cultivation is poorly mechanized (Wegener *et al.* 2013), whether by adapting or optimizing existing equipment (Vincent *et al.* 2001; Scandaliaris *et al.* 2005; Duquesne and Rondeau 2019), or developing equipment adapted for specific situations such as flood-prone areas (Davis *et al.* 2005; Okuzawa *et al.* 2019) or sloping areas (Lyne *et al.* 2007).

Some presentations also focused on the societal aspects of mechanized harvesting, seeing it as a necessary adaptation to rising living standards. Lyne's poster (2007), for example, presented the development of a portable cutter whose specifications considered ergonomic criteria and worker fatigue.

Most presentations dealing with harvesting mechanization focused on improving harvester efficiency in the early 2000s, both in terms of harvesting speed (Davis and Norris 2005; Davis *et al.* 2005) and their adaptation to green cane harvesting (Norris *et al.* 2001; Cruz *et al.* 2005; Meyer *et al.* 2005; Akachi 2007; Norris *et al.* 2007; Núñez and Spaans 2007).

In parallel, a series of presentations focused on the quality of mechanical harvesting, from the point of view of reducing sugar content in loads (Schembri *et al.* 2001; Whiteing *et al.* 2001; Richard *et al.* 2001; Larrahondo *et al.* 2005) but also juice losses and cane degradation (Caldera and Norris 2019).

In addition to these strategies for increasing productivity at farm level, some papers addressed it at the industry level by dealing with logistical issues associated with harvesting, in particular the optimization of cane loading and transport (Meyer *et al.* 2001; Wright *et al.* 2005; Sustaita *et al.* 2019), and the optimization of the sugar mill supply chain (Everitt *et al.* 2001; Le Gal *et al.* 2007; Chidoma, 2007; Abdel-Mawla, 2010; Sun *et al.* 2013) were highlighted.

These papers constitute a relatively exhaustive inventory of solutions for improving productivity through mechanization. On the other hand, few papers dealt with the agronomic impacts of mechanical harvesting, such as soil compaction and health (Torres *et al.* 2005; Norris *et al.* 2007), or stool degradation (Shinzato *et al.* 2013).

These issues were nevertheless addressed within the more general framework of mechanization of cultivation operations, presented essentially as a means of improving productivity through labour substitution (Akachi 2005; Yadav 2007; Wegener *et al.* 2013), or through intensification and industrialization of cultivation operations (Kidd *et al.* 2007). We see outlined classic agronomic issues such as the risk of compaction and degradation of soil structure (Thungsotanon *et al.* 2016), particularly in wetlands, in Colombia (Torres *et al.* 2005, 2007), and in Mauritius (Jacquin *et al.* 2001). Authors proposed solutions for controlling machine traffic (Erazo *et al.* 2016; Lecler 2016) combined with double-row cane planting (Núñez and Palomeque 2016).

At the same time, and to avoid the harmful consequences of mechanization driven by the quest for productivity (Bull *et al.* 2001), we saw the emergence of various new agronomic approaches, such as minimum tillage to combat compaction (Prammanee *et al.* 2001; Torres *et al.* 2007; Tesouro *et al.* 2019; Barbet-Massin and Mansuy 2023), green-cane harvesting, which was specifically the subject of the Agricultural Engineering Section workshop in Argentina in 2006 (Norris *et al.* 2007), and the practices termed conservation agriculture, which were also the subject of the Agricultural Engineering Section workshop in Thailand in 2010 (Norris *et al.* 2010).

Environmental impact

Environmental concerns were also reflected in papers in the Agricultural Engineering section, against a backdrop of global warming and the need to reduce greenhouse gas emissions. For example, several authors focused on the use of residues from sugar mills (Yan *et al.* 2010), harvesting and trash management in the case of green-cane harvesting, and the use of residues as biofuel (Fernández de Ullivarri *et al.* 2013) and its consequences on the adaptation of harvesting machinery (Amù *et al.* 2005). Positive agronomic impacts were being assessed through experimentation (Núñez and Spaans 2007) or crop growth modelling (Cerqueira *et al.* 2013). More recently, presentations have explored the environmental impact of sugarcane production, through life-cycle analysis (Kaab *et al.* 2023), or the assessment of greenhouse gas emissions (Acreche *et al.* 2013; Todoroff *et al.* 2023).

Irrigation

Some presentations discussed both the technical and economic performance of drip irrigation systems, often in comparison with sprinkler systems in the early 2000s, in East Africa and Central America (Ndlovu *et al.* 2001; Castro *et al.* 2005). The aim was to demonstrate the productivity gains offered by micro-irrigation techniques. This search for productivity was later complemented by research into optimizing irrigation schedules (Cruz *et al.* 2010; Ng Cheong *et al.* 2016).

At the time, interest in gravity-fed irrigation was still strong in more arid countries such as Iran. Several papers presented technical and agronomic optimization studies of this practice at the 2013 Congress (Nouri and Boroomand Nasab 2013; Sheini Dashtgol *et al.* 2013). These same authors, perhaps inspired by the work presented at ISSCT congresses in the early 2000s, in turn contributed to promoting the practice of drip irrigation by presenting their research results on the adaptation of this technique in

their country at the Hyderabad congress (Sheini Dashtgol *et al.* 2023; Zanganeh-Yousefabadi *et al.* 2023). India followed suit (Shinde 2023).

Digital agriculture

Digital agriculture, driven by the development of remote sensing and Geographic Information Systems (GIS) technologies, emerged in the 1990s and rapidly spread in the sugarcane industry. This process can be seen in the scientific communications presented in the newly born Agricultural Engineering section, Digital Agriculture contributing one-third of the presentations.

Use of GIS and spatial analysis tools commenced at the end of last century in developed countries in a wide range of applications and played an important role in the development of digital agriculture. Tropical agriculture jumped on the bandwagon late, but its GIS expertise quickly came of age as evidenced by the relatively large number of communications presented in the Agricultural Engineering section from 2001 to 2013. Its applications mainly result in suitability maps for sugarcane crops, used as decision-support tools for the optimization of field operations (Promburom *et al.* 2001; Ramasamy *et al.* 2001; Segrera *et al.* 2001; Stringer and Cullis 2001; Torres and Cruz 2010; Aguilar-Rivera *et al.* 2010).

Precision agriculture, that is farming operations, often automated, that consider temporal and spatial within-field variability to improve agricultural productivity and sustainability, is another facet of digital agriculture. However, the few contributions to the Agricultural Engineering section, (e.g. Johnson and Richard 2005; Erazo *et al.* 2016; Magalhães *et al.* 2013) demonstrated difficulties in implementation in sugarcane agriculture compared to in annual crops agriculture. One reason is probably the lower number of cultivation interventions in sugarcane farming, making investment in precision agriculture less profitable in the short term. However, sugarcane agriculture contributed to and benefited from the progress in sensing technologies and developed its own version of precision agriculture. It made extensive use of in-field and on-board sensors to increase the map resolution of the biophysical properties of sugarcane fields and the temporal resolution of crop growth and yield. The technological solutions range from near-infrared spectroscopy cane-quality assessment to optimize the agricultural operations (fertilizer application, scheduling of farming operations, etc.) (Taira *et al.* 2007), to electromagnetic induction to map the spatial variability of soil properties (Sanches *et al.* 2016), laser-based yield monitoring system for harvesters (Nakayama *et al.* 2019), yield sensor data processing to analyse the productivity of the field and the harvest efficiency (Yoshimine *et al.* 2019), and IoT (Internet of Things) technology to automate irrigation (Radmehr *et al.* 2019).

Remote sensing has been a huge scientific and technological step forward in environment and crop monitoring. It has made a fundamental contribution to the development of digital agriculture since the 1980s, often in combination with new data processing algorithms and software. A small but steady number of papers were presented in ISSCT congresses since then, formerly in the Agronomy section and workshops, and then in the Agricultural Engineering section since 2001. Remote sensing applications in sugarcane agriculture were similar to those successfully used in intensive annual crop farming, as reflected in the contributions to the Agricultural Engineering section. The most popular application was yield forecasting, as it provided a key information for many mill-level and industry-level activities such as adjusting marketing and pricing strategies, planning of mill opening and closing dates, crushing rate and harvest delivery quotas, and logistics organization. Contributions highlighted the research on this topic conducted in South Africa (Schmidt 2001), France (Bappel *et al.* 2005), and Colombia (Bastidas-Obando *et al.* 2007, 2019). Crop identification was also a topic of interest. It was covered from several angles: weed detection from aerial imagery (Olea *et al.* 2001), variety identification (Murillo *et al.* 2007), assessment of soil moisture and salinity (Mohammadi Moalezade *et al.* 2023; Zahirnia *et al.* 2023), estimation of crop evapotranspiration (Neissi 2023), and land use/land cover mapping (Lin-Kwong-Chon *et al.* 2023).

Software development successfully accompanied and supported the development of digital agriculture. The wide variety of new technology-based sensors, especially remote sensing, produces a huge

amount of data whose analysis by human expertise is impossible. The development of computer processing power and increasingly sophisticated data processing algorithms such as deep learning image recognition algorithms, make full use of this data, adding value that can lead to significant productivity gains at both field and industry level.

This was illustrated by the paper of Jensen *et al.* (2016) on the automatic processing of noisy yield-sensor data to produce reliable yield maps, by the presentations of agricultural operations and supply chain logistics optimization algorithms (Everitt *et al.* 2001; Le Gal *et al.* 2007; Scarpari *et al.* 2007; Sustaita *et al.* 2019, and by Lin-Kwong-Chon (2023) demonstrating the power of deep learning techniques in sugarcane crop mapping.

PROMINENT CONTRIBUTORS

C.P. Norris made significant contributions to the ISSCT in the Agricultural Engineering section, presenting over nine communications between 2001 and 2016. His pivotal advancements in optimizing harvester performance, especially in green cane harvesting, played a crucial role in helping the sugar industry eliminate the practice of burning cane prior to harvest.

E. Bastidas-Obando made substantial contributions to digital agriculture within the Agricultural Engineering sector. He expertly adapted innovations in remote sensing to sugarcane farming, showcasing the advantages of satellite-based data for yield forecasting through his communications.

A. Sheini Dashtgol has been deeply involved in the development and optimization of irrigation system efficiency, particularly drip irrigation under sugarcane. His work is exemplary and well illustrates the efforts made to improve sugarcane productivity in dry regions.

IMPACT OF THE RESEARCH

The scientific papers presented in this young section of the ISSCT bear witness to the evolution and adaptation of agricultural practices in sugarcane cultivation at the start of this century. Technical studies aimed at optimizing traditional mechanization, transport and irrigation practices have been completed by more exploratory work driven by societal issues such as global warming and respect for the environment. Research into carbon footprints and agro-ecological practices is opening up new avenues for assessing and reducing the environmental impact of sugarcane cultivation.

The contribution of digital agriculture to improving farming practices, through solutions adapted to sugarcane farming, is particularly noteworthy in this section, where it is the second most represented theme.


The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Germplasm and Breeding 1924-1938

Raúl O Castillo Torres and Freddy Martin

rcastillo1197@gmail.com

INTRODUCTION

The development of varieties in all crops is the key element to improving crop production. In sugarcane, as the cultivation areas increased, several problems arose (diseases, insect pests, response to dry or flooding fields, harvesting, sugar content, etc.). Therefore, the scientific work in variety development was a necessary factor to be considered by governments and the industry. From the beginning of sugarcane selection work, breeding programs have relied on three main components: collection and evaluation of germplasm, cross-pollination, and selection schemes. Although these components are still the main system used to develop varieties, new biotechnology techniques are being applied to accelerate variety selection or to apply gene transformation or gene-editing tools that allow precise cutting and modifying DNA sequences for certain traits.

RESEARCH ADVANCES

Pre-ISSCT

Because sugarcane breeding started years before the first ISSCT Congress, it is important to include a short summary of the prominent work done in Java and Barbados before 1924. The comprehensive report by Jacob Jeswiet in 1927 showed that the initial scientific work started in 1885 with the establishment of the first experiment station in Semarang, Java directed by Dr. F. Soltwedel. In 1862, Noto Hami Prodjo (Java), already published a report in the Journal Science for the Netherland Indies 35:359 showing the production of true seed. Later Soltwedel in 1885 obtained a few seedlings from *Saccharum spontaneum*, and in 1886-87 made crosses between a Mauritian cane, *S. officinarum, S. spontaneum* and *Erianthus* but with no great success. In 1887, Ostermann in Java produced seedlings from a Javan variety (probably Ardjoena). Soltwedel also produced seedlings from *S. officinarum* crossed with a strong cane from Hawaii. Apart from the Javan work, Harrison and Bovell produced seedlings in Barbados in 1889, planting in 1890 the first seedlings for selection. From 1892-93 Moquette continued the work of Soltwedel and crossed about 38 varieties and, together with Walker, produced interesting technical information on cane crossing and flowering. From these crosses came the well-known POJ100. In the same period, Bouricius, with a cross between Black Cheribon and a Fijian cane, released B245. These two varieties revolutionized the Javan sugar industry.

In 1903, Stock crossed Black Cheribon with Bartjan and released DI52. In 1911, Vensteegh selected EK28. Moquette, Walker and Kobus made several crosses between. *S. officinarum*, local canes, *S. barberi*, *S. spontaneum* and a wild cultivar like Kassoer cane to release new varieties planted in Argentina, Formosa and Cuba named POJ36, POJ139, POJ213, POJ228, POJ234, among others. From 1915 to 1921, the crossing and selection work by Jeswiet and others in Java, using previous hybrids with *S. officinarum*, Kassoer wild canes released POJ2714, POJ2722, POJ2725 varieties. POJ2878 came from a cross between EK28 x POJ2364 and POJ2727 was from Batjam x POJ2364. This is called “the nobilisation process”, where *S. officinarum* being the noble cane and several crosses

were performed with wild local canes and other *Saccharum* species. The numerous crosses between *S. officinarum* and other related species, including wild or local landraces, might have resulted in the so-called reduced gametes formation, to double in chromosome number with 2n+n chromosome transmission explained by Sreenivasan and colleagues in 1987.

1924 Congress

The first ISSCT congress was held in 1924 in Honolulu, Hawaii in August 1924 and was very different from modern-day congresses, it resembled the thematic workshops nowadays organized by the Society. The published proceedings indicate that most of the time in session was spent in discussions regarding plant health, insect pests, quarantine, and rodents. Smith made a comprehensive summary of the Breeding Section where the most important topics discussed during the meetings were: 1) Proper study is given to the inheritance of parental canes, 2) The behavior under climatic conditions where the new clones will grow commercially and 3) Are the desirable or undesirable characters transmitted to the next generations.

Brandes had prepared an outline of “Sugar Cane Breeding” topics to guide discussions in 1) Selection of parents, 2) Varieties naturally inclined to bloom, 3) Environmental conditions affecting blooming or maturity, 4) Techniques of crossing, pollen application, flower protection, and management of seed. It is interesting to note that some of the discussions and applications at that time are still used in breeding programs. Among many, the Hawaiian methods are used to determine pollen viability by observing under the microscope and using the iodine to identify if pollen granules are spherical, juicy, and full of granules of starch.

At the same time, Verret and associates described that sugarcane tassels could be kept alive by standing them in a weak solution of sulphur dioxide, marking the beginning of a new era for cane breeding. This is well known as the “Hawaiian Solution.” Until this technique was reported, pollen was either collected and brought to the female tassel, or stalks with male tassels were cut and brought to the female plant that was “blooming”. In the latter case, male tassels were tied over the female tassel with the cut end placed in water. However, due to clogging of vascular tissue, the male tassel had to be replaced every second day.

In addition, during the discussions, the topic of bud selection was extensively analyzed, concluding that the variation found by selecting materials by this method is strongly influenced by the environment, which obscures the yield and quality of the sugarcane varieties.

1927 Congress

The second ISSCT Congress was held in Habana, Cuba in March 1927, presenting a series of topic discussions that revolutionized sugarcane crossing techniques. Jeswiet (Java), presented an outstanding review on the history of sugarcane selection work in Java, including his pioneering breeding work and a description of the main crosses performed in Java. In another presentation, he established the basis of sugarcane flowering, the physiology of the plant cane and the use in crossing, and the development of new varieties.

Agee reported initial success in using sulfurous acid solutions to keep male tassels viable in Hawaii, leading to successfully producing viable seed by cutting both male and female tassels and placing them in the acid solution. He mentioned that this methodology was developed by Verret, assisted by Kutsunai, Das. Conant and Twigg Smith, since 1924.

Rao Sahib, Venkatraman, and Thomas reported that at Coimbatore, a method of growing a new set of roots on the parental stalks allowed for cutting both male and female stalks and moving them to a crossing “shed”. The use of a “shed” isolated the cross and subsequently helped reduce exposure to contaminating pollen. Later, in 1938, the use of crossing lanterns in Mauritius was described by de

Sornay. This allowed the tassels to be removed from the field and crossed in isolation, starting systems of isolating parental materials to establish clearly identified family progenies. Today sugarcane breeding programs throughout the world use variations of these methods to make controlled crosses with minimal chance of contamination.

Although the movement of sugarcane germplasm has not been properly managed at the time, an important subject presented was the establishment of controlled systems for sugarcane quarantine by. Brandes, directing to the modern germplasm exchange around the world avoiding the introduction of pests and diseases.

1929 Congress

The third ISSCT Congress was held in Soerabaia, Indonesia (Java) in June 1929. The cytology of origin of chromosome numbers in “saccharum” was a topic of discussion at this Congress, presented by Bremer in two papers.

Jeswiet reported disease resistance progress made by using related species in crossing. In addition, a comprehensive description on the development of selection and breeding of sugarcane in Java was presented by Jeswiet with a series of suggestions to improve crossing and selection methods.

A “Committee on Varieties”, chaired by Moir, was appointed after the Havana congress. The first undertaking was “straightening out the nomenclature and synonymy and serve as a central source of information for cane workers throughout the world.” The committee’s report at the 1929 and subsequent congresses included a world-wide list of cane varieties, including detailed descriptions, and the possibilities of germplasm exchange thorough the proper channel to comply with the quarantine systems.

1932 Congress

During the fourth ISSCT Congress held in San Juan, Puerto Rico in 1932, Davis extensively reported progress made by using progeny of self-pollination in successive generations performed in seedlings of Kassoer.

Moir gave an interesting discussion paper questioning if in the Java collection has new varieties or perhaps are just mutations because most of the varieties looked very similar with small differences, suggesting that the environment might be inducing to express vigor or different plant characteristics,

Ven Katraman reported on sugarcane breeding in different countries based on questionnaire send from Java, Mauritius, Puerto Rico, Peru, Philippines, Australia, Florida, and India. A long and detailed varieties listing and crossing was included, which set up the basis for the variety catalog produced later and available at Variety Notes on the ISSCT webpage.

Using root tips, Bremer reported on the somatic chromosome numbers of sugarcane forms and the chromosome numbers on indigenous Indian canes, which varied from 60, 91, 121 and 136 chromosomes.

In addition, Bregger (Puerto Rico) started discussions on the early stages of selection from seedlings. Arceneaux (Louisiana) presented a methodology to correlate variations in field experiments. Bell (Queensland, Australia) discussed the increase of major diseases in sugarcane and presented a methodology for screening diseases resistant in breeding programs.

1935 Congress

Most breeding reports in the fifth ISSCT Congress held in Brisbane, Australia in August 1935 were related to methods of selecting varieties using seedlings. Davis (Puerto Rico) explained the use of about 5,000 to 10,000 seedlings planted in field trial selections in three stages of plant growth. McIntosh (Barbados) suggested planting 20,000 seedlings in January and 10,000 in April. Trials were accompanied by proven crosses and new crosses with progenies from unknown performance of parental material. Selection of best clones went for up to three years before extended trials were performed and a new variety released. Bourne (Florida, USA) reported on a method of selecting cane seedlings in the Everglades. Seedlings were potted in 5-inch paper pots for 60 days and planted in the field. Each seedling (stool) was evaluated to identify the best clones in sugar content and plant architecture. The selected clones were field tested again and after 8-10 months a sample of 10 stalks was removed for lab analysis. Venkatraman summarised the methods for seedling selection as adopted at Coimbatore. Mangelsdorf made a comprehensive report on the sugarcane breeding system in Hawaii and indicated that Hawaii has also indigenous sugarcane canes; however, to speed up the development of varieties, the importations included Yellow Caledonia (Tanna, Malabar), Bamboo canes, Cavengerie (Port Mackay), Badila, Uba, and, in due course, many of the Barbados, Demerara, and Queensland seedlings, mostly *S. officinarum*, and the use of *Saccharum* species in the breeding program.

Mangelsdorf also explained the nursery practices and preliminary testing, the regional trials, and some considerations in preliminary selection, including selecting for disease resistance.

Arceneaux (Louisiana) discussed the determination of theoretical yields of sugar in connection with sugarcane variety tests based on field samples related to laboratory-scale milling tests. Lennox and Mangelsdorf (Hawaii) discussed the plot techniques in testing sugarcane varieties; and Hill described the selection methods practiced in Mauritius.

1938 Congress

The Plant Breeding and Germplasm section presented several applications and methods for crossing – selecting, quarantine and collections – of varieties as a whole variety improvement system. Brandes and collaborators presented a comprehensive paper on the use of wild relatives for improving sugarcane varieties. They concluded that botanical study to identify and fix relationships of the specimens is regarded as fundamental and a more detailed study is being in progress. While breeding, a gradual understanding of the genetic make-up of the wild forms is being acquired concerning which will be possible for further use.

For the first time Artschwager (USDA) reported on the use of vegetative characteristics in sugarcane taxonomy including several plant organ drawings that nowadays are still used in several publications. DeSorney (Mauritius) described the use of improved crossing lanterns to make crosses comparing to those used in Barbados.

Lennox (Hawaii) reported on the sugarcane collection expedition in New Guinea in 1937 following those of Cowley in 1895 and Tryon in 1896 under the auspices of the Queensland Department of Agriculture. All canes collected by Tryon were named N.G., and the NG15 (Badila) was the most noteworthy for the Australian sugar industry. In general, exchange of germplasm was a free and friendly cooperation between breeders, agronomists, and farmers. Sasscer (USDA) discussed the Plant Quarantine Restrictions on the entry of sugarcane into United States based on legislation named Quarantine No. 15, and No. 16 that became effective on June 6, 1914, allowing entry materials into Hawaii and Puerto Rico only until 1934, when a quarantine station in Washington was established.

PROMINENT CONTRIBUTORS

Jacob Jeswiet performed many crosses with local wild varieties and initiated the nobilization of canes using *S. officinarum* in Java following the initial breeding work started by Dr. F. Soltwedel. Many POJ varieties were released and cultivated around the world. He also extensively worked in the development of disease-resistant varieties and first time described the process of flowering in sugarcane.

J.A. Verret developed the “Hawaiian Solution,” which revolutionized sugarcane breeding and is still widely used in active breeding programs. The solution contains sulphur dioxide and keeps male and female tassels alive. Agee, in his presentation at the 1927 Congress, clearly explained that the solution was developed by Verret with the assistance of Kutsunai, Das Conant, and Twigg Smith.

A.J. Mangelsdorf pioneered plot techniques and advanced statistical methods for sugarcane selection. He initiated nursery practices and preliminary testing, regional trials, and fundamental considerations in the early stages of selection, including selecting for disease resistance.

IMPACT OF THE RESEARCH

Most breeding reports during the 1924-1938 period described the many difficulties of variety breeding and the developing techniques used in various programs. While there were healthy discussions on all topics, a great deal of discussion centered around breeding for disease resistance and identifying sources of resistant parental material. Some of the techniques and sources of germplasm are still used in the present day in breeding programs around the world. These early developments constructed the pathways for today’s breeding efforts around the world. Even today some of the early developed varieties are still used for commercial production or as parents in crossing.


The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Germplasm and Breeding 1950-1974

Anthony J Kennedy

tonyk@caribsurf.com

INTRODUCTION

The years between 1950 and 1974 saw many major advances and changes in sugarcane breeding and the use of germplasm. These changes were in both technology and breeding philosophy. All of this activity was well reflected in the presentations made in the germplasm and Breeding sections of the ISSCT congresses held every three years during this quarter of a century. They were held in all the major cane producing regions; Australia (1950), Jamaica (1953), India (1956), Hawaii (1959), Mauritius (1962), Puerto Rico (1965), Taiwan (1968), USA (1971) and South Africa (1974). Although starting slowly, with only six papers under this heading in 1950, following the hiatus of the preceding war years, an average of 30 papers were presented in the following eight Congresses. The highest number of papers was 47 at the Congress of 1959.

RESEARCH ADVANCES

The understanding of germplasm and its use in plant breeding inevitably interacts with all aspects of sugarcane cultivation and sugar production since new varieties of cane are the way in through which the industry copes with changes in both biotic and abiotic changes in the environment in which the crop is grown. Changes in cultivation practices require newly adapted varieties just as do encounters with new diseases and pests. By the late 1960s mechanical harvesting was being introduced and this would require varieties with new adaptations. All of these interactions are well documented in the germplasm and breeding research presented during these years.

Running through the presentations at all Congresses are papers that in a general way describe the overall breeding programmes that were ongoing in all of the major cane industries of the world. These papers are very important as a means of keeping breeders abreast of what their colleagues are doing and in helping to forge networks of communication between the different programmes and establishing an exchange of ideas among researchers that are scattered widely across the globe. These were days long before the ease of communication that pertains now. Congresses were a major source of information exchange. It is of interest to note that in the 1950 Congress discussion of the papers presented were also included in the printed proceedings providing an interesting insight into how each paper was received and the interest generated.

During the 1950s there were several papers that explored the use of inbreeding as a breeding methodology in sugarcane. This was no doubt triggered by the successes reported using this technique in the breeding of maize where inbred lines were eventually crossed to produce F1 hybrid varieties that showed remarkable heterosis. However, it was during this period that a very different approach was reported from Hawaii where a melting pot polycross was used to generate very large seedling populations from which to select new varieties. The melting pot concept was first reported in the 1953 Congress. To cope with the very large number of seedlings generated from a melting pot polycross the use of bunch planting was also introduced in Hawaii in contrast to single seedling selection used more

generally. Up to this point, most progress in production had been achieved by increases in cane yields but in the 1956 Congress reports were made of the first attempts to deliberately breed for high sucrose content (Buzacott 1956). Hence, this placed an emphasis on yield expressed as sugar per hectare as opposed to cane per hectare. The 1959 Congress also included a very important report of an expedition made in 1957 to collect new germplasm from New Guinea which was to have a significant impact on breeding approaches in later years (Warner and Grassl 1959).

The 1962 Congress contained the first reports of the use of quantitative genetics and the introduction of the concept of measurable genotype x environment interactions (Skinner 1962).

Since breeding requires the use of flowers a great deal of effort was reported at Congresses throughout the 1960s on sugarcane flowering and its control. Much was learned of the physiology of flower induction and subsequent emergence of the arrows. Many breeding locations were not in latitudes where cane flowering occurred naturally with any abundance. It was therefore necessary to find photoperiod treatments to induce flowering and to synchronise the flowering of parental material the that was desirable in the programmes. This need became more important as the genetic diversity of desirable germplasm increased.

The inclusion of a very important paper in the 1965 Congress entitled “Cultivated sugarcanes of the world and their botanical derivation” (Arceneaux 1965) made it clear that the germplasm in use worldwide was of very narrow origins, based on only six forms of *Saccharum officinarum* and two forms of *S. spontaneum* and that progress could only be made by broadening the genetic base in the production of new cultivated sugarcane varieties. This was undoubtedly the reason why increases in yield from breeding had appeared to stagnate. This paper sparked an immediate interest in the dissemination of new germplasm collections from the wild such as that reported in the 1959 Congress from the 1957 expedition to New Guinea. There was renewed interest in germplasm management and the making of wide crosses including those between *S. officinarum* and *S. spontaneum* that were becoming available from the new collections. Since, in most circumstances *S. officinarum* and *S. spontaneum* have very different flowering times, the Congresses of the later 1960s and up to 1974 reported many results on experiments in on the control of flowering and the synchronization synchronisation of flowering in the two species. A great deal was learned about the mechanism and physiology of flowering during this period.

As more new hybrids were made between *Saccharum* species there was an increase in the reporting of the cytogenetic consequences in these hybrids. These results were presented in the Congresses of 1968, 1971 and i1n 1974. Chromosome counting was the only means by which true interspecific hybrids could be verified. This was more so as generations of back crossing were introduced into the breeding and selection programmes because the resulting hybrids were morphologically closer to existing commercial sugarcane varieties.

The congress of 1971 contained a paper by Heinz entitled ‘New Procedures for sugarcane Breeders” which contained several topics that proved precursors of what was to become standard in years to come. Among them was the potential of tissue culture as a tool in the breeding process. He also discussed the use of computerization computerisation as a tool for the breeder. Computers were just becoming available, albeit in the form of mainframe machines. This would allow the use of formal quantitative genetic analyses to be used in cane breeding and this was also reported in the 1971 proceedings. It would not be until the 1980s that desktop computers became widely available to researchers.

In the 1974 Congress the first results from the use of isozyme polymorphisms were reported. This was a technique that was being applied to many crop breeding programmes. It was a first approach to molecular genetics as an analytical tool in the study of genetic diversity. As we know this has been superseded by the modern study of polymorphism directly in DNA.

PROMINENT CONTRIBUTORS

G. Arceneaux whose paper in the 1965 Congress analysed the genetic base of cane germplasm which led to a new approach to germplasm use and many genetic base broadening programmes that still impact breeding today.

D.J. Heinz whose paper in the 1971 Congress introduced many new approaches to cane breeding.

J.C. Skinner whose paper in the 1962 Congress introduced statistical analysis into variety trials.

IMPACT OF RESEARCH

Overall, the improvements in breeding techniques and germplasm management were well represented in the Congresses between 1950 and 1974. The biggest impact probably came from the Arceneaux paper of 1965 that changed completely the direction of breeding and germplasm management which led to major improvements in sugarcane production worldwide.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Germplasm and Breeding 1975-1999

Anthony J Kennedy

tonyk@caribsurf.com

INTRODUCTION

The eight Congresses between 1977 and 1999 were held in Brazil (twice) 1977 and 1989, Philippines 1980, Cuba 1983, Indonesia 1986, Thailand 1992, Colombia 1995 and India 1999. Almost 200 papers on aspects of plant breeding were presented over the course of these eight Congresses. In 1995 Plant Breeding and Molecular Biology were separated and presented in separate sessions of the Congress. Much of what was presented under Molecular Biology had great relevance to Plant Breeding. The introduction of desktop computers in the early 1980s had a strong influence on both plant breeding methodology and the design of selection trials associated with breeding programs. This will be evident in the papers discussed in this review.

RESEARCH ADVANCES

A theme running throughout this review period is the emphasis given to the analysis and interpretation of genotype by environment (g x e) interactions. Seventeen papers were presented with contributions in every one of the eight Congresses reviewed. Genotype by environment interactions have an influence on breeding strategies and the design of selection trials. Information gained from those trials in turn influences decisions on how to release new varieties into a sugar industry of any given area. The availability of increasing computer power after 1980 allowed for the complex designs and analyses to be available to most breeding programs. There was an increasing demand for varieties adapted to environments such as low moisture or saline conditions. G x E data provided the appropriate analyses to meet this need. By their very nature, individual papers were specific to local environments and specific situations but the overall trend in interest in this type of analysis was clear.

The importance of describing and evaluating new germplasm was evident throughout the period. These activities were a direct response to the understanding of the restrictively narrow genetic base that had been reported in the 1960s and highlighted in the Congresses of that earlier period. The 1976 germplasm collection (sponsored by the ISSCT) from the Indonesian archipelago had proved extremely important in broadening the genetic base of many breeding programs. Newer collections from the Philippines (Medina *et al*. 1986) and Thailand (Sanksathan *et al*. 1992) have provided additional interesting material.

Much work has been done on the importance of description and conservation of the existing germplasm collections (Roach 1992; Tai *et al.* 1995). In general, there were two approaches adopted to this work. Most programs used the introgression of specific traits from new germplasm. *Saccharum spontaneum* was the common source of new genes. Several authors described this kind of work to introduce traits such as cold tolerance and drought tolerance. A different approach was adopted by the program in Barbados (Walker *et al*. 1977) where an attempt at a broad population approach was adopted to incorporate new *S. spontaneum* genes into both Nobles and commercial varieties. Very broad selection

criteria were used with no emphasis on specific traits, creating large populations of new hybrids from which to select new parents.

For many years the use of the so-called Hawaiian Solution to preserve the flowering stalks of sugar cane taken from the field during controlled crossing in lanterns was standard practice. The basis of this was the use of sulphur dioxide dissolved in acidic solution acting as a preservative preventing bacterial and fungal growth. The solution was produced by bubbling gaseous sulphur dioxide through water to achieve the required concentration of solute. This proved a simple but very effective technology. It was, however, recognised that the use of sulphur dioxide gas in this way was both polluting and potentially dangerous. Further, one major breeding programme (Barbados) was forced to find an alternative to the gas method because sulphur dioxide was no longer imported to the island. This involved using crystalline potassium metabisulphite as the source of sulphur dioxide. This had long been the source of a sterilizing agent in industries such as brewing and wine making. The gas is released into solution as the bisulphate dissolves. This approach was adopted during the early 1980s. The method was presented in the Congress of 1989 as used in Mauritius (Ramdoyal and Domaingue 1989). This change in an important but simple technology saved that program in Barbados and is far safer and environmentally more acceptable.

By contrast, in the same 1989 Congress came the report of a very new and very complex technology applied to sugarcane. The use of molecular genetic markers to analyse the structure of crop genomes was already well established in some crops. It was still very new in sugar cane. Glaszmann *et al.* (1989) presented a paper on the use of Restriction Fragment Length Polymorphism (RFLP) markers to analyse the cane genome. They were able to establish a wide diversity in the crop. Large linkage groups were established, probably representing chromosomal linkages. There were also markers that were specifically of *S. spontaneum* origin. Further research into RFLP markers was reported by Burnquist *et al* (1992). It was clear from this early work that the complex polyploid, interspecific architecture of the genome was slowing progress in this area of research.

There are two major phases of plant breeding programs. Firstly, the management of germplasm collections from which active breeding material is chosen, and secondly the selection schemes that are used to find new varieties among novel populations generated from the breeding. In the 1980s the availability and rapid increase in computing power at the disposal of breeders had a great impact on both of these phases. Many major cane-breeding programs began to use computers to assist in choosing which parents to use and how to combine them to produce the best seedling populations from which to select improved varieties. Large quantities of data were accumulated describing germplasm collections covering ancestry, phenotypic characteristics and progeny outcomes. These databases became too large to be used efficiently without the aid of computers. Breeders began to write computer-based systems to help them use all of the data that was available before making decisions on which crosses to make. One such system was reported from Australia (Hogarth and Skinner 1980). The use of computers in the selection phase of breeding was reported by many authors.

Computing power allowed for the introduction of more complex trial designs that improved accuracy and predictive ability. These included complex lattice designs and augmented designs that meant larger numbers of potential varieties could be included in the trials and multi-location trials to investigate G x E interactions. The outcome was an overall increase in breeding efficiency and germplasm management. Family selection as an alternative to individual seedling selection was beginning to be investigated from the mid-1980s. Results were reported by Sukarso (1986) and Jackson *et al.* (1995). Family selection in various forms has been adopted by several programs since then.

Earlier work in the 1960s and early 1970s established the protocols required to initiate flowering under controlled photoperiod treatments. In crossing programs where natural, in field flowering was not prolific it was difficult to use natural flowering to carry out optimized crossing plans. The introduction of controlled floral initiation to bring desired parents together was beginning to be used routinely to make planned crosses with proven parents that did not flower at the same time. Some of these programs were described by Nuss (1977) and Nuss and Berding (1995).

PROMINENT CONTRIBUTORS

D.M. Hogarth who contributed to quantitative genetics, selection and computing in cane breeding.

B. Roach who contributed to germplasm management and selection techniques.

D.I.T. Walker for his leadership in genetic base broadening and germplasm utilization.

IMPACT OF THE RESEARCH

Overall, the period under review was one of change driven by technological innovations. Some were simple but important such as the introduction of potassium metabisulphite making the crossing activity safer. Others were more complex such as the introduction of computers and the use of molecular marker analysis to understand the genetic structure of germplasm.


The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Germplasm and Breeding 2000-2023

Goolam Badaloo, Deepack Santchurn, Nazline Meethoo and Hashini Kaniah

goolam.badaloo@msiri.mu

INTRODUCTION

Traditional breeding and selection of new varieties, though complex, lengthy and costly, remain the most important R&D thrusts in contributing to increased yield, yield stability and is acknowledged as worthwhile investment in ensuring efficiency and progress. Avenues explored during the ISSCT Congresses 2000-2023 include broadening the genetic base, early identification of best parents and crosses, induction of flowering, new and more robust selection strategies, shortening of the lengthy selection cycle, and breeding for high biomass canes in light of new opportunities and challenges facing the industry. Traditional and new breeders are versatile in testing and adopting the latest statistical and genetic modelling, and biotechnology tools in studying sugarcane genome and ensuring higher genetic gains. Access to germplasm remain important, together with the need to breed for resistance to diseases and pests. Lessons learned from other crops and animal breeding programs are evaluated before application in sugarcane improvement programs.

Since the millennium, seven Congresses were held in different parts of the world: Australia (2001), Guatemala (2005), South Africa (2007), Mexico (2010), Thailand (2016), Argentina (2019) and India (2023). Overall, 113 papers and 109 posters were presented and discussed, which broadly comprised 109 (49%) devoted to germplasm and breeding efficiencies, 88 (40%) addressing selection efficiencies and 25 (11%) others that were related to application of molecular tools, database, cloud computing, climate change and crop modelling.

RESEARCH ADVANCES

Germplasm collection, evaluation and characterisation

Germplasm collections are the foundation of any crop improvement program. The genetic diversity and breeding potential of parents have always remained the main research thrusts in this field of study and new genetic analysis tools are constantly being investigated to improve precision. Nayamuth *et al*. (2005) reported that higher genetic variability for sucrose accumulation pattern and maturity behaviour are obtained when assessment is done during the exponential phase of growth, with pol % dry matter cane as the best criterion. Castillo *et al.* (2005), in Ecuador, used the cluster analysis to evaluate 200 parental clones. Nagatomi and Degi (2007) reported on efforts to collect wild species (*Saccharum spontaneum*) and the related genera in Japan since 1977, and the collection of 500 accessions. Clones displayed tolerance to cold, with vigorous ratooning ability, and are valuable. SPAD chlorophyll meter readings (SCMR) were found to be reliable in screening drought-tolerant germplasm under natural drought conditions in northeastern Thailand (Kuangpatee *et al.* 2016). Sakaigaichi *et al.* (2007) found that larger and deeper root system are important traits for tolerance to water stress. Various multivariate statistical methods such as principal component analysis, canonical discriminant analysis, cluster

analysis and multiple correspondence analysis, are routinely used in the characterisation of germplasm (Rangel *et al.* 2007; Zhou *et al.* 2013).

The use of molecular markers is important in studying genetic variability and breeding values (BVs) of parents in germplasm collections. As far back in 2001, Hartatik *et al*. (2001) studied 23 morphological markers and found most of them sufficiently stable to be used in variety identification. Genetic markers (SSR) were reported to have potential in predicting the performance of crosses for stalk height, stalk number, brix, cane and brix yields (Bressiani *et al*. 2007). Gao *et al.* (2013) used sequence-related amplified polymorphism (SRAP) and SSR markers to identify true hybrid from crosses between *Saccharum spp*. x an intergeneric hybrid (*Erianthus arundinaceus* x *Saccharum spontaneum*) in introgression breeding. Perera *et al.* (2013) found that both molecular and morphological data are useful in estimating genetic diversity. Saavedra-Diaz *et al.* (2023) identified nine molecular markers (SNP) in the parental pool for sucrose accumulation. Racedo *et al.* (2023) reported that a useful tool to increase genetic gain rate for early maturity consists of integrating phenotypic and genomic information in genomic selection (GS). GS is a method in which individuals are selected based on their predicted BVs calculated from genome-wide DNA marker profiles.

Flowering

One of the most important breeding impediments is poor and variable flowering, especially in tropical sugarcane improvement programs. Very often, genetic combinations are restricted to the best possible combination among the parents flowering on a day instead of using the best parents in crosses. Berding (2005) utilised the experience and efficacy gained with initiation of flowering under controlled photoperiod facilities in a tropical environment in Australia to validate the technology in Ecuador. Torrecilla *et al.* (2010) proposed that growing parent varieties at different altitudes is useful in increasing flowering intensity in Cuba, with a negative correlation between pollen fertility and altitude. Berding and Moore (2001) explored the interaction of environmental and management variables with flower induction process. A regime using 11 h 05 min commencing night length increasing by either 30 or 45 s/night was near optimal.

Sattar *et al*. (2013) studied pollen from *Erianthus arundinaceus* at different times and tested for viability and found that pollen collected from the first anthesis had the highest viability. In Brazil, pollen grains were collected during anthesis and kept for a minimum of 30 days at -18°C and 20% humidity in order to overcome the problem of asynchronous flowering (Amaral *et al.* 2013).

Crossing, genetic variation and family evaluation

Crossing

In Hawaii, Tew *et al.* (2010) reported that over the 50-year period, polycrosses were more labour efficient and contributed more than biparental crosses. Shanmugha Sundaram *et al*. (2010) reported that intergeneric hybridisation, through the use of *Erianthus,* has been gaining importance in an attempt to broaden the genetic base and to obtain commercially useful traits. High efficiency of photosystem II, low stomatal conductance, low leaf temperature, high chlorophyll content and high wax content were the main characteristics associated with efficient water use (Viveros Valens *et al.* 2013). Variation and inheritance of leaf stripping ability were studied in order to facilitate efficient mechanical harvesting, reduce production costs, and increase sugar yield (Badaloo *et al.* 2001; Huang *et al.* 2016). Estimates of narrow sense heritability for ease of trashing varied from low (0.16, sub-humid environment) to moderately high (0.64-0.70; super-humid and humid environments), demonstrating that breeding for the trait is possible (Badaloo *et al.* 2001). Zapata Martinez *et al*. (2019) estimated the genetic variation components of randomly selected populations adapted to semi-dry environments and heritability estimate of sucrose % cane based on the North Carolina Design (NCD) I mating design. Both the additive and dominance variance were significant, low narrow-sense heritability and advocated an inter-population improvement method for the production of conventional hybrids. Koonjah *et al.* (2023)

developed and applied an innovative Business Intelligence platform in breeding and selection, whilst integrating climate and crop data.

Family evaluation

The early identification of crosses that have the highest probability of producing elite genotypes is a desirable feature to enhance the efficiency of sugarcane breeding programs. Narrow-sense heritability for important agronomic traits ranged from low to moderate (0.16-0.62) at the seedling stage but improved in the replicated trial (0.67-0.95) (Badaloo and Ramdoyal, 2007). Silva *et al.* (2007) observed families with high values for stalk diameter, stalk number and stalk height under water stress conditions. Bivariate analyses for pol and fibre, based on the sum of ranks (RANK) and the observed frequency of genotypes that transgress pre-established threshold levels simultaneously (FREQ) within F1, BC1 and BC2 crosses, were useful in identifying families producing genotypes with different levels of pol and fibre (Ramdoyal and Badaloo 2007). Xavier *et al.* (2013) observed variability among families and promising crosses for incidence of mosaic and effects associated with genetic resistance to Sugarcane Mosaic Virus (SCMV). Cursi *et al*. (2019) observed that highest expected genetic gain was obtained from the Australian Sequential Selection approach (9.8%), compared to individual BLUP method (6.4%), whilst random selection method was very inefficient. Santchurn *et al*. (2023) used up to the past five decades of breeding data to identify best crosses that could potentially be repeated, and the best-categorised parents that could be exploited judiciously to further improve the breeding efficiency.

Related studies towards breeding efficiency

Intensive breeding programs have exploited genetic variation available within primary gene pools, resulting in a narrow genetic base. A traditional response to this has been the introgression of genetic variation. Swapna and Pandey (2023) observed that bi-parental crosses, compared to selfing, might be superior in breeding for high-sugar content, with the possibility of a higher frequency of favourable, novel gene combinations. Hemaprabha *et al*. (2023) observed a steady improvement for juice quality and cane yield characters over generations of breeding, with the best parents and cross combinations belonging to different generations and a predominance and diversity of species *Saccharum officinarum* in the best parents. Wei and Jackson (2016) addressed the slow rates of long-term genetic gain in sugarcane, high non-additive genetic variance and found it encouraging regarding the use of DNA markers for rapid improvement of parents. Zhou (2019) similarly reported higher non-additive genetic than additive genetic effects for cane yield.

Disease resistance and tolerance to pests

Disease resistance

Using a balanced diallel type II design in the study of resistance to leaf scald, Bressiani *et al.* (2005) reported high broad sense (h^2_b = 0.98) and moderate narrow-sense (h^2_n = 0.57) heritability estimates. Molina *et al.* (2013) confirmed that the *Bru1* marker is a useful tool in the breeding for resistance to brown rust disease *Puccinia melanocephala*. Chapola *et al*. (2013) analysed data from 2009 to 2011 and found that extreme conditions of temperature and humidity led to increased incidence of orange rust disease, caused by *Puccinia kuehnii* and highlighted the need for rigour when selecting clones due to atypical weather conditions. During the period 2005-2015, Visacane had imported 1033 varieties and exported more than 7200 batches of cuttings of disease-free varieties worldwide. Major sugarcane diseases were detected in 22% of the material (Guinet-Brial *et al.* 2016).

Insect tolerance

Breeding for resistance to insect pests of economic importance is one of the goals of most breeding programs, addressed through an integrated approach involving conventional and molecular breeding. Dumont *et al.* (2023) reported on the availability of genetic variability and scope for breeding for resistance to yellow sugarcane aphid *Sipha flava*. Da Silva *et al*. (2005) utilised SSR markers to identify genotypes with extreme reactions to the stemborer *Diatraea saccharalis*. Increasing selection rates at the seedling stage is expected to capture greater variability and would potentially include those transgressive segregants combining positive agronomic traits with the stem borer resistance (White *et al.* 2010). Butterfield *et al.* (2007) worked on stalk borer *Eldana saccharina* resistance on a family level and reported narrow-sense heritability estimate of 0.57, and high family repeatability (0.90).

Selection efficiency

Since the millennium, there have been significant innovations in terms of new genetic tools and software available and their progressive use in improving selection efficiencies in sugarcane breeding worldwide. Between 2000 and 2023, 104 papers/posters were presented in the ISSCT Congresses that were directly or indirectly related to optimising selection efficiency in sugarcane and, at times, merging with other main objectives. The early selection stages comprised 11 presentations compared to 65 (> 60%) at the advanced selection stage. Thirteen presentations addressed selection of high biomass/energy canes whilst eight presentations focussed on breeding strategies and new programs established in different countries.

Improving efficiency at early selection stages

Selection at early stages is recognised to be the least effective of all other stages due to large populations, small plot sizes, unreplicated test genotypes, large competition effects and low broad-sense heritabilities of most characters. Kimbeng *et al.* (2001) reported that family selection intensities were optimised when combined with individual clone selection rates. Jackson (2016) observed that the overall genetic gains were not very sensitive to selection intensity in seedlings in the populations studied. Stringer and Cullis (2001) addressed adjustment for fertility trends and the inter-plot competition using spatial analysis methods. At the same line, Xavier *et al.* (2010) studied the inter-plot competition at advanced stages of selection. Zhou *et al.* (2013) proposed logistic regression models with high discriminating ability and greater precision at early stages of selection. For the cane quality traits, Amaya *et al.* (2001) first reported on the advantages of a methodology using NIR spectroscopy as a quick, precise, efficient and cost-effective determination of sucrose content. Quite recently, innovations in the generation and use of pre-budded seedlings in the early and advanced stages of selection are reported to speed up the development of new cultivars (Xavier *et al.* 2019; Da Silva *et al.* 2019).

Improving efficiency at advanced selection stages

The advanced selection stages involve precise estimation of yield and quality traits, adaptation and stability across environments and ratoons, commonly termed as Genotype by Environment Interaction (GEI), resistance to pests and diseases and identification of most promising varieties. With the advent of powerful computers and sophisticated software, the last two decades have seen major improvements in the options available for the analysis of multi-environment variety trials (METs). Linear mixed models (LMMs) are also attracting increasing interest among breeders.

Genotype x Environment Interactions (GEI)

GEIs are a major issue in plant breeding that complicates selection and requires breeders to assess the adaptability and stability of promising genotypes before release. Different methods have been developed to reveal patterns in METs data and many stability measures have been proposed. The large number of methods proposed mitigates against their widespread use (Santchurn *et al.* 2016). New statistical tools involve the use of biplot analysis techniques that incorporate multivariate methods using principal component analysis (PCA). The Additive Main effects and Multiplicative Interaction (AMMI) models were the most commonly used models in the ISSCT Congresses of 2000-2010 (Bissessur *et al.* 2001; Quemé *et al.* 2001, 2005; Rodriguez *et al.* 2010). More recently, the term GGE biplot was proposed and different biplot visualisation methods were developed to address specific queries relative to GEI data. Many ISSCT publications have subsequently focused in its use with good visual graphics and interpretations (Quemé *et al.* 2007, 2010; Rodriguez *et al.* 2010; Santchurn *et al.* 2016; Salazar *et al.* 2019; Chavanne *et al.* 2019; Aybar-Guchea *et al.* 2023). Authors reported on the most stable and adapted varieties as well as the delineation of mega-environments, so far difficult to investigate effectively.

Linear Mixed Models (LMMs)

LMMs and its Best Linear Unbiased prediction (BLUP) procedure can take into consideration different types (spatial, temporal and genetic) of correlations among measurements and accommodate unbalanced datasets, which is common in breeding data (Hoarau and Dumont, 2023). Cox and Stringer (2007) adopted the LMM technique to benchmark genetic gains from new cultivars in Queensland using productivity data. Neto *et al*. (2013) used BLUP methodology to identify the best parents for cane and sugar yields. Ostengo *et al.* (2013) successfully analysed the performance of a promising variety by a multi-environment and multi-age mixed model. LMM is reported to be more precise than AMMI models in the interpretation of GEI (Ostengo *et al.* 2013) and that the maturity profile of clones could be enhanced using BLUP methodology (Ostengo *et al.* 2023). Alarmelu *et al.* (2023) used BLUP values to estimate genetic progress for yield and quality from advanced cycles of reciprocal recurrent selection. Hoarau and Dumont (2023) highlighted the benefits of mixed models and its BLUP methodology in breeding and selection.

Molecular contribution to traditional breeding and selection

A Marker-Assisted Selection (MAS) is expected to bring more accurate predictions of BVs and contribute to shortening the generation interval. In the ISSCT Congresses 2000-2023, five topics dealt with MAS and two recent ones (2023) with GS, with relevance to the identification of parents with specific traits and optimising breeding efficiency. More details have been given in the germplasm section. In addition, Diaz Romero *et al.* (2019) reported that 70% of Tucumán's growing area is planted with seeds produced from the Vitroplantas project, aimed at producing disease-free planting material. In general, the various joint workshop and congress sessions were highly useful in bringing together competencies from traditional breeders and biotechnologists for better coordination of research efforts and identification of practical use of molecular tools in routine breeding and selection programs.

Breeding and selection of biomass varieties

Some sugarcane breeding institutions have renewed interest in introgression breeding with sugarcane wild relatives as the biomass potential of early generation sugarcane hybrids (F1, BC1 and BC2) generally exceeds those of modern cultivars. In the ISSCT Congresses 2000-2023, Miller *et al.* (2005) described the strategy used in Florida in crossing CP cultivars and wild relatives of sugarcane (*S. officinarum, S. robustum, Erianthus* and *Miscanthus*). Similarly, Ramdoyal and Badaloo (2007) and Krishnamurti *et al.* (2007) elaborated on the introgression of *S. spontaneum* and *Erianthus* spp., respectively, for the development of novel sugarcane clones for biomass. Landell *et al.* (2013)

introduced the concept of a primary energy index, which considers the total energy from sugarcane, in their selection program. Rao *et al.* (2007) reported on the selection of multipurpose high fibre sugarcane cultivars in Thailand and obtained candidates with improved fibre and sugar yield. Terajima *et al.* (2007) designed a program for the simultaneous production of sugar and biomass ethanol from high-biomass clones. Nacimento *et al.* (2013) developed an integrated web-database for the energy cane genomics and transcriptomic data that can be accessed through the interface (http://www.lge.ibi.unicamp.br/sugarcane). Santchurn *et al.* (2016) established the adaptation and stability of highly selected biomass/energy canes in Mauritius. More recently, Diaz *et al.* (2019) characterised the energy traits (bagasse, agricultural harvest residues and fibre yield) of sugarcane cultivars for their energetic quality components for use as fuel.

Novel Breeding Programs

The breeding strategies/policies involved first exposure to or establishment of new selection programs in different regions/countries such as Ecuador, Iran, Colombia, Pakistan (Berding and Castillo 2007; Garcia *et al.* 2010, Victoria *et al.* 2010; Yanquan *et al.* 2010; Afghan *et al.* 2016) or collaborations among countries (Thong-Chane *et al.* 2010).

PROMINENT CONTRIBUTORS

Nils Berding, made significant contributions to the control of flowering to allow planned and controlled crossing programmes, especially in circumstances of low natural in field flowering. He also contributed to the use of quantitative genetics in crossing programmes. Nils was responsible for the development of a robust, small sample whole cane analyser using NIR spectrometry which had immense influence on data collection from breeding populations and early selection stages.

Anthony Kennedy, contributed to breeding and selection across the diverse Caribbean network of variety development especially in variety trial design and analysis with emphasis on GxE interactions. Developed efficient use family selection within the Caribbean variety programmes. Developed and exploited the use of very high sucrose breeding populations. He exploited genetic base broadening population sand use them to introduce high fibre, energy and multi-purpose varieties in the Caribbean, he also established high throughput NIR analysis technology across the Caribbean variety development network.

Kishore Ramdoyal, who contributed in a wide range of areas of interest, including: Variation and genetic studies in leaf stripping ability, tolerance to herbicides; and sucrose accumulation patterns; Selection studies including AMMI models and GxE interactions; Commercial performance versus trial results; Early high sucrose content; Multi-environment trials; Biomass breeding and interspecific hybridisation.

IMPACT OF RESEARCH

More powerful computers, sophisticated genetic software and models were increasingly being developed and effectively utilised across the ISSCT Congresses 2000-2023. These include more efficient use of: (a) classical quantitative genetic analysis models, like the partial or complete diallels, multivariate analyses, (b) new technologies like AMMI and GGE biplots, LMMs, spatial analysis, and (c) latest biotechnological tools like SSR markers, Marker-Assisted Selection and Genomic Selection.

Most of these studies focus on additive genes that could be transferred from desirable parents to new cultivars. Wei and Jackson (2016) also reported on the probable causes of the slow genetic progress in sugarcane breeding programs worldwide for the last 50 years. The high non-additive genetic variation (NAGV), especially for cane yield, contributes to low narrow-sense heritability and means that selection of new parents based on phenotype poorly predicts BVs. Zhou (2019; 2023) observed the same high NAGV and advocated development of heterotic groups that are diverse with complementary traits would

enhance utilisation of heterosis in sugarcane breeding. Consideration of these findings will certainly have a bearing on the breeding and selection strategies towards faster genetic progress in sugarcane crop improvement.

Over the period 2000-2023, there has been consistent need to broaden the genetic base, as far as feasible, and to have access to newer germplasm, through reciprocal exchanges, though often met with difficulties. New findings emerging from Research, Development and Innovation (RDI) in traditional breeding have to various extent been shared through ISSCT Congresses, Workshops and Webinars, as well as other forums, and tested and adopted in local Breeding and Selection programs in an attempt to increase efficiency. More emphasis is being placed on breeding *per se* in germplasm evaluation and characterisation before use, as well as achieving the best genetic combinations with high efficiency and increased precision in selection of high yielding varieties. New high-yielding cane varieties that have been increasingly tested under changing climatic conditions, with a suite of desirable characteristics, such as adaptation to mechanised harvest, resistance to diseases and tolerance to pests, good ratooning ability and suitability to different harvest periods, are expected to increase productivity and ensure more revenue to different stakeholders.

In spite of the inherent complexities, breeding and selection remain the first priority in most programs. Coupled with new statistical and molecular tools there is increasing recognition that investment in RDI would undoubtedly ensure progress in the sugarcane industry. Breeders are on the look out to adopt the most appropriate and efficient strategies, as well as innovative approaches, with the support of new molecular tools and high-performance computing models to achieve quicker gains for the benefit of the sugarcane industry. There is also a need for capacity building and for closer scientific collaborations between breeders, molecular biologists, bio-statisticians and computer scientists.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Plant Physiology 1924-1938

Michael K Butterfield

michael.butterfield@ctc.com.br

INTRODUCTION

Sugarcane has been cultivated for thousands of years, first in New Guinea, then in India and China, and by the early 1500s, sugar had become a globally traded commodity, with the first records of sugar being shipped to Europe for the Caribbean in 1516. By weight, it is the crop with the largest harvested tonnage in the world (1.9 Gt) ahead of maize with 1.5 Gt, and production has increased by a factor of almost four over the last 60 years. The expansion of sugarcane production has largely been driven by advances in breeding and agronomic practices – both of these areas being informed by an increased understanding of sugarcane physiology developed over the years.

RESEARCH ADVANCES

During the first 25 years of the ISSCT, there was no Physiology section, as this was not yet an established discipline. There was, however, one very significant advance in what could be considered under the umbrella of Physiology made in 1924, that went on to have a pivotal role in sugarcane breeding, and that is continued to be used today.

In 1924, JA Verret and colleagues in Hawaii conducted many experiments using different chemicals to preserve sugarcane cut tassels for a period long enough to use during crossing. It had been observed that wilting of tassels was being caused by the blockage of vascular bundles in the cut stem by the growth of microorganisms. Hundreds of combinations of different chemicals at different concentrations were tried, and a 0.03% solution of sulphurous acid was found to be effective at preventing the wilting of tassels. This became known as the “Hawaiian solution” and is still used – in modified forms - in sugarcane breeding programs to this day. Although Verret himself did not present this work at ISSCT, he published it in 1925 in the *Hawaiian Planters Records*. The results were summarized by Hamilton Agee, the Director of the Hawaiian Sugar Planters Experiment Station and presented at the second ISSCT Congress held in 1927 in Havana, Cuba. The work of Verret in revolutionizing sugarcane breeding was also acknowledged by Mangelsdorf in 1935 at the fifth Congress in Brisbane, Australia.

The fourth Congress held in 1932 in Puerto Rico had two papers presented by Ciferri from the Dominican Republic attempting to relate physiological and anatomical measurements of the leaf blade comparing healthy with mottled (mosaic infected) leaves. He used an apparatus called the Moll nephelo-absorptiometer as a proxy to measure leaf chlorophyll content and showed that mottled leaves had only 27% of photosynthetic capacity of healthy leaves. He also tried to establish a relationship between leaf thickness of mottled versus healthy leaves, taking 16,680 micrometric measurements. He concluded, however, that the variation between the leaf types was within the margin of experimental error of the measurement technique. It is, however, an interesting example of publishing a negative result – a practice that is nowadays very uncommon.

The sixth Congress held in Louisiana in 1938 was the first to contain a classification of papers presented under the sub-heading *Physiology and Taxonomy*, although the papers themselves were presented in sessions described as *Field and Soil* and *Varieties*.

Beauchamp and Lazo (1938) from Cuba measured the composition of various nutrients (potassium, phosphorus and nitrogen, calcium and magnesium in crude extracts of leaf chlorophyll under different fertilizer regimes and attempted to relate this with cane growth parameters. In their experiments, increased levels of potassium in fertilizer had a corresponding effect on potassium in chlorophyll as well as cane growth, but phosphorus had no such effect. Adding nitrogen reduced the content of the other elements in chlorophyll extracts and also reduced sucrose content in juice. They concluded by stating that more studies related to nutrition and performance were warranted.

Along similar lines, Saito and Kenjo (1938) from Formosa/Taiwan studied the effects of phosphorus deficiency on cane growth under hydroponic conditions. They found that growth retardation appeared after 6 weeks in phosphorus-deficient solutions, that levels of nitrogen and silica increased significantly, and that the shoot:root ratio increased by a factor of six-fold, showing the phosphorus deficiency reduced vegetative growth far more than root growth.

Root growth was also studied by Evans (1938) from Mauritius, in an attempt to understand drought tolerance of different sugarcanes. He argued that response to drought must be a function of transpiration of water and absorption of water and developed an index of the ratio of total leaf area per total number of root hairs (measure by a laborious protocol of root extraction, washing and counting). Evans showed that this ratio varied greatly between varieties (from 4 to 17), with an anecdotal relationship with drought tolerance (2 varieties with low ratios were known to be well suited to the drier environments in Mauritius). Of additional interest, Evans remarked that his studies showed no correlation between transpiration rate and the number of stomata per unit area. He also noted that the number of stomata on the lower leaf surface roughly doubled that of the upper leaf blade, but that transpiration measured separately (by sealing the leaf surface with Vaseline) showed equal transpiration rates from the lower and upper surface.

PROMINENT CONTRIBUTOR

J.A. Verret was a member of ISSCT and attended the first meeting in Hawaii in 1924. He also had a paper on sugarcane agriculture in Hawaii published in the proceedings of the third Congress held in Soerabaia, Indonesia. The development of the Hawaiian crossing solution by Verret is considered as the first major contribution to sugarcane Physiology and Breeding and celebrates its 100th anniversary in 2024.

IMPACT OF THE RESEARCH

The discipline of sugarcane physiology was starting to develop during 1924 to 1938, and the few examples of studies presented at ISSCT congresses are summarized above.

One notable achievement by a sugarcane technologist to be celebrated was the development of the Hawaiian crossing solution by JA Verret from the Hawaiian Sugar Planters Experiment Station in 1924 and presented at the II Congress Cuba in 1927. This had an enormous impact on the ability to make crosses between selected parents, and variations of the “Hawaiian solution” are still used in breeding programs to this day. This work was published in the Hawaiian Planters Records in 1925, so this year is celebrating the 100th anniversary of the publication of this significant advancement in sugarcane technology.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Plant Physiology 1950-1974

Michael K Butterfield

michael.butterfield@ctc.com.br

INTRODUCTION

Although ISSCT did not form a Plant Physiology Section until 1974, the understanding of sugarcane physiology following the Second World War, particularly the C4 pathway, has driven advances in breeding and agronomic practices. With the discovery of the structure of DNA and the development of new molecular and genetic techniques, this has morphed into the Molecular Biology section. However, the basis for much of this understanding was laid during 1950-1974.

RESEARCH ADVANCES

1950 Congress

In the first ISSCT Congress after the Second World War, held in Brisbane, Australia, there were four papers presented in the Agricultural section that touched on aspects of sugarcane physiology. Bourne (USA) studied the physiological effects of phosphorus in the low-mineral organic peat soils of Florida. He showed that phosphorus deficiency showed yellow or pale green leaf symptoms with drying at the leaf tips and margins, as well as stunting of growth, resulting in lower cane yields. He also remarked that the most outstanding physiological effect of P deficiency was the increase in susceptibility of most varieties to root-rot complex caused by several fungi and commented that this correlation had also been observed in Hawaii. Two papers were presented investigating the effect of photoperiod and aspects of sugarcane growth. In the first, Brandes (USA) examined changes in seasonal growth gradients in Saccharum species grown at different latitudes, ranging from 3° N to 39° N. He derived two important conclusions from this work. Firstly, clones showed regular trends of increased growth rate with longer days in summer, and that in winter the longer days at lower latitudes did not compensate for the relatively shorter days in summer. The rapid summer growth surge at higher latitudes was able to compensate for lesser growth in winter, with the results that the annual growth as different latitudes was similar. Secondly, in general, the clones used did not show specific adaptation to any particular latitude. Brandes hypothesized that this could be due to the high level of polyploidy conferring adaptive plasticity to a range of ecological conditions.

In the second paper to study effects of daylength, Lee and Lin (Taiwan) studied the effect of artificial photoperiod ranging from 6 h to 15 h on growth parameters of sugarcane grown in pots. They showed an increase in growth rate from 6 h to 12 h daylength, but a reduction in growth at 15 h. Of interest was their observation that the increase in growth rate was not due to an increase in the number of internodes, but rather an increase in the length of internodes at longer daylengths. There was a smaller effect on internode diameter, but the shape of the internode changed under reduced daylength.

In the final physiology-themed paper, Nolla (Puerto Rico) studied the effect of 2,4D on sugarcane, after reports of damage caused by herbicides. They showed that application of 2,4D can cause hypertrophy of the root band, necrosis of epidermis, cortex and vascular bundles, and bending or breaking of culms at the growth ring. Bending is caused when 2,4D is applied to one side only of the internode, causing

uneven growth of the intercalary meristem, while stem breakage occurs when 2,4D is applied to the whole growth ring resulting in rapid growth of the entire intercalary meristem. They also showed that cane younger than 2 months showed little effect of 2,4D on growth.

1953 Congress

The eighth ISSCT Congress held in Jamaica in 1953 had the first report of a research area which later would go on to contribute significantly to the discovery of C4 photosynthesis. George Burr of the Hawaiian Sugar Planters Association Experiment Station (HSPA) presented a summary of work using radioisotopes of CO_2 and other elements that had begun in the late 1940s. He reported that 44 hours after exposing a single leaf to ^{14}C-labeled CO_2, labeled photosynthate could be detected in all 16 stalks of the sugarcane plant, indicating a rapid flow throughout the whole plant, including to adjacent stalks. He also showed that radiolabeled sucrose was taken up rapidly from the leaf (50% uptake after 1 day), while phosphorus and rubidium had slower uptake rates (15 days for 50% uptake). In the same paper, he described the uptake of ^{15}N-labeled ammonium sulphate and showed that within one week, even protein in the oldest mature internodes, as well as old leaves had exchanged as much as 10% of “old” nitrogen for labeled nitrogen. From this, he concluded that no part of the plant can be considered as metabolically inactive or cut off from the circulatory system. In a footnote, Burr acknowledged the work of various researchers at HSPA, including Dr Constance Hartt, a physiologist at HSPA since 1936, who Burr encouraged to study the use of radioisotopes in sugarcane, and who later would do significant work in this area. An interesting historical anecdote is that it appears that the source of the ^{14}C used by Burr in the early experiments originated from the Manhattan Project, an R&D program undertaken during World War II to produce first nuclear weapons.

1956 Congress

In 1956, the ninth ISSCT Congress was held in New Delhi, India. At this meeting there was little material presented regarding sugarcane physiology. One paper of interest was given by Raheja (India) who summarized several decades of physiological research in relation to sugarcane agronomy in India. This was a high-level review of many research projects studying aspects of physiology such as germination, tillering, growth rate, respiration, water relations and drought tolerance, photosynthesis, nutrient uptake, frost tolerance and lodging. Due to its highly summarized nature, it is difficult to highlight any specific research finding, but it is relevant to note the attempts to use different physiological measurements to understand sugarcane growth in relation to field productivity.

1959 Congress

The tenth ISSCT Congress held in Hawaii in 1959 likewise had few papers dealing with physiology *per se*. It is worth noting, however, contributions by Tanimoto and Burr (Hawaii) on nitrogen nutrition, and by Hartt (Hawaii) on phosphorus nutrition given the role that Burr and Hartt played in the physiology of photosynthesis in sugarcane.

1962 Congress

The eleventh ISSCT Congress held in Mauritius in 1962 contained two significant contributions to sugarcane physiology. In the first, Hartt and Kortschak (Hawaii) reported on tracing sugar in the cane plant using radioisotopes – continuing the work reported by Burr in 1953. Using $^{14}CO_2$ they studied translocation of photosynthate under normal conditions, as well as conditions of nutrient deficiency (N, P and K), temperature of air and roots and osmotic stress. They showed that sucrose is the main compound translocated, and that sucrose synthesized in the leaf travels rapid downwards, at rates that can exceed 2 cm/min. Labeled sucrose can be detected in leaves above the point of feeding after 90 min, and after 24 h, approximately 35% of labeled sucrose is above the point of feeding, and 36% is in

lower internodes, adjacent stalks and roots. Rates of sucrose translocation decreased with nutrient stress and increased with increasing temperature of air and roots. Increased osmotic stress reduced the translocation upwards to internodes above the point of feeding. This paper contains several informative figures illustrating the path of synthesized sucrose in the sugarcane plant, and, despite the work being more than 60 years old, remains essential reading for sugarcane technologists.

The second significant contribution was a paper by Glasziou *et al*. (CSR, Australia) on the accumulation and transformation of sugars in storage tissue. Citing the earlier work of Burr demonstrating a circulatory system of photosynthate in sugarcane, they used $^{14}CO_2$ as well as ^{14}C-glucose and ^{14}C-fructose, to study in detail the fate of sugars within the cell. They showed that there is a constant cycling of sucrose between the cytosol and vacuole. Respiration provides the energy for sucrose to enter the vacuole against large concentration gradients, where inversion to glucose and fructose occurs due to invertase enzymes. The hexose sugars diffuse back to the vacuole, where sucrose is resynthesized. In the paper they describe the 12 chemical reactions involved in the cycling of sucrose within the cell, and comment that in immature cells, much of the sucrose in the vacuole is inverted and returns to the cytoplasm. I

In addition to these two landmark papers regarding photosynthesis, Cutler and Vlitos (Trinidad) presented a study of the natural auxins present in sugarcane roots and shoots and different growth stages. Using paper chromatography, they showed that sugarcane produces a complex mix of acid, neutral and basic growth promotors that vary between tissue type and growth stage, but that the predominant growth promotor is an acid with properties very similar to IAA (indole-acetic acid).

1965 Congress

The twelfth ISSCT Congress held in 1965 in Puerto Rico saw a growth in physiology themed papers within the Agricultural section, with seven papers of interest.

The Hawaiian group continued to report on their studies of sugarcane photosynthesis with two important papers by Hartt and Kortschak on radioactive isotopes in sugarcane physiology, and Hartt and Burr on factors affecting photosynthesis in sugarcane. These two papers contain many insights, the most important being: (i) malic acid is the first stable product of photosynthesis, with sucrose being the end product, which begins to accumulate 10 to 30 seconds after exposure to CO_2; (ii) sucrose is translocated and the reducing sugars are formed by hydrolysis in the internode tissue, thus ripening is due to reduced hydrolysis rather than reduced translocation of glucose and fructose; (iii) solarization (decrease in photosynthetic rate) is due to accumulation of sucrose in the leaf and not by stomatal closure. Translocation of sucrose out of the leaf is thus vital to maintain photosynthesis at a maximum. These two papers also listed 18 important refence publications made by the Hawaiian group, starting in 1936, many of them with Constance Hartt as first author. The reason this is significant is that in 1966 Hatch and Slack published their landmark paper *Photosynthesis by Sugar-cane Leaves* in the *Biochemical Journal,* describing what later became known as C4 photosynthesis, or the Hatch-Slack pathway. In 1980, Hatch and Slack, along with Kortschak were awarded the Charles F Kettering Award in recognition of the significance of this discovery, but the role of Constance Hartt in laying most of the groundwork for the description of C4 photosynthesis, including the discovery of malic acid as the first product was overlooked. In 2011, Benson and Maretzki published a short biography of Constance Hartt as a tribute to her contributions to the discovery of the sugarcane carbon fixation pathway, now known as C4 photosynthesis.

The other papers dealing with sugarcane physiology at the twelfth congress included a study on the effect of GA and invertase on internode expansion by Glasziou and Bull (Australia), two papers by Alexander (Puerto Rico) on the biosynthesis on starch, as well as the effect of Diuron on sucrose metabolism, and a paper by Most and Vlitos on characterizing endogenous GA-like hormones in sugarcane. A final paper of note was by Nickell (Hawaii) who reported on tissue and cell culture in sugarcane research. This was the first report of sugarcane tissue culture presented at ISSCT.

1968 Congress

Taiwan hosted the thirteenth ISSCT Congress in 1968. There was still no specific Physiology section, but eight papers related to different aspects of sugarcane physiology were presented.

In a special symposium on increasing sugarcane yields, Alexander (Puerto Rico) summarized knowledge on sugarcane photosynthesis and growth regulation by hormones to suggest how both biomass and sucrose content could be optimized. In the same symposium, Nickell (Hawaii) summarized work on basic plant-water relation in sugarcane, showing that the amount of water utilized by cane plants has a liner relation to dry matter produced, regardless of variety studied and temperature regime. He further commented that no area of sugarcane research could be effectively conducted without understanding the crop water status.

Outside of the symposium on sugarcane yield, Alexander (Puerto Rico) presented an additional four papers studying various aspects of enzymology in sugarcane, including the effects of silicon and manganese on enzyme activity.

Coleman (Hawaii) presented one paper on the possible role of phytotoxins present in sugarcane roots on the observed phenomenon of yield decline. He demonstrated that there does appear to be toxic compounds in sugarcane root tissue, but that their potential contribution to yield decline was difficult to establish. Coleman also presented a second paper on the physiology of flowering in sugarcane, examining the role of photoperiod, temperature, age of cane and moisture on flowering, concluding that flowering is a complex process involving many biochemical reactions, many of which are not fully understood.

1971 Congress

In 1971, the fourteenth ISSCT Congress was held in Louisiana, and for the first time had a section dedicated to Weed Control, Physiology and Biochemistry with seven papers related to physiology, with one additional physiology paper within the Fertilization section.

James Irvine (USA) presented two papers; one on polysaccharides (gums) in juice as a quality indicator, particularly after freezing injury, and a second on photosynthetic rate in cane affected by mosaic virus, RSD, chlorotic streak, leaf variegation, ‘red-freckle’ and freezing injury. RSD and chlorotic streak had no effect, while the other factors reduced photosynthesis and chlorophyll content.

Bowen (Hawaii) also presented two papers, one on the effect of chorine on growth, and the second the effect of boron and boron deficiency.

Yates (UK) presented a review of work on chemical ripeners, and Smith and Hall (Australia) described anthocyanins in different parts of healthy or diseased sugarcane.

In an attempt to extend the work on C4 photosynthesis in sugarcane, Gross *et al.* (UK) attempted to study biochemical reactions in the two classes of sugarcane chloroplasts (grana-type, and non-grana type related to Kranz anatomy). Although they were able to successfully separate the two types of chloroplasts, large quantities of phenolic compounds interfered with their attempts to study photosynthesis in more detail.

In the Fertilization section, Alexander *et al*. (Puerto Rico) continued the work presented in previous Congresses on sugarcane enzymology by studying the ATP-ases in leaves under different conditions of light intensity and nitrogen. They suggested that light ATP-ase is linked with photosynthetic steps related to rapid growthy, while dark ATP-ase is related to active sucrose transport and storage.

1974 Congress

With the growth in research in sugarcane physiology, the fifteenth ISSCT Congress held in South Africa in 1974 was the first to have a dedicated Plant Physiology section, with the first Chair being Dr James Irvine (USA), and Vice-Chairs Mr Harry Rostron (South Africa) and Dr Alex Alexander (Puerto Rico). There were 13 papers presented. Four delt with growth hormones and chemical ripeners; three dealt with sugarcane growth, yield components and growth modeling; two on methods for testing for sugarcane maturity pre-harvest; and one paper each on the topics of flowering physiology, photosynthetic active light spectra, and the use of isoenzymes to study variability after tissue culture.

Three results from this section are of general interest. Alexander and Biddulph (Puerto Rico) studied photosynthesis at different wavelengths and showed that sugarcane has an exceptionally high photosynthetic activity in the blue spectrum, although there is some variation among genotypes.

Bull and Tovey (Australia) described aspects of modelling sugarcane growth by computer simulation. This is the first report at ISSCT of crop modelling in sugarcane, a tool that is today widely used for different aspects of commercial yield forecasting and research.

Liu *et al.* (Taiwan) reported on detection of isoenzymes in sugarcane leaves. They showed that up to 5% of tissue culture derived planted had differences in isozyme banding patterns, and up to 8% of plants derived from gamma irradiated single-bud setts showed differences. This is the first paper at ISSCT on a topic which later would be incorporated into the Molecular Biology Section of ISSCT.

PROMINENT CONTRIBUTORS

Constance Hartt, George Burr and Hugo Kortschak of the Hawaiian Sugar Planters' Association Experiment Station conducted seminal work on CO_2 fixation in sugarcane, which later became known as C4 photosynthesis. Although Hatch and Slack received recognition for describing in detail the biochemical reactions involved in C4 photosynthesis, most of the groundwork had been done by Hartt, Burr and Kortschak and had been presented in summarized form at several ISSCT Congresses. This trio from HSPA deserves recognition for their pioneering work in discovering how CO_2 is fixed as sucrose, how sucrose is transported through the sugarcane plant, and how sucrose is cycled between the cytosol and vacuole in storage tissue. As this group of three scientists worked together in the same area of research, it is fitting to acknowledge their contributions as equal, with each of them bringing unique skills and insights to their work on photosynthesis and sucrose metabolism.

IMPACT OF THE RESEARCH

In summary, the second 25 years of ISSCT witnessed the growth of the area of sugarcane physiology, culminating in the formation of the Plant Physiology Section in 1974.

During this period, the pathway of photosynthesis in sugarcane was extensively researched and described. Even though much of this work was done more than 60 years ago, the papers published in ISSCT proceeding are still vital reference works for anyone interested in photosynthesis and sucrose accumulation and storage in sugarcane.



The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Physiology and Molecular Biology 1975-1999

Asha Dookun-Saumtally

asha.saumtally@gmail.com

INTRODUCTION

Sugarcane, one of the world's most important crop with a C4 photosynthetic pathway, is renowned for accumulating sucrose, a very important source of carbohydrate. Its significance in recent years has further increased as a leading biomass crop for bioenergy and bioethanol production. Research and development (R&D) across various fields have played a crucial role in advancing sugarcane, with the International Society of Sugarcane Technologists (ISSCT) occupying centre stage in promoting and disseminating the research outcomes through workshops and congresses of the society.

Physiology studies play an important role in better understanding the sugarcane fundamental processes and mechanisms that govern growth, development, and productivity. Early research focused on studies of growth, development, key factors influencing germination, stalk height, tillering, water requirements and photosynthesis, thus paving the way for optimal cultivation practices and improved sugar production. Subsequent studies delved into factors influencing sugarcane respiration, flowering, stress tolerance and treatment using ripeners.

As for the application of molecular biology techniques to sugarcane during the early period of 1975 to 1995, much emphasis was placed on development and refinement of the tissue culture technique and its application for mass propagation of plantlets *in vitro*. Later, increasingly precise tools, such as genetic transformation, DNA markers, and genetic mapping were developed.

RESEARCH ADVANCES - PHYSIOLOGY

1977 Congress

During the XVI ISSCT Congress in 1977, held in Brazil, the reports focused mainly on the use of ripening agents. Chemical control of ripening in sugarcane gained significant importance, especially in areas where the climatic conditions for natural ripening are not ideal. The application of the chemical Polaris (N, N-bis phosphonomethyl glycine) early in the maturing phase was found to maintain juice quality in the declining phase of sugarcane (Alves *et al*. 1977). Several authors reported on the significant increase in Pol % cane, in variety Co 331, vastly cultivated at that time, following application of Polaris. Azzi *et al*. (1997) from Brazil noted a 39% increase in Pol % cane over the control after 4-8 weeks application in plant cane. Fernandes *et al*. (1997) found that in variety IAC48/65, Polaris produced major changes in the first six internodes of sugarcane, with higher Pol % and total juice weight, while also shortening the length of the first four internodes. A decrease in reducing sugars % juice was noted in the first ten internodes. Pan and Lee (1977) found Polaris to be effective in increasing sucrose content in both plant cane and ratoon cane and stressed that time of spraying and interval between treatments and harvest were important. Julien (1977) reported on the importance of time interval between application and harvest as well as on other factors that are important for benefiting from the application of the ripener including the environment, the stage of growth of the sugarcane to apply ripener and the concentration of the chemical.

The plant growth regulator Ethrel (2-chloro-ethyl phosphoric acid) which liberates ethylene in plant tissue was also used as a ripening chemical in Colombia by Jaramillo *et al.* (1977) and found to increase cane yield, while the addition of a surfactant enhanced the ripening effect in sugarcane. A review by Roston (1977) on the use of Ethrel on sugarcane in South Africa over five years revealed consistent improvements in the juice purity and sucrose % cane at the start of harvest, following the application of the chemical. Profitable increase in sugar yield from 0.8 to 2.4 t/ha was observed following spraying with Ethrel.

1980 Congress

At the XVI ISSCT Congress held in Philippines in 1980, application of ripeners was still an important topic. Julien *et al*. (1980) not only looked at the effect of application of Polaris on sugarcane, but also investigated various factors such as influence of environment, flowering, rainfall and dosage of application on the crop's response. Rainfall during or just after the application reduced the positive response on Pol % cane, while both flowered and vegetative stalks responded equally well to the treatment with the ripener. An interesting study was carried out by Martin *et al*. (1980) in Louisiana, where the efficacy of glyphosine, registered as a growth regulator to promote sugarcane maturation and an analog of glyphosate was tested on ratoon stunt-infected and non-infected plots. Glyphosine increased sucrose content in all treatments but was significantly greater in the non-infected RSD plots.

The use of Asulam as a sucrose enhancer in sugarcane was found to improve juice quality and increase sugar yield when applied 5-10 weeks before harvest (Hardisty 1980), while higher gains were noted in higher yielding varieties, such as in NCo varieties planted in Africa. However, economic gains were found to be minimal if applied less than 4-5 weeks prior to harvest, while the optimum timing for application was about 10 weeks before projected harvest date.

Another ripener, MON 8000, a glyphosate salt formulation gave interesting results and was found to be more consistent than Polaris, with less response variation amongst different cultivars and also did not affect response where soil and plant nitrogen were in excess of natural ripening requirements (Hilton *et al*. 1980). Here again the effect of MON 8000 on sugarcane growth, sucrose production and ratoon regrowth were dependent on the amount and concentration of the ripener applied as well on the timing between application and harvest.

Moore (1980) investigated the use of gibberellic acid, a plant hormone, to increase sugarcane yields in Hawaii. Significant gains were noted in fresh weight of cane without affecting quality, while also allowing to overcome winter stunting of growth, thus increasing cane and sucrose yields.

Besides studies on growth and sucrose enhancers, studies were made on several subjects of interest to physiologists. Mishra and Mishra (1980) investigated the polyphenolic constituents of sugarcane, that cause difficulties in juice clarification. Following initial work carried out by Brett and Harding (1974) on artificial flowering induction under controlled conditions, Nuss (1980) in South Africa successfully induced many varieties to flower under a photoperiod house.

Soopramanien and Julien (1980) reported on the physiological basis of yield variation between and within varieties grown under contrasting conditions and concluded that sucrose yield was influenced by environmental conditions and the variety grown, while tiller density was found to be a more important yield determinant factor than stalk dry weight or sucrose accumulation. The role of side shoots, in particular the leaves, in flowered sugarcane were reported to play an important role in maintaining dry matter and sucrose content in Mauritius (Julien *et al*. 1980). They concluded that heavily flowered fields, where side shoots are few, should be harvested soon after anthesis in order to minimize sucrose loss, while in flowered fields where side shoots are well developed, harvest may be delayed by several months after anthesis. They also reported that sugarcane breeders should select high-flowering varieties provided that they develop side shoots.

Masaki *et al*. (1980) studied the efficiency of solar energy utilization in sugarcane and found a close positive correlation coefficient between it and leaf area index in the early period of rapid growth. Efficiency of solar energy utilization was also positively correlated with solar radiation.

1983 Congress

Moving into the XVIII ISSCT Congress in 1983, in Cuba, fewer papers were presented on ripeners. An interesting paper by Pinna *et al*. (1983) proposed a method for the estimation of real evapotranspiration in sugarcane and also showed the possibility of estimation of the crop yield based on real evapotranspiration as it is possible to estimate the relationship between consumption and yield.

1986 Congress

In 1986, at the XIX ISSCT Congress in Indonesia, inhibition of flowering in sugarcane gained attention. Three papers reported the successful use of Ethephon to suppress flowering in sugarcane in Brazil (Coleti *et al*. 1986), Sudan (Hardy and Dove 1986) and in Hawaii (Moore and Osgood 1986). Treated canes gave better juice quality and showed reduced pith tissue compared to untreated canes, while increasing cane yield and overall sugar yield.

Donaldson and Staden (1989) reviewed ripeners in sugarcane in South Africa, reporting on the large number of chemicals tested as potential ripeners, but with only few reaching registration stages. They concluded on the efficacy of Ethrel and Embark on immature canes, with juice purity less than 75%, while varieties responded differently to the application of ripeners.

1989 Congress

In Brazil, at the XX ISSCT Congress, Silva *et al*. (1989) reported that application of Ethephon, especially at the beginning of the harvest season produced high sucrose levels in canes.

Scandaliaris *et al*. (1989) from Argentina described on the benefits of plantation design in wide bottom furrow at 1.6 m interrow instead of 1.2 m that gave a 15% increase in sugarcane yield and associated this increase with higher stalk population and leaf area index, that improved efficiency of solar radiation capture by 20%. However, they also noted a decline as from the third harvest and in successive harvests.

1992, 1996 and 1999 Congresses

As from the XXI ISSCT Congress held in Thailand in 1992 to the XXIII Congress in India in 1999, fewer papers were presented in physiology, not because there was less interest in this field, but due to emphasis shifted to the molecular understanding of the sugarcane plant.

Investigations on the use of ripeners, germination, artificial flowering and sugarcane ratooning remained subjects of discussion and were further refined. Donaldson (1999) comprehensively reviewed the benefits of using ripeners under the South African climatic conditions and gave an account how their uses had become a standard practice in some parts of the South African sugar industry, due to several factors including good weather conditions, large choice of good varieties and improved technology transfer, thus maximizing profits of farmers, particularly for irrigated crops.

Nuss and Berding (1999) submitted an interesting paper on artificial flowering under photoperiod facilities for breeding that was increasingly being adopted in some sugarcane research centres in the USA, South Africa and Australia. Such pioneering work thereafter led many countries to adopt artificial flowering to induce parents to flower under field conditions, enabling their crossing to produce valuable seeds.

RESEARCH ADVANCES – MOLECULAR BIOLOGY

During 1975 to 1999, there was remarkable development in sugarcane molecular biology, paving the way for unprecedented understanding and advancements in crop improvement. At the XXI ISSCT Congress held in Thailand in 1992, a Molecular Biology Section was established in the ISSCT Proceedings and sugarcane physiology was integrated under molecular biology. The first molecular biology inter-congress workshop took place in 1994 in Brazil before the congress held in Colombia in 1995. This era witnessed the emergence of various molecular techniques and approaches that have revolutionized sugarcane research and allowed the unravelling of the highly complex sugarcane genome.

1977 and 1980 Congresses

Plant tissue culture offered a means to rapidly propagate disease-free, high-yielding sugarcane plants, ensuring genetic purity and uniformity in large-scale production. Sugarcane tissue culture technique introduced by Nickell (1964), was refined for mass multiplication of elite sugarcane varieties and witnessed progress made in culture medium optimization and callus production presented during the XVI and XVII ISSCT Congresses, respectively. Interest in protoplast culture of sugarcane was shown by Krishnamurthi (1980) to produce hybrid material asexually, but difficulties were also encountered.

1983 Congress

At the XVIII Congress in Cuba in 1983, successful production of tissue culture plantlets from different sugarcane organs were reported by Prasad and Krishnamurthi (1983). Moreover, they proposed selection of superior sub-clones from donor clones and proposed this method as an improved breeding technique to advance varieties in the variety evaluation program. Chen and Shih (1983) readily isolated protoplasts from cell culture of sugarcane. However, although some protoplasts produced calli, further differentiation and regeneration of the calli into plants were not successful. Differentiation of sugarcane protoplasts is still a problem today after four decades.

In Cuba, Ruiz and Maribona (1983), proposed the use of isoenzymes patterns for peroxidases in the identification of sugarcane varieties and was able to distinguish several varieties from each other. However, in later years the isoenzyme technique was overtaken by more precise DNA-based techniques that allowed to characterize sugarcane varieties more precisely.

1986 Congress

At the XIX ISSCT Congress in Indonesia, further use of tissue culture to select for salt tolerance and disease resistance in *in vitro* sugarcane plantlets were presented by Maribona *et al*. (1986). Plantlets selected *in vitro* to eye spot disease toxin in the culture medium produced resistant plants, while stress tolerant plants obtained in medium with NaCl.

1989 Congress

At the XX ISSCT Congress in Brazil, sugarcane molecular biology had started to become more predominant. Glaszmann *et al*. (1989), reported on advances made in using of Restriction Fragment Length Polymorphism (RFLP) marker with a ribosomal DNA probe to characterize sugarcane varieties. They demonstrated that use of molecular markers to differentiate *Erianthus* species from other *Saccharum* species. During the symposium presentation, Nonato *et al*. (1989), also proposed RFLP as a tool for genetic diversity studies among species and among cultivars of sugarcane, and their potential impact on improving conventional breeding. Irvine (1989) introduced the potential of producing

transgenic sugarcane using the biolistic gun and also discussed genetic modification technology as a useful tool to assist classical sugarcane breeding program.

1992 Congress

At the XXI ISSCT Congress in Thailand, Irvine (1992) comprehensively reviewed the potential application of genetic transformation in sugarcane. He discussed the difficulties of using *Agrobacterium* in graminaceous crops as compared to dicots, as well as stressing the right vector choice, promotor and selectable markers in order to achieve stable genetic transformation in sugarcane. He debated at that time on the controversy stigmatizing the technology, which after three decades has not changed in many countries, thus preventing full adoption of GM technology. Moore (1992) elaborated on the various progress being made, notably in the application of RFLP and PCR for mapping linkage groups in sugarcane, and a variety of applications including DNA fingerprinting of varieties, detection of major genes and QTLs in sugarcane using molecular markers. Glaszmann (1992) reported on the pioneering findings of large regions homology between sugarcane and maize. All these reports in successive years prompted extensive work on comparative mapping of sugarcane with other Gramineae, which showed extensive collinearity with sorghum, that became the model crop to study sugarcane.

Visessuwan *et al*. (1992) successfully produced SCMV-free plantlets by culturing meristems and shoot tips of sugarcane. The success rate ranged from 80-100%. This was an important finding and many laboratories adopted mass production of sugarcane plantlets using meristem tip culture, with the objective to eliminate sugarcane viruses.

1996 Congress

At the XXII ISSCT Congress in Colombia, significant progress had been achieved in molecular biology in different countries and results were presented. This was the era when sugarcane molecular biology really took off to be applied in many disciplines.

Moore (1996) reviewed the progress made in sugarcane molecular biology, while Almazan del Olmo (1996), Autrey *et al*. (1996) and Lingle (1996) reviewed papers on the application of biotechnology tools to sugarcane by-products, pathogens detection and sugarcane physiology, respectively. The latter stressed the importance of physiologists and plant breeders to work together to improve sugarcane yield and sucrose content along with enlisting molecular biologists. On the co-product side, value-added products such as antibiotics and polymers from molasses were suggested, while the use of vinasse for single cell protein production was also put forward. As for ethanol, second- and third-generation derivatives including acetic acid, ethyl acetate and PVC were discussed, while the conversion of sucrose to fructo-oligosaccharide (FOS) that exhibits high sweetness levels between 30 to 50% of sucrose were also discussed, a subject still of considerable interest today.

Following the breakthrough obtained at Cornell University on sugarcane genetic mapping utilizing molecular markers, the so-called single dose markers, D'Hont *et al*. (1996) made a significant breakthrough in genetic mapping of sugarcane and presented the genetic map of the modern cultivar R570. Comparative mapping of sugarcane was carried out with sorghum and maize maps, where common loci were identified, showing broad similarities with maize and sorghum genomes.

Carroll and Curtis (1996) reviewed advances made in plant biotech and in the application of several techniques including genetic engineering, molecular markers, transposon tagging and chromosome walking to clone important genes from plants, as well as gene silencing and stressed the importance of understanding sugarcane genetics, in order to apply biotech tools to sugarcane.

Successful production of transgenic sugarcane with different traits became more obvious. Transgenic sugarcane resistant to the lesser cornstalk borer were reported by Fitch *et al*. (1996), while Gallo-Meagher and Irvine (1996) were successful in obtaining transgenic plants of NCo 310 with the *bar* gene that confers resistance to the herbicide glufosinate ammonium through biolistic bombardment of

embryogenic sugarcane calli. In Australia, Zhang and Birch (1996) produced transgenic sugarcane resistant to *Xanthomonas albilineans*, the pathogen responsible for leaf scald disease in sugarcane.

1999 Congress

At the XXIII ISSCT Congress in India, Moore (1999) again gave a thorough review on the progress achieved in sugarcane biotechnology. He stressed the importance of investigating sugarcane genomics and the genetic transformation technology that could allow several traits of the crop to be improved. By 1999, there was an extensive application of genetic markers, genetic mapping, QTL mapping, DNA sequencing and analysis and bioinformatics to sugarcane. GM technology became a valuable tool to improve sugarcane. Smith *et al*. (1999) from Australia reported on successful production of transgenic sugarcane plants for resistance to *Sugarcane mosaic virus* using the coat protein gene of the virus, as well as canegrub-tolerant plants using constructs to express the potato proteinase inhibitor II or the *Galanthus nivalis* lectin gene from snowdrop. Already in 1999, the pyramiding of the two genes into sugarcane was already being investigated, showing the quick development in GM technology in the complex polyploid sugarcane crop.

PROMINENT CONTRIBUTORS

Jim Irvine (USA) is known as an eminent sugarcane breeder and for his contributions to biotechnology. His work laid the foundation of using the biolistic gun to produce transgenic sugarcane. This procedure was optimized during the following years and the biobalistic transformation to produce transgenic sugarcane is still the most utilized technique to express traits of interest in sugarcane. Jim was a strong advocate for integrating biotechnology into traditional breeding programs. He believed that genetic modification could complement conventional sugarcane breeding, offering new ways to improve crop traits such as disease resistance, drought tolerance, and yield.

Jean Christophe Glaszmann (France) made significant contributions to sugarcane genetics and molecular biology, particularly through the use of molecular markers and genetic mapping. His work played a key role in advancing the understanding of the sugarcane's complex genome. He pioneered work on the use of Restriction Fragment Length Polymorphism (RFLP) markers in sugarcane and demonstrated that these markers could differentiate *Erianthus* species from other *Saccharum* species. He also showed that molecular markers could be used to assess genetic diversity among sugarcane species and cultivars. His research also contributed to comparative genetic mapping between sugarcane and other related crops like sorghum and maize. His findings highlighted large regions of homology between these crops, which advanced the study of sugarcane genetics by leveraging knowledge from better-studied crops like maize. Following these reports, his team at CIRAD made a significant breakthrough in the genetic mapping of sugarcane, presenting the first genetic map of a modern cultivar, R570.

Régis Julien (Mauritius) was a prominent sugarcane breeder and physiologist. He had published extensively in the congress proceedings. He made significant contributions to sugarcane research, particularly in the areas of ripening, sucrose yield, and flowering. Régis emphasized the importance of ripening agents, like Polaris and how environmental factors, the growth stage, and the timing of ripener application affect the sucrose content in sugarcane. He highlighted that rainfall during or shortly after the application of ripeners reduced their positive effects on sucrose content. He also noted that both flowered and vegetative stalks responded equally well to ripeners. He also extensively studied the physiological basis of yield variation in sugarcane and reported that tiller density was a more important yield determinant than stalk weight or sucrose accumulation. In flowering sugarcane, he observed that side shoots played a crucial role in maintaining dry matter and sucrose content. He recommended harvesting soon after anthesis in fields with few side shoots to minimize sucrose loss.

IMPACT OF RESEARCH

The period 1975 to 1999 witnessed significant progress in sugarcane physiology and the advent of molecular biology, leading to improved varieties, optimized cultivation practices, and enhanced sugar production. Biotech tools applied to sugarcane breeding programs around the world started to be adopted. The knowledge and understanding of the molecular aspect of the sugarcane crop during this review period laid the foundation for much progress in sugarcane biotechnology in the years ahead.

The collaborative efforts of physiologists, breeders, pathologists, molecular biologists, and scientists from various disciplines have been instrumental in advancing sugarcane R&D. These advancements provide a valuable resource for future studies and underscore the importance of continued interdisciplinary collaboration for sustainable sugarcane production.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Molecular Biology 2000-2023

Angélique D'Hont and Nathalie Piperidis

dhont@cirad.fr

INTRODUCTION

The field of molecular biology in sugarcane emerged in the late 1980s and an ISSCT Molecular Biology section was established during the XXI congress in Thailand in 1992. At the same time, an International Consortium for Sugarcane Biotechnology (ICSB) was set up to collectively support biotechnology research projects, in order to improve sugarcane variety development programs and enhance basic knowledge of sugarcane genetics. The first secretaries of this consortium were James Irvine and Paul Moore. Both ISSCT, with the organization of regular molecular biology workshops, and ICSB were essential for the development of molecular biology in sugarcane.

RESEARCH ADVANCES

During the 2001 congress in Brisbane, two papers, one by Burnquist and one by D'Hont and Glaszmann reviewed the first decade of research on molecular biology in sugarcane. These reviews grouped research into four fields: molecular genetic markers, genome architecture gene, discoveries, and genetic modification. This review follows that structure.

Molecular genetics

During 2001-2023 genotyping technologies evolved substantially. Several reports described the implementation of different types of PCR-based markers such as Random Amplified Polymorphic DNA (RAPD), Simple Sequence Repeat (SSR) and Amplified Fragment Length Polymorphism (AFLP), that progressively replaced Restriction Fragment Length Polymorphism (RFLP) that were very labor intensive and low throughput. RAPD, although useful at that stage, proved later to be not very stable. SSR progressively became the most effective markers for validation of crosses and varietal identification in sugarcane. Different sets of SSRs were developed over the period, within the frame of the ICSB (Maccheroni *et al.* 2007). SSR markers are now still effectively used for varietal identification in many countries (Piperidis *et al.* 2001; Cordeiro and Henry, 2001; Matsuoka *et al.* 2005).

At the 2001 congress, a first generation of high-throughput markers, DArT (Kilian *et al.* 2001), was reported, allowing hundreds of markers to be revealed in one experiment; this later became frequently adopted for genetic studies in sugarcane (Franco *et al.* 2013).

During the 2016 congress, two new high-throughput genotyping technologies were reported. Aitken *et al.* (2016) reported on the development of a sugarcane Single Nucleotide Polymorphism (SNP) Chip Array. This method allowed to genotype in one experiment 345,000 SNPs. However, only SNPs present on the array can be genotyped, so the germplasm sampled, used to design the array, is crucial. Riasco *et al.* (2016) and Parmessur and Dookun-Saumtally (2016) reported on the implementation of genotyping by sequencing (GBS) which exploited Next Generation Sequencing technologies. One advantage of these types of genotyping technologies (such as GBS, RADseq, DArTseq, Capture-seq)

based on sequencing is that polymorphism can be detected and discovered simultaneously. This is one of the reasons this type of high-throughput genotyping technology has been more widely adopted for sugarcane (Garsmeur *et al.* 2019; Chaves *et al.* 2023). Given the high polyploidy of sugarcane, deep sequencing data are essential for accurately detecting single-dose SNPs and minimizing potential confusion with sequencing errors.

These types of molecular markers were used by many teams to analyze diversity within collections or breeding or base broadening material (Jannoo *et al.* 2001; Cero *et al.* 2001; Leon *et al.* 2001; Mu Qing *et al.* 2001; Sangeeta *et al.* 2005; Bressiani 2007; Jackson 2010; Perera *et al.* 2023).

Molecular markers were used to better understand the genetic determinisms of agronomic traits through analysis of QTLs (Hoarau *et al.* 2001; McIntyre *et al.* 2001; Da Silva *et al.* 2001; Franco *et al.* 2013; Parmessur and Dookun-Saumtally 2019). Many of these QTL studies, in particular for yield components, revealed numerous QTLs with relatively small effects that revealed the polygenic control of these characters and might be accentuated by the potential multiple interactions among alleles and loci resulting from the highly polyploid nature of the sugarcane genome.

Studies of the genetic determinism of resistance to diseases demonstrated cases of simpler genetic controls. The first major resistance gene, *Bru1*, providing resistance to brown rust, was identified in 1996 (reviewed in Burnquist *et al.* 2001). Fine genetic and physical mapping strategies adapted to the complex genome of sugarcane were developed to find markers closely linked to *Bru1* and identify the gene involved in the resistance (D'Hont *et al.* 2001). It led to the design of PCR diagnostic markers for *Bru1* (Costet *et al.* 2012) that are now used in many breeding programs. These markers revealed that *Bru1* is the main sources of rust resistance to brown rust in many countries. Diagnostic markers can be used to identify breeding material having *Bru1* but also to explore alternative resistance sources since it is crucial to avoid overreliance on a single gene that could become susceptible over time.

Major QTLs were reported for resistance to yellow spot fungal disease caused by *Mycovellosiella koepkei* (now *Passalora koepkei*) by Al-Janabi *et al.* (2005) and to smut disease caused by the fungus *Sporisorium scitamineum* (Umeda *et al.* 2019). QTLs representing alternative sources of resistance to brown rust than *Bru1* were also reported (Chaves *et al.* 2023).

Classically, QTLs studies were performed using bi-parental crosses. Genome Wide Association Study (GWAS) approach that involved the genotyping of sets of different cultivars to find genetic markers associated with a particular phenotype were developed during the period with a first report at the 2005 congress (Butterfield 2005). This type of approach benefits from the important linkage disequilibrium (LD) (i.e., the non-random association of alleles at distinct loci) found among modern sugarcane cultivars. The breeding history of sugarcane which involved only a few genotypes of *S. officinarum* and *S. spontaneum* with only a few generations since the original hybridization events, explains this important LD (Jannoo *et al.* 1999). Given the complexity of the sugarcane genome, marker-assisted selection approaches have to be adapted to address this challenge. Several studies have addressed those genetic and statistical aspects (Butterfield and Nuss 2001; Butterfield *et al.* 2007).

Genome architecture and assemblies

Sugarcane is probably the crop with the most complex genome, being highly polyploid, aneuploid and of interspecific origin.

An important step for progressing in the understanding of this complex genome was initiated in the 1990s with the development of molecular cytogenetics that allowed differentiation of the chromosomes from different species. Applied to the model modern cultivar R570, it revealed that it contained around 80% and 10% of chromosomes from *S. officinarum* and *S. spontaneum,* respectively, and around 10% of recombined chromosomes between the two species. Molecular cytogenetics also showed that the genome of the two ancestral species is organized in 10 basic chromosomes in *S. officinarum* and *S. robustum* and 8 in *S. spontaneum* (Burnquist *et al.* 2001; D'Hont and Glaszmann 2001).

During the 2001 congress, Piperidis and D'Hont reported on the use of the same methodology to analyze the interspecific composition of nine modern cultivars showing that the proportion of *S. spontaneum* chromosomes varied from 10 to 20% and recombined chromosomes from 5 to 17%. The technique was also used to demonstrate the 2n+n transmission in crosses between *S. officinarum* and *S spontaneum* and to analyze the composition of intergeneric hybrids between *S. officinarum* and *Erianthus* (D'Hont and Glaszmann 2001).

Given the complexity of the genome of sugarcane, it was only in 2013, 13 years after the publication of the first assembled plant genome *Arabidopsis*, that initial attempts to sequence and assemble the sugarcane genome were reported. Lembke *et al.* (2013) and Lembke (2016) reported on a large initiative in Brazil that aimed to sequence and assemble the genome of the Brazilian sugarcane variety SP80-3280 and in its initial steps provided a complete catalog of sugarcane genes. Various sequencing techniques were used including Whole Genome Shotgun using the 454 platform and BAC sequencing.

In the XXVIII congress, Berkman *et al.* (2013) reported on the sequencing and assembly of 72 BAC clones from cultivar R570. This work was done within an international initiative aiming at sequencing and assembling the genome of the modern cultivar R570. Supported by ICSB and later by the US DOE/Join Genomic Institute, this led to the production of the first reference genome for sugarcane (Garsmeur *et al.* 2019). To produce this reference genome assembly, a minimum tiling path of 4,660 sugarcane BACs that best covers the gene-rich part of the sorghum genome was selected and assembled in a 382 Mb single tiling path of a high-quality sequence. A total of 25,316 protein-coding gene models were predicted. In the same paper, they reported, based on a dense SNP map of cultivar R570, that the chromosome rearrangements that explain the difference in basic number between *S. officinarum* (x= 10) and *S. spontaneum* (x=8), involved two sets of three ancestral chromosomes that were each rearranged in *S. spontaneum* in two chromosomes. This was further confirmed with the first polyploid genome assembly of a tetraploid *S. spontaneum* (Zhang *et al.* 2018).

During the 2023 congress in India, Trujilo Riasco *et al.* (2023) reported on the monoploid genome assembly of the Colombian cultivar CC 01-1940. They used a shot-gun strategy with PacBio long reads, Illumina paired short reads, and Hi-C reads and the sequence contigs were collapsed in a monoploid assembly. D'Hont *et al.* (2023) reported results of collaborative work that exploited the R570 monoploid sequence assembly to design chromosome specific probes. This allowed for the first time exploration of the number of copies of each class of chromosome in a sugarcane cultivar. It showed that cultivars have mainly 12 copies of each chromosome, but this number can vary depending on chromosome classes and on cultivars. Inter-chromosome translocations were also found. This aneuploidy and translocation were also observed in the parental species *S. officinarum* and *S. spontaneum*. D'Hont *et al.* (2023) also showed by using these chromosomes specific probes that some *S. spontaneum* accessions have a basic chromosome number of 9. Added to the previous report *of S. spontaneum* with a basic chromosome number of 10 (Meng *et al.* 2020), it showed that in *S. spontaneum* from a basic chromosome of x = 10, rearrangements occurred in two steps leading to x = 9 and then x = 8. Each step involved three chromosomes that were rearranged into two.

This difference in the basic chromosome number for the two species involved in cultivars led the authors to propose a nomenclature of the chromosomes that optimize the correspondence among *Saccharum* species. In the same report, D'Hont *et al.* (2023) presented the first polyploid assembly of a modern sugarcane cultivar (R570) that was done in a collaborative project involving the Join Genomic Institute, involving the teams of K Aitken and A D'Hont. In that paper, the authors also proposed a new nomenclature of sugarcane chromosomes to maximize correspondence within species.

Gene discovery

Gene discovery programs in sugarcane started in the mid-1990s with the South African Sugarcane Research Institute (SASRI), in particular, playing a pioneering role and laying the foundation for similar projects in Brazil, Australia and USA (Burnquist 2001). The aims of these programs were to identify and understand the functions of genes associated with specific traits. The main method initially used was

based on production and analysis of Expressed Sequence Tags (ESTs). The principle was that expressed genes are initially transcribed as an mRNA molecule, that can be reverse transcribed to its complementary DNA form (cDNA) and sequenced producing the EST. A particularly ambitious programs in Brazil (the SUCEST project), involving a network of teams, constructed the most complete database of sugarcane gene sequences. Using different tissues (root, stalk, leaves, flowers, developing seeds, etc.), the group sequenced 290,000 sugarcane cDNAs representing 81,000 sequence clusters (Burnquist 2001). This database has been used to identify genes involved in various traits, including carbohydrate metabolism, response to environmental stresses or plant defense against pathogens (Falco *et al.* 2001).

Gene expression profiling approaches were developed to identify genes expressed in specific conditions or specific stages, through comparison of cDNA libraries produced in contrasted conditions or maturity stages that were used to analyze gene expressed during stem maturation and sucrose accumulation (Casu *et al.* 2001; Carson *et al.* 2001), defense response (Bower *et al.* 2001) or response to environmental stresses such as water deficit (Ferro *et al.* 2007).

Genetic transformation was also used to study sucrose metabolism. Botha *et al.* (2001) produced transgenic canes with reduced acid invertase activity but found no changes in sucrose load or purity. Groenewald and Botha (2001) produced transgenic canes with down-regulated pyrophosphate-dependent phosphofructokinase (PFP) activity and found an increase in hexose concentration in young internodes but no change in sucrose concentration.

Following the SUCEST project on gene sequence identification, another large project, the SUCEST-FUN Project, was implemented in Brazil aiming at associating putative biological functions to sugarcane genes. cDNA microarrays containing sugarcane ESTs and quantitative PCR were used to determine temporal and spatial gene expression data. Using cDNA microarrays containing 1,280 distinct elements, individual gene expression variation of plants grown in the field and transcript abundance in six plant organs (flowers, roots, leaves, lateral buds, first(immature) and fourth (mature) internodes were analyzed (Papini-Terzi *et al.* 2007). SUCEST-FUN identified 3,500 genes related to signal transduction and developed a microarray with 1,300 of these genes. The microarray was tested using total cDNA populations from cultivar SP80-3280 exposed to various treatments. A SUCAST catalogue (Sugarcane Signal Transduction) and a SUCAMET catalogue (Sugarcane Metabolism) containing genes related to Signal Transduction and Metabolism, respectively, were assembled.

An improved version of the SUCEST database was presented by Ten-Caten *et al.* (2019) in which many of the genes with no known function were re-annotated. The novelty was to align sugarcane assembled sequences (SAS) and EST sequences to the newly defined gene-space assembly of the SP80-3280 sugarcane cultivar. For thousands of SAS without annotation from alignments against databases, it was possible to associate annotation based on the alignment to the gene-space assembly. Overall, 67.8% of SAS sequences were annotated.

In summary, gene discovery and expression profiles in sugarcane involve a multi-faceted approach, leveraging advanced in genomics, transcriptomics, and functional genomics techniques. These genes are envisioned as targets in gene-transformation initiatives, with the goal of improving sugarcane varieties with enhanced agronomic traits

Genetic transformation

The field of genetic transformation in sugarcane started in the 1990s, with pioneering work particularly by Robert Birch's team at the University of Queensland in Australia. The main targets for breeding programs were herbicide tolerance, insect and disease resistance, and carbohydrate metabolism (Mirkov 2001; Burnquist 2001). During the period, new methods for sugarcane genetic engineering have been tested or improved, including transformation through *Agrobacterium* (Enriquez *et al.* 2001; Matsuoka *et al.* 2001; Dong *et al.* 2013), virus-derived transgene (McQualter *et al.* 2001), and peptide

target to vacuole (Gnanasambandam and Birch 2001). A first report on exploiting the CRISP/Cas9 technology in sugarcane was given by Sosa *et al.* (2023).

One of the challenges in transgenic approaches in sugarcane is the silencing of the transgenes that may occur through the transcriptional (promotor methylation) or post-transcriptional levels (mRNA degradation) (Mirkov 2001). Several studies during the period aimed at understanding the mechanisms involved (Mirkov *et al.* 2001; Prak *et al.* 2007) or at overcoming this problem (Waldron *et al.* 2001). The inheritance and expression of transgene in progenies was also investigated (Harrison *et al.* 2001), as well as the occurrence of somaclonal variation during the tissue culture phase of genetic engineering programs (Arencibia *et al.* 2005).

Another important challenge is the consumers' concern regarding genetically modified crops. Several studies were conducted in Australia on understanding those concerns (Wegener *et al.* 2005; Romanach *et al.* 2007). The Wegener *et al.* (2005) report identified negative perceptions of genetically engineered plants in the Australian sugar industry, citing limited knowledge of genetic engineering, concerns about technology ownership and media influence as factors affecting public acceptance. Enhancing community understanding through education and informed decision-making were proposed as crucial for acceptance. Studies were also conducted to show that sugar crystalized from GM sugarcane did not contain detectable trace of transgenes (Joyce *et al.* 2013).

Genetically modified sugarcanes were reported during the period. Sugarcane lines resistant to yellow leaf disease virus (ScYLV) were obtained through the bombardment of embryogenic callus with specific plasmids designed for virus resistance (Rangel *et al.* 2005; Zhu 2007). Sugarcane tolerant to glyphosate was also obtained by microprojectile bombardment (Racedo *et al.* 2019; Romero *et al.* 2019). Another important goal also concerned the obtention of varieties resistant to the borer *Diatraea saccharalis* (Budeger *et al.* 2023).

While many countries still encounter reluctance towards GMOs and try to navigate through deregulations, the official approval for the commercial release of the first transgenic sugarcane cultivar, RA87-3RG, resistant to glyphosate, was issued by the relevant regulatory bodies in Argentina in 2015, but was put on hold for safety concerns (Noguera *et al.* 2019). Finally, despite global hesitancy towards GMOs, the world's first genetically modified sugarcane, developed through particle bombardment by Centro de Tecnologia Canavieira (CTC), received approval in 2017, affirming its safety for human consumption by Health Canada and the FDA (Cheavegatti-Gianotto *et al.* 2019). CTC20BT clones were distributed to growers in Brazil in 2017 and have reportedly given very good control under field conditions against the sugarcane borer *Diatraea saccharalis*.

PROMINENT CONTRIBUTORS

Angelique D'Hont has led groundbreaking research in sugarcane, advancing our understanding of the complex origin and genome architecture of sugarcane cultivars. She pioneered work in molecular cytogenetics in sugarcane, led work on molecular genetics, in particular on the characterisation of a durable major rust resistance gene (*Bru1*), and more recently led initiatives on the first genome assembly of a modern sugarcane cultivar (R570).

Frikke Botha has had a distinguished career in sugarcane research. His primary research focus centred on the genetic and molecular regulation of carbon partitioning in the culm and leaves of C4 grasses, particularly sugarcane. This work is critical for understanding the factors that drive sucrose accumulation and biomass composition. He also worked on genetic modification of sugarcane and understanding yellow canopy syndrome.

Erik Mirkov devoted his career to pioneering research in sugarcane biotechnology and virology. He made significant contributions to the understanding of transgenic approaches in sugarcane, particularly in identifying the challenges posed by the silencing of transgenes at both the transcriptional and post-transcriptional levels, such as mRNA degradation.

IMPACT OF RESEARCH

Between 2001 and 2023, research in sugarcane molecular genetics made substantial progress, facilitated by advancements in genotyping platforms, genome assemblies, and functional genomics. The transition from early PCR-based markers to high-throughput genotyping technologies such as DArT, SNP arrays, and GBS enabled more efficient varietal identification, diversity analysis, and QTL mapping in the highly polyploid sugarcane genome. Efforts in genome sequencing led to the development of high-quality reference assemblies for key cultivars, improving our understanding of genome structure and chromosomal variation.

Large-scale transcriptomic initiatives, notably SUCEST and SUCEST-FUN, significantly expanded the sugarcane gene catalogue and enabled the functional characterization of genes involved in key agronomic traits. These genomic resources have underpinned the development of marker-assisted selection strategies and supported early successes in genetic transformation and genome editing, including the release of the first commercial genetically modified sugarcane cultivar in Brazil in 2017.

All these advances have laid a foundation for precision breeding and genetic improvement in the complex sugarcane plant.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Entomology 1924-1938

Cecilia Easdale

ceasdale@ledesma.com.ar

INTRODUCTION

The International Society of Sugar Cane Technologists (ISSCT) was established in 1924, providing a global platform for researchers, scientists, and agricultural professionals to address critical issues affecting sugarcane cultivation. From the creation of the ISSCT in 1924 until 1938, six congresses of sugarcane technologists were held: 1924 (Hawaii), 1927 (Cuba), 1929 (Indonesia), 1932 (Puerto Rico), 1935 (Australia), and 1938 (United States). However, due to World War II, these meetings were discontinued until 1950.

From the beginning, there was significant participation in topics related to the Entomology Section. The ISSCT congresses were a vital forum for the discussion of various pest challenges facing the global sugarcane industry. Between 1924 and 1938, 76 papers were presented on entomological topics, illustrating the importance of pest management in sugarcane cultivation. These papers covered a wide range of pests, but several themes emerged as particularly significant during this period.

The main themes addressed in these works were stemborers (approximately 40% of the papers focused on this topic) and whitegrubs (10.5% of the papers). Additionally, studies were presented on other pests such as aphids, leafhoppers, mealybugs, aphids, and termites, among others.

The period from 1924 to 1938 marked a critical era in sugarcane entomology research and development. As the global demand for sugar surged, the sugarcane industry faced increasing challenges from insect pests that threatened crop yield and quality. To safeguard this vital agricultural commodity, researchers and scientists worldwide dedicated themselves to studying sugarcane pests, developing innovative control strategies, and exploring biological solutions for sustainable crop protection. This report focuses on pest management strategies, advancements in research and development, and the long-term impact of these innovations.

RESEARCH ADVANCES

Main pests and management strategies

The identification and management of pests were central topics across the ISSCT congresses, particularly in the earlier years when sugarcane plantations faced serious infestations with limited control options. Borers, particularly the sugarcane moth borers *Diatraea* spp., were reported as a major problem in different regions of America. Infestations caused significant losses in crop yields, with some areas reporting that up to one-third of their sugarcane was destroyed by borer infestations.

The cane borer was noted for its ability to burrow into sugarcane stalks, weakening the plants and making them more susceptible to secondary infections by fungi and other pathogens. Efforts to control this pest included the use of biological control agents, chemical treatments, and cultivation practices designed to minimize the conditions favourable to borer infestations. Papers presented at the

congresses highlighted the variability of borer infestations by region, with some areas reporting success in controlling the pest through early planting or adjusting harvest times to disrupt the borer's life cycle.

Another major pest discussed were whitegrubs. They were particularly problematic in regions such as Hawaii and Australia, where they fed on the roots of sugarcane plants, causing stunted growth and reducing yields. The introduction of biological control agents, such as parasitic wasps from the Philippines, was one of the strategies employed to combat whitegrubs. In Hawaii, these efforts were largely successful in reducing grub populations, demonstrating the potential of biological control as a sustainable pest management strategy for introduced pests. Not so in Australia, where endemic whitegrubs continued to be key pests.

Though pests such as aphids, leafhoppers, mealybugs, scale insects, weevils, and termites did not always cause the same level of damage as borers or whitegrubs, they posed significant challenges in certain regions. For example, in Mexico, the pyralid moth borers were particularly difficult to control due to the limited availability of effective field management practices.

Pest ecology and behaviour

Researchers during this period emphasized the importance of understanding the ecology and behavior of sugarcane pests to develop targeted control strategies. Comprehensive studies on the life cycles, feeding habits, and breeding patterns of key pests, provided valuable insights for designing effective management practices.

Detailed observations allowed entomologists to identify vulnerable stages in the pests' life cycles, pinpoint optimal timing for control interventions, and assess the impact of environmental factors on pest populations. This knowledge proved crucial in developing pest management strategies tailored to specific regions and crop stages.

Regional pest challenges and solutions

The global nature of the ISSCT congresses meant that pest challenges were discussed from a variety of regional perspectives, with each region facing unique environmental and agricultural conditions. In Queensland, Australia, for example, the focus was on controlling endemic canegrubs that posed significant threats to sugarcane crops. Experiments conducted there demonstrated that cane fields with taller plants tended to attract more adult beetles, which laid their eggs in the soil, leading to higher grub infestations. In response, researchers experimented with planting fast-growing cane varieties that disrupted the beetles' life cycle, reducing grub population.

In Fiji, the cane weevil borer was identified as one of the most destructive pests, with infestations in certain regions leading to the loss of one-third of the sugar crop. Efforts to control the pest included the introduction of parasitic wasps from New Guinea and the Philippines, but results were mixed, with some areas experiencing greater success than others due to variations in environmental conditions. Biological control efforts were also hampered by the fact that many of the pests in Fiji had adapted to the local environment, making it difficult to introduce new predators without disrupting the ecosystem.

In South America, pest challenges varied by region. In Ecuador and British Guiana (Guyana), moth borers of the genus *Diatraea* were reported as a significant threat, while in Barbados, whitegrubs such as *Phytalus smithii* and *Diaprepes abbreviatus* were the primary concern. Researchers noted that many of these pests had originally fed on native plants but had shifted to sugarcane as it became more prevalent. This adaptability made it difficult to control the pests using traditional methods, leading to a greater emphasis on biological control and varietal resistance.

Mexico faced unique pest challenges, particularly in the northern region of Sinaloa, where the primary pests were pyralid moth borers such as *Chilo loftini* and *Diatraea linaolata*. These pests proved difficult

to manage, and while natural predators such as the *Trichogramma minutum* parasite were introduced, infestation rates remained high, affecting up to 60% of some cane fields.

In regions such as Egypt, *Pseudococcus sacchari* mealybug posed a significant threat to the sugar industry.

India highlighted termite infestations, which damage cane before it matures by boring into the stalks. Traditional chemical methods have proven largely ineffective against these pests.

Control measures and technological innovations

The 1920s and 1930s were a time of significant innovation in pest control methods, with many of the papers presented at ISSCT congresses focusing on the development of new technologies and strategies for managing sugarcane pests. Research and development during this period focused heavily on biological control, quarantine practices, and varietal resistance. The goal was to develop sustainable pest management strategies that could be applied across different regions and environmental conditions.

Undoubtedly, biological control was the main focus of management during this period, with researchers exploring the use of natural predators and parasites to reduce pest populations in different countries. In Hawaii, for example, the introduction of egg parasites from Australia and parasitic flies from Amboina helped to control leafhopper and cane borer populations, significantly reducing the need for chemical pesticides.

Another notable technological advancement during this period was the development of aerial dusting, involving the use of airplanes to distribute insecticides over large cane fields. Aerial dusting was first tested in the early 1920s for controlling the *Catalpa sphinx* caterpillar; then for cotton boll weevil and was later adapted for sugarcane pest control. The use of airplanes allowed for rapid and efficient application of insecticides (200-500 acre/hour), even in fields that were difficult to access by traditional methods because of the soil conditions or height of the cane.

Other control measures discussed at the congresses included:

- Chemical control: Experts from different countries also shared their experiences on chemical control of some pests, in some cases with successful results and in others not so much.
- Plantation practices: Various control measures were discussed, including deep planting, which was suggested to be an effective method of reducing borer infestations in some regions. The use of hot-water treatment on seed cane was also discussed as a way to kill borer larvae within the cane before planting.
- Trash Preservation: The benefits of not burning the cane trash after harvesting were highlighted. Preserving trash on the fields was found to support borer parasites, potentially helping to control borer populations naturally.
- Trap cropping is a strategy that involves planting alternative host plants, such as corn, to attract pests away from sugarcane fields. While trap cropping showed some success in certain regions, it was labour-intensive and not always feasible on a large scale.
- Cutting and destroying the infested shoots before the borers transform into moths and leave the stalks, thus reducing the number of borers that can propagate and infest the cane later in the season, was another practice with good results.

Biological control

The ISSCT congresses emphasized biological control as a critical area of research, with many papers discussing the introduction of natural predators and parasites to control sugarcane pests. Biological

control was seen as a sustainable alternative to chemical pesticides, which were expensive and often harmful to the environment.

In Hawaii, biological control efforts were highly successful in controlling *Perkinsiella saccharicida* leafhopper, *Rhabdocnemis obscura* cane borer, and *Anomala orientalis* beetle populations with the introduction of natural enemies from other regions, including egg-parasites from Australia and parasitic flies from Amboina. These biological agents were able to reduce pest populations by up to 90%, making them a key component of Hawaii's pest management strategy. The introduction of the *Anagyrus* parasite, *Pullus* ladybeetles, and *Scelio* wasps represented significant steps forward in controlling the pink mealybug and Chinese grasshopper, which had both shown potential to cause substantial damage to sugar cane crops.

In Taiwan, there was extensive research on the use of fungi and parasitic insects to control pests like beetles and borers. The introduction of *Metarrhizium anisopliae* fungi and egg-parasites from Java demonstrated significant success in reducing pest populations, with some areas reporting a 50% reduction. These findings were particularly important in regions where chemical treatments were not feasible due to environmental or economic constraints.

In Louisiana, researchers experimented with the introduction of *Lixophaga diatraeae*, a parasitic fly that targeted the sugarcane borer. While initial results were mixed due to the region's colder climate, subsequent efforts to introduce the fly into warmer regions, such as the Caribbean, showed more promise. The use of biological control agents became a central focus of pest management strategies during this period, with researchers exploring the potential of various parasites, fungi, and predators to control pests in different regions.

In Barbados, a mass release program of *Trichogramma minutum* was implemented to control the sugar cane borer (*Diatraea saccharalis*). Despite criticisms about its non-specific parasitism and the high natural mortality of borer larvae, it was concluded that *Trichogramma* was effective. In regions like Guyana and Antigua, the results were less successful. Despite releasing large quantities of *Trichogramma*, no significant reduction in borer infestations was observed. This led to doubts about the practicality of large-scale releases without more robust statistical evidence of effectiveness. The consensus was that while *Trichogramma* showed promise, more research was needed to fully validate its effectiveness.

Quarantine practices

Quarantine was another critical area of research during this period, as the global nature of the sugarcane industry meant that pests could easily spread through the movement of planting materials across regions. The establishment of strict quarantine protocols was essential to prevent the introduction of new pests and diseases.

One of the most notable quarantine efforts was the establishment of a quarantine greenhouse located at Arlington Farm near Washington D.C., designed to safely import and grow cane varieties for experimentation before they were distributed to commercial fields. This greenhouse provided a controlled environment where cane cuttings could be inspected and treated to ensure they were free from pests and diseases.

The 1929 ISSCT congress held in Indonesia emphasized the importance of international collaboration in quarantine efforts. The congress recommended that all imported sugarcane plants undergo a minimum of one year of isolation before being introduced to commercial fields. This isolation period allowed for thorough inspection and treatment of the plants, reducing the risk of introducing new pests. These quarantine measures were instrumental in preventing the spread of pests such as the sugarcane moth borer and root grubs.

Varietal Resistance and Cultivation Techniques

The development of pest-resistant sugarcane varieties was also an important subject of research during this period. Researchers worked to identify sugarcane varieties that were naturally resistant to pests, particularly borers and whitegrubs. Some varieties were found to be more resistant to stalk borers than others, providing a natural defense against these pests. For example, studies conducted in Cuba and the Caribbean showed that certain sugarcane varieties were less susceptible to *Diatraea saccharalis* infestations, reducing the need for chemical or biological interventions.

PROMINENT CONTRIBUTORS

Several key figures played a pivotal role in advancing entomology and pest management during this period. Their research and contributions were instrumental in shaping the strategies used to control sugarcane pests and improve crop yields.

Cyril Pemberton's work should be emphasized for its innovative approach to pest management, focusing on sustainable biological methods. Pemberton played a crucial role in the introduction of natural enemies to control major sugarcane pests. His work, particularly in Hawaii, was instrumental in reducing pest populations, such as the *Anomala* beetle and the pink sugarcane mealybug, through the successful introduction of parasitic wasps and other biological agents. These efforts significantly minimized crop losses without relying on chemical pesticides. Pemberton was a strong advocate for sustainable, biological control, emphasizing the need for long-term ecological balance rather than short-term chemical fixes. His focus on importing tropical parasites to combat pests in tropical climates was a forward-thinking approach that laid the groundwork for future biological control programs in agriculture. He worked closely with researchers across various countries to exchange knowledge and implement biological control strategies in regions like the West Indies and South America. Pemberton’s work underscored the importance of understanding the ecological context when introducing biological control agents. He highlighted how factors like climate, habitat, and the interaction between native and introduced species could affect the success of pest control efforts, making his contributions particularly valuable in refining and adapting biological control strategies to local conditions.

Another key figure was Warren Hinds who conducted extensive research on sugarcane pests, particularly the sugarcane borer (*Diatraea saccharalis*). His studies focused on understanding the lifecycle, population dynamics, and control methods for these pests, which are critical for sugar cane agriculture. His work offered practical, data-driven insights into pest behaviour, which helped develop more effective control strategies. Hinds was a strong proponent of using biological control methods, particularly the use of *Trichogramma* as a natural enemy of the sugarcane borer. One of Hinds’ significant contributions was developing and refining methods to monitor pest populations. He introduced more accurate sampling techniques for counting sugarcane borers, which allowed for better predictions of pest outbreaks. His approach to using measurable, field-based data helped improve the timing and effectiveness of pest control interventions. Like Pemberton, Hinds was involved in international collaboration, sharing his research and findings with sugar cane technologists around the world. His involvement in global discussions contributed to the dissemination of knowledge on pest control strategies, making his work influential beyond local applications.

Harold Box was born in England and worked for the Imperial Institute of Entomology in the Caribbean. He is best known for his work on *Diatraea* stemborers, particularly on the taxonomy of the genus and on biological control. He also compiled a detailed list of insects and mites that attack sugarcane across the globe.

IMPACT OF THE RESEARCH

The entomological advances made between 1924 and 1938 had far-reaching impacts on the global sugarcane industry. These innovations not only improved the sustainability of sugarcane production but also had significant economic and environmental benefits.

The economic impact of the pest control advancements discussed at the ISSCT congresses was substantial. In regions where pest infestations had previously caused significant losses, the introduction of biological control agents and improved cultivation practices led to increased crop yields. For example, in Cuba, the introduction of parasitic wasps and other biological control agents significantly reduced the impact of the sugarcane moth borer, resulting in a 10% increase in crop yield.

Similar economic benefits were seen in Hawaii, where the reduction of leafhopper and borer populations through biological control allowed sugarcane growers to increase their production and meet the growing demand for sugar. By reducing the reliance on chemical pesticides, farmers were also able to lower their production costs, making sugarcane cultivation more profitable.

One of the most significant environmental impacts of the entomological advances was the reduced reliance on chemical pesticides. The successful introduction of biological control agents allowed farmers to manage pest populations without the need for harmful chemicals, promoting a more sustainable approach to agriculture. The use of natural predators and parasites helped to restore ecological balance, reducing the environmental damage caused by chemical treatments.

The development of pest-resistant sugarcane varieties also contributed to the sustainability of sugarcane production. These varieties were able to withstand pest infestations without the need for frequent interventions, allowing farmers to reduce their use of pesticides and other pest control methods. This not only benefited the environment but also made sugarcane farming more sustainable in the long term.

The ISSCT congresses facilitated global collaboration and knowledge exchange, allowing researchers and farmers from different regions to share their experiences and learn from one another. This exchange of knowledge was critical in advancing pest management practices and ensuring that innovations in entomology were applied across the world.

For example, the biological control methods developed in Hawaii were successfully adapted for use in other tropical regions, while quarantine practices established in the United States were adopted by other sugar-producing countries. This global collaboration helped to standardize pest management practices and ensure that sugarcane growers in different regions could benefit from the latest advancements in entomology.

The period between 1924 and 1938 was a time of remarkable progress in the field of entomology, particularly in the context of sugarcane pest management. The ISSCT congresses provided a platform for global collaboration, leading to significant advancements in biological control, quarantine practices, and varietal resistance. These innovations not only improved the sustainability of sugarcane production but also reduced the industry's reliance on chemical pesticides, promoting a more environmentally friendly approach to agriculture.

As the world continues to face new challenges in agricultural pest management, the lessons learned from this period of innovation remain as relevant as ever, reminding us of the importance of collaboration, research, and sustainability in ensuring the future of global food production.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Entomology 1950-1974

Peter G Allsopp

peter.allsopp@bigpond.com

INTRODUCTION

Following World War II, sugarcane cultivation moved into new areas and became more intensive. Discoveries in chemistry and new farming practices changed how pests were managed and resulted in changes in pest spectra. This was underpinned by new studies on the impact, biology, natural-enemy and host-plant interactions and taxonomy. Much of this was reported in the 148 entomology papers in the nine ISSCT congresses from 1950 to 1974.

Major changes saw:

- The growing importance of various species of stemborers across most production areas;
- The rise of new pests (from termites to pocket gophers) as areas under cultivation expanded;
- The use of synthetic pesticides that often provided cheap and effective control;
- Attempts to introduce new parasitoid species (not always successfully) and augment resident populations;
- A growing realisation that management should rely on a combination of tactics, not a single method (embryonic Integrated Pest Management).

RESEARCH ADVANCES

General lists of pests

Lists of major and minor pests from different areas of the world are useful for biosecurity monitoring. A large set of these have been published in the proceedings – South Africa, USA, Mexico and Hawaii in 1950, Venezuela, Colombia and an updated worldwide list in 1953, Venezuela and Cuba in 1959, Papua New Guinea and other Pacific areas in 1962, the Americas and Puerto Rico in 1965, and Okinawa and Papua New Guinea in 1968. These show a wide range of insect, mite and vertebrate pests, most of which are endemic species that have found sugarcane attractive.

Papers on the introduction of anomala whitegrub (*Anomala orientalis)* to Hawaii (Bianchi 1959), *Diatraea centrella* to Bahamas (Beg and Bennett 1971), and *Chilo sacchariphagus* to Mauritius (Ghani and Williams 1962), as well as the natural movement of eldana borer (*Eldana saccharina)* to East Africa (Girling 1971) and ultimately to South Africa highlight the importance of strict biosecurity measures.

Stemborers

The importance of stemborers across most sugarcane-producing areas (except Australia and Fiji) was shown by about half of the papers presented across all 1950-1974 congresses. Major groups include species of *Diatraea* in the Americas and of *Chilo* and *Sesamia* from Africa across to New Guinea and Taiwan, but there are several more localised groups.

Stemborers impact both cane and sugar yield and also cane quality, often producing material that causes problems in the mills. Some of the yield loss is mitigated by plant compensation (Khanna 1956) and carry-over effects into following ratoons can be seen (Mathes *et al.* 1965). Differences in the susceptibility of varieties were outlined in many of the congresses but the mechanisms behind this resistance were little understood. David and Kalra (1965) reported rind hardness, that impeded larval entry into the stalk, was important, and Coburn and Hensley (1971) noted leaf-sheath tightness as an important factor in survival of eggs. The breeding potential of this resistance were first developed in Mathes and Charpentier (1962) that outlined test methods for screening varieties. However, no specific breeding programs were reported.

Many of the papers outlined aspects of the biology of the different species, with two major groups – those where larvae complete their development in one stalk, and those where half-grown larvae leave their original stalk and move to nearby stalks. The impact on carry-over populations of preharvest burning was highlighted in Questel and Bregger (1959), and Kirst and Hensley (1974) outlined the deleterious effects of cold winter temperatures on these populations.

Many of the papers focused on biological control, either through the simple introduction of foreign parasites or through augmentative releases. The main species involved were the egg parasite *Trichogramma* and the larval parasite *Lixophaga* (the so-called Cuban fly). The usefulness of these species varied from place to place and from target species to target species. For example, parasites failed to establish in Mauritius (Ghani and Williams 1962), *Trichogramma* was important in Louisiana, but *Lixophaga* was of little use (Bennett and Pschorn-Walcher 1968), whilst biological control was seen as a success in many parts of the Caribbean (Box 1959; Simmonds 1959). One cause for this variation was the encapsulation of larval parasites in the tissue of the host larva (Beg and Bennett 1974).

Augmentative releases of *Trichogramma* in Barbados showed no evidence that the *Trichogramma* method exerted any degree of control of *Diatraea.* Chen and Hung (1959) Caresche (1962), Etienne (1968, 1971) and Sanford (1971) outlined rearing methods for producing large numbers of parasites, with Guerra (1974) giving a methodologies for mass rearing *Trichogramma* using wax moths, a species easier to culture than sugarcane stemborers, and for rearing *Lixophaga* on borer larvae reared on artificial diet.

Not surprisingly , insecticides were widely tested against borers. Initially, this saw the use of mineral cryolite (sodium hexafluoroaluminate) and the botanical insecticide ryania, but with only moderate success (Mathes *et al.* 1953; Dugas and Concienne 1956). Synthetic insecticides (endrin and thiodan) were shown to be more effective by Long *et al.* (1959) and organophosphates were preferred by Sanford *et al.* (1965) and Badrey and Hensley (1974). The new *Bacillus thuringiensis* formulations were tested by Badrey and Hensley (1974) but were inferior to standard synthetic insecticides.

Reductions in the number of insecticide applications against stemborers while maintaining effectiveness could be achieved through discontinuance of insecticidal control of the first generation and of late-season infestations; utilization of a reliable economic population threshold for determining the need for insecticide treatment; improvement in field survey methods for detecting potentially damaging infestations; use of highly-effective synthetic insecticides in control programs; and more emphasis on host-plant resistance to obviate the need for insecticide use (Hensley 1971).

The failure of any single tactic to control most species was evident throughout most of the stemborer papers. Pradhan (1968) stimulated significant discussion on the usefulness of integrated pest management. A concluding statement in the following discussion points to future approaches – “This paper is of value if only that it has suggested to us that we look beyond our present horizons in pest control”.

Whitegrubs/canegrubs

Endemic species of whitegrubs, larvae of scarabaeid beetles, are major pests in Australia and endemic and introduced species are second-tier pests in many other locations. Larvae live underground and, hence, sampling to determine numbers and subsequent treatment are difficult. Barton (1950), Mungomery (1950), Wilson (1950, 1959) and Wolcott (1950) demonstrated the effectiveness of benzene hexachloride (BHC) and other organochlorines against Australian species and Puerto Rican species. This provided the first useful insecticide against these pests and use continued until the mid-1980s.

Avasthy (1965) outlined the damage from and life history of whitegrubs in India. Cultural and mechanical controls were not effective. Again, BHC was effective in some trials but not consistently. Perhaps, this was due to the formulation used, as Wilson (1968) cautioned against having a very refined γ-formulation instead of a mixture of isomers. However, dieldrin proved more effective against a range of South African species (Carnegie 1974).

The resurgence of the introduced *Anomala* whitegrub in Hawaii after a period of apparent control by *Campsomeris* wasps was outlined by Bianchi (1959). Better weed control, which led to a dramatic decline in nectar-bearing plants as wasp food, was thought to be the cause. The wasp had been introduced from the Philippines and Bianchi (1962) gave details of its biology and ecology under laboratory and field conditions. Field observations indicated that the distribution and abundance of adult wasps coincided with the distribution and abundance of larvae of the host and were not necessarily dependent on the presence of abundant food sources.

Minor pests

Sugarcane weevil borer (*Rhabdoscelus obscurus*) introduced from New Guinea, has been a minor pest in Australia and a major pest in Fiji. Mungomery (1953) attributed a resurgence of the pest following a reduction in pre-harvest burning when labour became more available after World War II. Buring reduced the carry-over population. A similar resurgence occurred in the 1990s when pre-harvest burning was again abandoned. A similar problem was caused by the weevil *Cholus morio* in Mexico (Flores and Gonzalez 1959). It is difficult to obtain an effective control of this pest because the insect spends most of its life within the sugarcane stalk. The only way to control it is to destroy the adults when they are present on the foliage – organochlorines were used. No parasites were known.

Termites as pests of sugarcane were highlighted in the Dominican Republic (Luke 1953) and India (Siddiqi and Agarwal 1956; Gupta 1959). They invade seed pieces and the growing cane stalk. Infestation in the cane stalks is mostly at the base, where most of the sugar content is concentrated, entrance to the stalk being from the roots, as well as directly through the rind when covered by the leaf sheath. If the drying leaf sheath tends to pull away from the stalk, the termites will fill in at the top with earth. Damage to older ratoons can run to 50% or more. Again, organochlorines such as aldrin, chlordane and BHC, provided control, presumably due to their long activity in the soil.

Soldier flies (larvae of stratiomyids) feed on the roots of sugarcane in eastern Australia, reducing yield and killing stools. The biology of the pest was outlined by Osborn and Halbert (1971), and its predators, parasitoids and pathogens were detailed by Osborn (1974). Biological control is not effective although several organisms, especially the fungus *Metarhizium anisopliae*, appeared to be of potential value.

Wireworms (larvae of elaterids) can damage the buds of planting material as well as the newly developing shoots. Field tests with insecticides for the control of wireworms were reported from Louisiana (Mathes *et al.* 1953). Chlordane, toxaphene, parathion, and BHC greatly reduced the amount of damage, although the last may have had a depressing effect on germination. The soil fumigant D-D was also very effective and gave a better control than ethylene dibromide.

Cicada nymphs first came to prominence in the mid-1960s. Chen and Hung (1968) and Pan and Yang (1968) described the type of injury and the biology of local species from Taiwan. Control was achieved through flooding fields and crop rotation. Similar descriptions of life cycles and damage in Madagascar

and in Okinawa were outlined by Betbeder-Matibet (1971) and Itô and Nagamine (1974), respectively. Another paper from Australia (Wilson 1968) indicated that the increase in cicada populations was due to the use of organochlorines to control whitegrubs – these chemicals reduced populations of ants, the main predators of young cicada nymphs. Reduced ant predation was also implicated in the high populations in Okinawa. *Metarhizium anisopliae* was seen to be an important pathogen in Taiwan (Leu and Wang 1971), but no subsequent development as a bioinsecticide was reported.

Earthpearls (margarodids) also feed on the roots of sugarcane. Hitchcock (1965, 1968) outlined the biology of Australian species and the damage they caused. Chemical application was ineffective, presumably because the insects are encased in a hard 'shell' and move only at adult emergence and during the first nymphal stage.

Symphyla gouge small holes in the roots of sugarcane. Papers by Bynum *et al.* (1950) and Mathes *et al.* (1956, 1962) described the type of damage and showed that the organochlorines dieldrin and endrin provided some control.

Funnel ants (*Aphaenogaster*) are seen as a problem in Queensland where they live around the roots of sugarcane plants, exposing them and ultimately killing the stool. They flourish in open areas, so there is the question of whether they cause the open areas or whether they invade areas of poor growth and then worsen them. Control using heptachlor was outlined by Hitchcock (1968).

Sugarcane planthopper (*Perkinsiella saccharicida*) is a minor pest in its own right but is more important as a vector of Fiji leaf gall virus. The insect originated in New Guinea but was introduced to Australia, Fiji and the Americas (the last without the virus). Feeding habits and damage were described by Baber and Robinson (1950) and indicated that the insect was not a very efficient vector of the virus as it could not penetrate deeply into the plant tissue in some cane varieties and so would not inoculate the xylem vessels. The population dynamics were outlined by Osborn (1974), again suggesting that some varieties (NCo310) were good hosts, whilst others restricted population increase. The release of radiation-induced sterile insects was proposed by Husain *et al.* (1968), but the concept was not developed for field releases.

Froghoppers (cercopoids) are significant pests in central and southern America. The life cycle of a Mexican species and the damage it causes were detailed by Hernandez and Flores (1956) and Iturbe and Ruano (1962), along with the use of organochlorines for control. Further work in Trinidad (Merry *et al.* 1962; Fewkes and Lawrie 1965) tested organophosphates (phorate) and carbamates (carbaryl) alongside organochlorines. All three types of insecticides gave a quick initial kill and a residual control of nymphs. Rotation of these chemicals was recommended as the pest had developed resistance to BHC by 1954 when that insecticide was used alone. A later (1971) paper reported that resistance to carbaryl had developed in Trinidad and recommended that it be withdrawn and replaced with organophosphates. An increase in the number of yellow sugarcane aphid, *Sipha flava*, was also noticed where insecticides had been used against froghoppers.

A similar problem arose in southern Africa during the mid-1960s. Outbreaks of the indigenous planthopper *Numicia viridis* (Tropiduchidae) were successfully controlled with aerial applications of mercaptothion (also known as malathion), but there was some indication that insecticide application was followed by an increase in numbers of that insect and of other cane insects (Carnegie 1971). Other organophosphates and endosulfan in various formulations gave some control. Mention was also made of two hymenopteran egg parasites.

Pyrilla is another planthopper native to Asia. Attempts to use the fungus *Metarhizium anisopliae* as an augmented biocontrol were made in India (Patel 1956). These were not successful as the fungus works slowly and only naturally appears late in the infestation period. Similar leaf yellowing caused by *Phaeocantha* leafhoppers was reported from Malaysia (Tan and Johnson 1974). The insecticide endosulfan gave good control.

Grasshoppers, either as invasive locusts or more sedentary species, can cause severe damage to leaves. Some varieties were almost completely defoliated, whereas others in the same plot showed

little or no injury (Agarwal and Kandaswamy 1959). The most striking contrast was observed between varieties with dark and light-coloured leaves.

The thrips *Fulmekiola serrata* is another pest that has been transported across sugarcane-growing areas. Williams (1956) described its appearance, biology and the damage caused in Mauritius. Data presented show the occurrence of varietal susceptibility - a variety that was light green and that had soft leaves allowed the highest populations to develop.

Several species of mites have been recorded occurring as minor pests of sugarcane, with the life history, damage and control of the Indian *Schizotetranychus andropogoni* being outlined by Kalra and Chaudhary (1965). A chlorbenside/malathion liquid was the most effective treatment resulting in 84% decrease in webbing 8-12 days after spraying.

Yellow sugarcane aphid is an important pest throughout the Americas. Papers by Flores and Ramirez (1956) and Martorell and Guad (1965) detailed the damage caused and the biology and natural enemies of the pest. Aerial application of organophosphate insecticides provided some control in Puerto Rico. In Mexico, field releases of a coccinellid predator showed some promise (Flores and Ramirez 1956).

The biology and natural enemies of pink sugarcane mealybug (*Saccharicoccus sacchari*) and grey sugarcane mealybug (*Dysmicoccus boninsis*) in Hawaii were outlined by Beardsley (1959). Most notable was the tending of the mealybugs by the introduced Argentine ant and predation by an introduced Australian coccinellid. There were large differences in populations between two sugarcane varieties, with higher populations on the one with tight leaf sheaths that provided a protected habitat.

Studies on scale insects were presented in papers from Tanzania and Mauritius (Fewkes 1971; Williams 1971). *Aulacaspis tegalensis* was introduced into East Africa from Southeast Asia in the early 1900s with an outbreak during 1969-1970 causing loss of up to one-third the potential yield of sugar. The biology and natural enemies were outlined with hot-water treatment of planting material, low cutting at harvest and stubble shaving alleviating the problem. Use of resistant varieties was promoted, and insecticidal control was thought not to be feasible.

West Indian canefly, *Saccharosydne saccharivora* , is a pest of sugarcane in the Caribbean and surrounding land areas. Epidemics of it occur at irregular intervals in Jamaica and affect, principally, young plant or ratoon cane whose growth is consequently retarded. Fewkes *et al.* (1974) outlined the pest's biology, while natural enemies were reviewed by Frank (1971), with the unusual occurrence of a parasitic strepsipteran.

Rodents, as rats, were reported from Mexico , Guyana, Puerto Rico, Hawaii, Florida and Australia (Bates 1962; Callado and Ruana 1962; Martorell *et al.* 1965; Hilton *et al.* 1971; Redhead 1971; Samol 1971), and as pocket gophers from Mexico (Riess and Flores 1971). Life cycles and damage were outlined, as well as the use rodenticides. Warfarin and other anticoagulants were widely used but difficulties in applying baits and getting rats to ingest sufficient amounts to cause death, limited their use. Resistance to the chemical also developed in the Guyana species. More successful was the use of zinc phosphide baits, especially where the only residue was zinc salts. Pocket gophers presented a different problem as they form extensive burrows. Commercial fumigants that were in use included cyanogas, methyl bromide, and aluminium phosphide. The best and most economical control was obtained with pieces of cane soaked with sodium fluoroacetate and placed at entrances of pocket gopher galleries.

PROMINENT CONTRIBUTORS

Silverio Flores – Mexico – During 1950-74, he was the most significant entomologist in Latin America. His studies ranged widely over sugarcane pests in Mexico and resulted in improved management options.

George Wilson – Australia - During 1950-74, he was the most significant entomologist in the Australian industry. He played a major role in the commercialisation of BHC after World War II, which provided the industry with its first viable option for the management of sugarcane whitegrubs.

David Fewkes – United Kingdom – During 1950-74, he played an important role in understanding sugarcane pests and developing management strategies through the Caribbean and Africa. Although based in the UK, he travelled widely through those areas.

All three contributed to a number of ISSCT congresses.

IMPACT OF THE RESEARCH

What then to make of entomology's contributions in this quarter century? There was certainly a confirmation of the large number and variety of pest species either endemic species that crossed to sugarcane or introduced species and that affected all parts of the plant. With increased areas under sugarcane and more intensive production the need to manage populations became more acute. Stemborers were the major pests, affecting cane yield and sugar yield and quality. Synthetic insecticides proved much more effective than pre-war materials, but their cost, the development of resistance and the resurgence of target and non-target species meant that they were not a panacea. Introduction and augmentation of natural enemies, especially parasitoids, held great hope but they were not successful in many cases – unsuitable hosts, difficulties in and high costs of rearing, and timing of releases.

The stage was set for the development of sets of integrated strategies tailored to pest biologies and ecologies, farming systems, off-target impacts and commercial outputs. Entomologists were still needed!

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Entomology 1975-1999

Régis Goebel

regis.goebel@cirad.fr

INTRODUCTION

This paper gives an overview of the papers presented at the eight ISSCT congresses during the period 1977-1999. There was a significant reduction in entomology papers during the period, from 29 in 1977 to 7 in 1999. However, the number of papers stagnated during 1983-1999 with an average of nine papers per congress.

Generally, research topics (and pests) presented and discussed various topics and pests according to the location of congresses, showing the importance of holding congresses and workshops in different areas. Research on caterpillar stemborers was dominant, with papers mainly focused on biological control. *Diatraea saccharalis* was the most cited pest (33%) with biological control the most implemented strategy for this group of pests. Whitegrubs, leaf-feeders and sap-sucking insects (aphids, mealybugs, whiteflies, leaf and froghoppers) were also presented and discussed. There were very few papers on nematodes at this time and only one on rodents.

RESEARCH ADVANCES

Stemborers

Carnegie (1983) gave an overview of control measures against *Eldana saccharina*, a key pest in the South African sugar industry. Survey methods, population monitoring and light trapping, pheromones, effects of different crop management practices (crop age, variety, fertilizers, herbicides, nematicides, ripeners and pre-trashing), biocontrol agents (rearing, production) and chemical control were described and discussed in an IPM approach.

Biological control

Many papers focused on parasitoids to control *D. saccharalis* (14 papers) such as the tachinid flies *Lyxophaga diatraeae* and *Parathereisia claripalpis*, and the braconid wasp *Cotesia falvipes* (King *et al*. 1977; McPherson *et al*. 1977; Mendonça *et al*. 1977; Risco 1977; Saraceni and Mourao 1977; Roth and King 1977; Teran *et al*. 1977; Bothelo *et al*. 1986; Macedo *et al*. 1986; Samoedi *et al.* 1989; Suasa-ard and Charernsom 1992, 1996, 1999) and other moth borers with *Trichogramma* spp. (Trichogrammatidae) (El-Sherif *et al*. 1977; El-Sherif and Kira 1977; Gomez *et al*. 1996). These papers described key biological parameters that are needed to better understand the type of parasitism and improve the mass rearing and field releases of these parasitoids. They also indicate the then dominance of biological control over insecticides. The early use of biological control in the sugarcane industry shows the difficulty that farmer managers have in targeting stemborers using chemical applications because larvae spend most of the time hidden in the stalk. Other borer species discussed were *Tetramoera schistaceana*, *Elasmopalpus lignosellus* and *Sesamia* spp. (Lim and Pan 1977; Fallon 1977; Daniali *et al*. 1977).

Bothelo *et al*. (1983) discussed biocontrol of *D. saccharalis* by the larval parasitoid *Cotesia* (= *Apanteles*) *flavipes* in Brazil. Dispersion characteristics of this parasitoid set the minimum number of *C. flavipes* to be released per hectare/year at 5,000, and it showed a prominent role in the control of *D. saccharalis*. This explained by the much shorter life cycle of *C. flavipes* (16-25 days), compared to *Metagonistylum minense* and *Paratheresia claripalpis* (tachinid flies), the other biocontrol agents used. Another effective parasitoid on borer eggs, *Trichogramma galloi*, was not mentioned.

Harsanto and Sunaryo (1986) reported on the biology and development *A. pyralophagus*, a larval ectoparasite of *Eoreuma loftini* (origin Mexico), that was introduced from Pakistan to Sumatra in 1982 for trial against *Scirpophaga nivella*. All the three sugarcane borers found at Lampung, *S. nivella*, *Chilo auricilius* and *C. sacchariphagus*, are suitable hosts for *A. pyralophagus*. Although *C. sacchariphagus* was not tested in the laboratory, the parasitoid was recovered from it in the field. However, *S. nivella* seems better for its development, most probably because of its bigger size and sluggish habits. The females developed on it were also bigger and probably have higher fecundity. Pramono and Wirioatmodjo (1986) assessed the efficacy of biocontrol using *A. pyralophagus*.

Chen and Cheng (1996) discussed the laboratory propagation of *Meloboris sinicus* (=*Dioctes lineatus*) (Ichneumonidae), a larval parasitoid of stemborers in Taiwan including *Argyroploce schistaceana*, *Chilo infuscatellus*, *C. venosatus*, *Sesamia inferens*, *C. supressalis* and *Scirpophaga incertulas*. Of the female parasitoids introduced into male colonies, 95.2% mated, 90.0% of the mated females inserted their ovipositors into the hosts, and 57.1% of the attacked host larvae were parasitized. When host larvae were provided to a mated female for a 30-min period every day until her death about 2 week later, 69.5 progeny cocoons were obtained from the parasitized host. Of the cocoons recovered, 75.8% emerged to adults with a sex ratio of 1:3.7 in favour of males. The immature stage lasted about 18 days.

Cheng and Chen (1999) assessed the occurrence of *Telenomus beneficiens* var. *elongatus*, an egg parasitoid of sugarcane top *Scirpophaga nivella*. Of the 249 egg masses over 10 crop years, *T. beneficiens* var. *elongatus* emerged from 89 and 54 hatched top borer larvae, including 21 which had both hatched larvae and emerged parasitoids. Furthermore, 5 *Trichogramma japonicum* emerged from 4 egg masses, of which 3 had 50 *T. beneficiens* var. *elongatus* emerging simultaneously. Parasitization of the egg masses by *T. beneficiens* var. *elongatus* varied from 0 to 59.6%, with an average of 35.7%, and varied from 0 to 2.9%, with an average of 1.6% for *T. japonicum* in different crop years. Differences in the parasitism levels among years and seasons was observed. They concluded that *Telenomus* is the most important egg parasitoid for the control of the top borer in cane fields.

Crop losses and varietal resistance

Hensley *et al.* (1977) discussed the important role of varietal resistance in the management of *D. saccharalis* in Louisiana. About 50% of the Louisiana sugarcane crop was planted with NCo310, CP52-68 or L62-96, all of which are much less susceptible to *D. saccharalis* attack than the three other major varieties grown. Consequently, they required fewer insecticide (azinphosmethyl) applications to maintain economic control. Less use of insecticide reduced mortality of birds, fish and arthropod predators and after 12 years of use, there was no indication of resistance to this product developing in *D. saccharalis* populations.

Ayquipa *et al.* (1980) focused on the evaluation of recoverable sugar losses caused by the sugarcane borer *D. saccharalis* and associated pathogens in variety H32-8560 in Peru. He found a loss of 0.025 kg/t cane for each 1% of bored internodes, and there was a linear regression between recoverable sugar loss (in kg/t cane and in percent) as a function of the percentage of bored internodes.

Sosa (1996) artificially infested sugarcane stalks with third-instar borer larvae using microcentrifuge tubes and estimated resistance through damage ratings of 10 commercial varieties based on borer tunnel length. He concluded that varietal resistance could be rated based on tunnel length: resistant (24.9 cm), intermediate (5-7.9 cm), or susceptible (28 cm). This method could also be used to measure yield losses due to stemborers.

In Taiwan, varietal resistance to *Argyroploce* (=*Tetramoera) schistaceana* (Tortricidae) was investigated through oviposition preference, larval establishment and the degree of larval injury on young plants of different varieties in laboratory experiments (Pan and Yang 1977). Larvae were reared on sterilized young stems of 4-month-old plants and there were significant differences among varieties in the number of eggs laid by the females. The close correlation between the degree of larval injury on young plants and on maturing stalks suggested further screening of large number of new clones for resistance to *A. schistaceana* in early stages of development. A strong degree of resistance to the moth borer was found in variety F171.

Yield losses due to infestation of the white top borer, *Tryporyza nivella intacta* (Pyralidae), were estimated by Samoedi (1996) on three commercial varieties M 442-51, F154, Ps56 in West Java. Borer infestation reduced sugar yield by at least 8.5% on Ps56, 9.1% on F154 and 9.3% on M442-51.

Allam and Abou Dooh (1996) studied varietal resistance to the sugarcane moth borers (*Chilo* spp. on 26 commercial varieties. Bored internodes ranged from 0.0 % for high-fibre variety N51-539 to 17.33% for lower fibre variety CP55-30. Fifteen varieties were more resistant to borer infestation, but 10 were more susceptible than the standard variety NCo310. A significant inverse relationship between fibre % cane and infestation level was developed. High fibre content may be partially responsible for resistance of N51-539, PR1059, CP52-68, US59-16-1, B43-62 and CP48-103, whereas tolerance may have contributed to the high yield of the lower fibre Co979, PR1013 and Co845 They concluded that apparent resistance to borers may involve tolerance and that tolerance and resistance are inherited separately.

In South Africa, Rutherford (1996) discussed using near-infrared detection of biochemical differences at the point of entry of *E. saccharina* (surface structure and wax components of buds versus Internodes) that correlate significantly with resistance or susceptibility to eldana. Models capable of predicting eldana resistance of unknown clones from the plant selection program could be generated.

Effect of nitrogen fertilizers

Lopez *et al.* (1983) described the effect of nitrogen applications on damage levels of *D. saccharalis* in Cuba and showed that borer infestation and its attack intensity tended to increase with increased nitrogen rates up to 100 kg/ha. Infestation percentage and attack intensity were maximum when the N dose was split among different applications, including one at the beginning of the main growth period. There are very few studies on the effect of agricultural practices on sugarcane pests, with this one showing that the application of fertilizers should be made carefully to minimise pest infestation and additional crop losses.

Sex pheromones

Almeida *et al.* (1983) tested the performance of synthetic pheromones on *D. saccharalis* in Brazil. Attractancy of the pheromones was significantly lower (27% of trapped males) than to virgin females (72%). There was a tendency to higher catches of males with pheromone E (0.5 mg/capsule) compared to other formulations (A: 5 mg/capsule; B: 1 mg/capsule).

Armyworms

Carnegie (1977) in South Africa focused on three species of armyworms, *Mythimna phaea*, *Simplicia extinctalis*, *Athetis ignava* (Noctuidae). These caterpillars rest under the trash blanket by day and feed on the young ratoons at night during the first few weeks of cane growth. The activity period of the larval and adult populations (captured by light traps) of these species was described, giving useful information on how to manage them, particularly with insecticides. Ganeshan and Rajabalee (1995) discussed IPM approaches for armyworms in Mauritius.

Whitegrubs

Cochliotis melolonthoides is a scarab beetle which can heavily infest sugarcane in northern Tanzania (Waiyaki 1980). Previous work highlighted some effective hymenopteran parasites *Campsomeris mansueta*, *C. felina*, *C. lachesis* and *C. caelebs*, as well as some predatory elaterid larvae. Waiyaki observed a reduction in yield from 125 t/ha in plant cane and 60 t/ha in ratoons, to an average of 50 t/ha in both plant cane and ratoons. The only entomopathogenic fungus observed was *Cordyceps*.

Bull *et al.* (1986) gave an overview of chemical treatments (laboratory and field bioassays) used at this period to reduce whitegrub infestations in sugarcane in the Bundaberg region, Australia. Efficacies of different formulations of ethoprop, fensulfothion, carbofuran and chlorpyrifos insecticides on *Alepida picticollis*, *Lepidiota negatoria*, *Alepida crinita* and *Antitrogus consanguineus* were compared. Allsopp and Chandler (1989) and Allsopp *et al.* (1996) outlined advances in research and control of Australian whitegrubs over the preceding 20 years. Attempts were made to broaden the canegrub control options, not only in terms of the more efficient use of insecticides, but also by cultural and biological controls. Control measures such as varietal resistance which have no ongoing costs deserved reappraisal. Such options would enable growers to adopt a more flexible pest management approach that will involve them in making more decisions on the most cost-effective strategy for their situation.

Vercambre and Davis (1989) described the natural decline of the white grub *Hoplochelus marginalis*, a key pest in Réunion, following the introduction of the fungus *Beauveria hoplocheli*; both originated from Madagascar. The application of Betel, based on *Beauveria*, showed spectacular results and led to the decline of *H. marginalis* populations over almost 10 years.

Samoedi (1992) studied the seasonal abundance of the white grub *Leucophilis* sp. near *armata* (Scarabaeidae) in South Kalimantan, Indonesia. This pest probably has one-year lifecycle with adults emerging at dusk in mid-September coinciding with the beginning of monsoon and reaching a peak in October. Young larvae appeared between September and February. Third-instar larvae, the most harmful stage, were abundant between November and March but very scarce between August and October. The grub entered the pupal stage between June and August and October. Two species of natural enemies of the grub were found, *Campsomeris* sp. (Scoliidae) and an unidentified fungal pathogen.

Another paper (Sunaryo *et al.* 1992) on whitegrubs in Indonesia focused on *Pachnessa nicobarica* at Gunung Madu Plantation. Adult females could survive for 25 days and each laid an average of 28 eggs. The species has a 1-year lifecycle, with eggs laid in June, grubs from July to March, pupae in April and adults in May. However, this pest is less important than other species *Phyllophaga helleri*, *Lepidiota stigma, Leucophilis rorida* and *Apogonia destructor.*

Rajabalee *et al.* (1992) overviewed the biology and ecology of the whitegrubs in sugarcane in Mauritius. *Phyllophaga smithi* is by far the most common species, being found over almost all the island. It is kept under control through various factors, the actions of some of them remain to be determined. Scoliid wasps introduced in the past for its control are still quite common, while gregarines infect a high proportion of the larvae. *Heteronychus licas* and *Alissonotum piceum* are very localized and of no economic importance.

Sap-sucking insects

The biology and behaviour of sap-sucking insects such as the aphids *Ceratovacuna lanigera* and *Longiunguis sacchari* (Lim *et al*. 1977), the root froghopper *Mahanarva fimbriolata* (Mendes *et al*. 1977), and the scale insect, *Pulvinaria iceryi* (Etienne 1977) were reported. Population dynamics of *C. lanigera* and *L. sacchari* were studied in Malaysia using yellow-pan traps that gave good results on alate individuals compare to other trapping systems. In Brazil, Mendes *et al*. (1977) studied *M. fimbriolata* population fluctuations, periods of occurrence and the influence of climatic factors on trapping of adults. The pest occurred from November to April, with a peak in the first two weeks of March and populations

were influenced to an extent of 81% by climatic factors, with soil temperature being responsible for 55.9% of this total.

The white sugarcane aphid, *Ceratovacuna lanigera* (Aphididae), was a serious pest of sugarcane in Indonesia and useful data on seasonal fluctuations of its population were obtained (Pramono *et al.* 1999). Efficient predators among the populations of this aphid species included ladybeetles (Coccinelidae).

In Réunion, Etienne (1977) showed that the scale insect *Pulvinaria iceryi* is a potential pest with high risk of damage and significant yield losses. Outbreaks were rapidly stopped by the beneficial action of chalcidoid parasites and damage was contained. However, any disruption of the balance between the scale and its parasites, such as insecticide applications, would likely increase damage.

Inkerman *et al.* (1986) showed that pink sugarcane mealybug, *Saccharicoccus sacchari* (Pseudococcidae), was the only species of mealybug found in commercial crops of sugarcane in Australia. Though, on occasions, this mealybug causes some losses of sugar, population levels are apparently kept at below the economic threshold and its life cycle is greatly influenced by agricultural practices. The distribution of this mealybug is aided by the planting of insect-infested canes and by the current practice of retaining leaf sheaths on cane plants, as well as by ants. The mealybug has a guild of natural enemies such as the pathogenic fungus *Aspergillus parasiticus*, the encyrtid wasp *Anagyrus saccharicola* and larvae of the drosophilid fly *Cacoxenus perspicax*. There was no conclusive evidence of parasitism of *S. sacchari* by *A. parasiticus*, but the mealybug mortality observed may have been due to the high concentrations of aflatoxins (B and G) associated with infected mealybugs.

Pseudaspidoproctus flulleri (Cockerell) (Margarodidae) was recorded by Rajabalee and Banymadhub (1992) attacking sugarcane in Mauritius. It is probably the only margarodid known to feed on cane leaves and has been described from grass heads in Africa. Bermudagrass, *Cynodon dactylon*, is very susceptible to the pest. The life cycle of the insect and its natural enemies was documented, but the species did not represent a danger at the time of its discovery

Suasa-ard and Charernsom (1992) described the natural enemy complex of the sugarcane whitefly, *Aleurolobus barodensis*, in Thailand.

Rao *et al. (*1999) conducted laboratory experiments on a potent fungitoxicant and insect repellent (1,8-cineol) against the sugarcane pest *Pyrilla perpusilla*, a planthopper (Lophopidae). This species is not an economic pest of sugarcane, and they concluded that further large-scale trials are needed to find a commercial use for this biopesticide.

Patil and Dorge (1999) researched the leafhopper *Arboridia* sp. (Cicadellidae) which was recorded infesting sugarcane for the first time in India in 1982 and subsequently became a major pest. An integrated management programme (resistant varieties, chemicals, etc) was applied to this pest but due to the inefficacy of some insecticides, the studies focused on natural enemies present in the field, such as the lacewing *Chrysoperla carnea (*Chrysopidae) an effective predator of sap-sucking insects. They proposed testing augmentative release of this species to reduce *Arboridia* populations.

Weevil borers

Tamanikaiyaro *et al.* (1996) determined losses in cane quality due to damage caused by the cane weevil borer, *Rabdoscelus obscurus* (Curculionidae), in Fiji. Results indicated that 2% stalk damage in terms of length and weight caused an average 1.5% loss in pure obtainable cane sugar and a 3.3% loss in purity. Four regression models were derived to predict percent loss in sugar content and sugar purity given the stalk length and weight damaged. They concluded that % stalk length could be used for any future borer damage assessment instead of % stalk weight. Of the 4,064,325 t cane crushed in 1994, 81,000 t were badly damaged by the weevil borer causing a loss of about 2600 t sugar.

Nematodes

These pests were outlined in a key paper by Carbonnel (1977) on the main genera damaging sugarcane in Peru. *Meloidogyne*, *Helicotylenchus*, *Xiphinema*, *Rotylenchus*, *Hemicydiophora* and *Aphelenchoides* were among the 19 genera collected. Damage caused an 8% decrease in sugarcane production in Valle del Tambo of southern Peru, with a 3% loss in the total annual yield of the Peruvian sugarcane production. Root-knot nematodes, *Meloidogyne* spp., are the most aggressive and important of the phytonematodes associated with sugarcane in many countries. In the Peruvian sugarcane fields, it comprises 72% of the nematode population and it prefers the sandy and sandy-clay soils bordering the coast that are generally poor soils. They attack both plant cane and ratoons, and the widespread variety H32-8560 suffered very severely from attacks, especially when edaphic conditions were favourable for nematode development.

A second paper from India showed that fluctuations in the population of *Tylenchorhynchus* and *Pratylenchus* were more pronounced than other species (Singh and Misra 1977). The nematicides Nemagon, DD, Vapam and Dasanit were applied in the furrow along with nitrogen fertilizers. Dasanit appeared to be the most efficient on nematodes populations, followed by DD, Vapam and Nemagon in descending order of effectiveness.

Rodents

In the eight congresses, there was only one paper on rodents (Wang 1992). He reviewed the wild species and their abundance in sugarcane fields in Taiwan; *Mus formosanus, Bandicota nemorivaga*, *Apodenius agrarius* and *Rattus losea* comprised 50,4%, 20.0%; 13.2%, 10.7% and 1.4% of the trapped population, respectively, while the domestic species, *Rattus rattus*, was only 0.3%. Pregnant females contained averages of 4.4, 4.7, 5.4 and 4.1 progeny, respectively.

PROMINENT CONTRIBUTORS

P.S.M. Bothelo contributed significantly through his research and advances on IPM of *Diatraea saccharalis* in Brazil, particularly biological control and varietal resistance. He produced with his colleagues 10 publications and paved the way to control this key pest in Brazil without using insecticides at a time where pest control in agriculture was dominated by pesticide treatments.

D. Samoedi also contributed significantly to entomological research in Indonesia, particularly on *Tryporyza* (=*Scirpophaga*) *nivella intacta* and its biological control.

A.J.M. Carnegie is a key name attached to the work on *Eldana saccharina* and other important Lepidoptera species in South-Africa.

IMPACT OF THE RESEARCH

Over these 22 years, research on sugarcane pests and control strategies were dominated by biocontrol and related studies on parasitoids of moth borers, with *Diatraea saccharalis* as the most studied pest. The biology and management of whitegrubs and sap-sucking insects such as aphids, scale insects and froghoppers were also presented and discussed. In particular, progress made in biocontrol during these two decades paved the way for more research and development in the production technology of parasitoids and releases in the field. Brazil was a leader in biological control of *D. saccharalis*, followed by other countries confronted with borer problems (particularly *Chilo* spp.) such as Thailand, India and Indonesia. Due to difficulties in management via biocontrol, whitegrub control was dominated by chemical treatments particularly in Australia where the soil pests are the main problem.



The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Entomology 2000-2023

Julien Beuzelin

jbeuzelin@ufl.edu

INTRODUCTION

At the eight ISSCT congresses held since the beginning of the millennium, 135 entomology submissions from 25 countries were presented. These submissions included eight to 15 oral presentations per congress, including one workshop summary per congress in 2005, 2007, 2010, and 2013, for a total of 80 oral presentations. These submissions also included 4-15 poster presentations per congress for a total of 55 poster presentations.

More than 50% of the oral and poster presentations for the entomology section focused on moth borers. Whitegrubs were the second most studied group of pests, with >10% of oral and poster presentations. Additional arthropod pests addressed in at least five presentations across the eight congresses were longhorn borers, aphids, leafhoppers (Hemiptera: Cicadellidae) and planthoppers, and armyworms.

Oral and poster presentations addressed the yield and economic losses caused by arthropod pests associated with sugarcane, as well as the fundamental biology of these pests. The tactics of integrated pest management (IPM) such as biological control with predators and parasitoids, the use of entomopathogens, cultural practices, host plant resistance, and insecticides were addressed. Research on management approaches using pheromones, behavioral manipulation, and the sterile insect technique (SIT) was also presented. In addition, modeling efforts to improve pest management decision making, biosecurity efforts to prevent or mitigate the effects of invasive pests, and educational efforts to disseminate research results and increase impact were presented.

RESEARCH ADVANCES

Yield losses caused by arthropod pests

A total of 17 presentations, or 12.6% of oral and poster presentations at congresses between 2001 and 2023, focused on studies determining yield losses caused by arthropods feeding on sugarcane. These studies provided data that could be used to determine the pest status of insects to determine if management is justified, develop or update thresholds to determine when to trigger management, and evaluate production practices decreasing the severity of pest infestations.

Losses caused by moth borers

Fourteen presentations focused on moth borers, emphasizing the importance of considering both cane yield and sugar yield when assessing losses caused by borers.

Eight presentations reported results of studies sampling commercial fields, recording borer injury, and determining yield parameters from stalk samples. In Argentina, the relationship between the percentage of bored stalks and yield loss in three commercial varieties revealed that *Diatraea saccharalis* caused

sugar losses >50,000 t in Tucumán Province. Losses increased as the season progressed, and losses increased when harvested stalks were stored for 4 days. A comparable study showed that *Elasmopalpus lignosellus* can cause as much as 55% sugar yield loss in Argentina, and that irrigation and green cane harvesting minimized pest pressure. In Panama, *D. tabernella* caused sugar yield losses up to 2.6 t/ha.

In Ivory Coast, the comparison of fields with lowest and highest injury levels showed that as much as 0.44 t/ha of sugar was lost because of *Eldana saccharina*. The study highlighted differences among commercial varieties and showed that irrigating and limiting N fertilization mitigated infestations. In Zimbabwe, the relationship between the percentage of stalks bored by *E. saccharina* and yield loss showed that the country's industry lost 5,000 t of sugar annually between 2000 and 2005.

Four presentations reported results of studies using field plots with suppressed infestations using insecticides or parasitoid rereleases, natural infestations, and sometimes enhanced infestations using pest releases. In Réunion and South Africa, the relationship between borer injury and sugar yield losses showed that *Chilo sacchariphagus* caused 4.8 t/ha in losses and *E. saccharina* caused 3.4 t/ha in losses, respectively.

In Indonesia, each sugarcane stalk infested with *Scirpophaga excerptalis* lost nearly three times more biomass than a stalk infested with *C. sacchariphagus* or *C. auricilius*. Comparisons between treated and untreated plots showed that this borer complex caused losses attaining 45.4 t/ha (4.2 t/ha sugar) and 12.5 t/ha (1.3 t/ha sugar) in plant cane and ratoon cane, respectively.

In Brazil, studies used natural or artificial *D. saccharalis* infestations combined with natural *Mahanarva fimbriolata* infestations in caged plots to prevent insect movement, showing sugar losses >4 t/ha between infested and non-infested plots. In one study, sugar yield was 15.6% (borer only) and 30.2% (spittlebug only) lower in infested plots than in non-infested plots. Combined losses were additive, not synergistic.

Additional moth borer studies addressed injury levels caused by *Acigona steniellus* in India and *S. excerptalis* in China.

Losses caused by armyworms and soil insects

Two presentations focused on losses caused by armyworms. In Mauritius, plots with different levels of natural and simulated *Mythimna* spp. defoliation exhibited a reduction in plant height attaining 16% when injury occurred relatively late in the growing season, which emphasized the role of harvest date and timing of infestation. In Argentina, field plots infested with *Pseudaletia unipuncta* sustained 23% sugar yield loss relative to plots treated with insecticides. Greater *P. unipuncta* infestations were associated with early green-cane harvesting.

Only two presentations focused on insects causing belowground injury. In Guatemala, the comparison of treated and untreated plots showed that whitegrubs (primarily *Phyllophaga dasypoda*) caused cane yield losses approaching 12 t/ha whereas wireworms (*Dipropus* sp.) were not associated with yield loss. In China, *Exolontha castanea* was a serious pest in Guangxi, causing as much as 32% cane yield loss and 23% sugar yield loss.

Biology of arthropod pests

A total of 21 presentations focused on the biology of sugarcane insects, representing 15.5% of the oral and poster presentations at the past eight congresses.

Five presentations reported results of field surveys conducted to document the general biology and identify natural enemies of moth borers in Iran (*Sesamia nonagrioides*) and China (*C. sacchariphagus*, *C. infuscatellus*), aphids in Thailand (*Ceratovacuna lanigera*), and a new hopper pest in Mauritius

(*Numicia dorsalis*). In addition, three presentations studied the population dynamics of longhorn borers (*Dorysthenes buqueti*) in Thailand, whiteflies (*Aleurolobus barodensis*) in India, and a scale (*Aulacaspis tegalensis*) in Indonesia, which allows the identification of stages that should be targeted for optimal timing of management.

Three presentations focused on the role of non-crop hosts in the biology and population build-up of three moth borers, showing that weedy grasses and sedges are infested by *E. saccharina* in South Africa, *D. tabernella* in Panama, and *Eoreuma loftini* in the USA. Results provided a foundation for the development of potential management tactics including the manipulation of non-crop hosts.

Four presentations mapped and determined spatial patterns of sugarcane insects, which provided information on the spatial scale of moth borer management with natural enemies in Cuba and Iran, as well as information on how to sample *M. fimbriolata* in Brazil. For *Dermolepida albohirtum* in Australia, high-resolution remote sensing was used to characterize the landscape surrounding sugarcane fields. The density of trees surrounding sugarcane fields, the distance to forests, and the distance to palm plantations were positively correlated with *D. albohirtum* damage, allowing for the development of risk maps.

One presentation focused on the role of insects as vectors of viruses, with field surveys and acquisition-transmission laboratory experiments with *Melanaphis sacchari*, which led to recommendations on the importance of producing virus-free seed in Mauritius. Another presentation focused on the identification of six armyworm species (*Mythimna* spp.) infesting fields in Mauritius, which emphasized the importance of insect pest identification, especially if there are behavioral differences among pest species.

In two presentations, soil characteristics were shown to affect whitegrubs. In Guangxi, China, all soils included in a study were suitable for *Alissonotum impressicolle*; however, the highest whitegrub infestations were observed in fields with slightly acidic soils and relatively abundant organic matter. In Australia, naturally occurring soil pathogens can have a major effect on *D. albohirtum* severity. A presentation focused on the distribution of *D. albohirtum* in the soil, showing that early instars were primarily in the upper 10-20 cm of soil whereas third instars were deeper and concentrated near the center of the sugarcane rows. This study provided critical information to determine the optimal placement of insecticides in the soil, thus improving chemical control.

In one presentation, an obligate and mutualistic symbiont of *Matsumuratettix hiroglyphicus*, a vector of sugarcane white leaf disease in Thailand, was identified. This result suggested that pest microbiome manipulation might be used for *M. hiroglyphicus* management.

Biological control with predators and parasitoids

A total of 20 presentations specifically focused on the status of biological control programs or on the study of natural enemies and their use in biological control programs. Six presentations mentioned above focused on the biology and ecology of pests including the identification of natural enemies and quantification of parasitism rates. The integration of biological control and other management tactics was also discussed in four presentations mentioned in subsequent sections. Thus, 22.2% of oral and poster presentations at the past eight congresses addressed biological control.

Biological control of moth borers

Two presentations focused on *D. saccharalis*, which is the main pest of sugarcane in the Caribbean. In Jamaica, biological control efforts relying on releases *of Cotesia flavipes* were successful between 1980 and 1999. However, augmentative releases were needed to maintain satisfactory *D. saccharalis* control. In Cuba, a national biological control program was created in 1980. As of 2016, four parasitoids (*Lixophaga diatraeae*, *Tetrastichus howardi*, *Trichogramma* sp., *Eucelatoria* sp.) and one

entomopathogen had been mass-produced and released, maintaining *D. saccharalis* populations below economic levels.

Two presentations focused on *C. infuscatellus*, *C. sacchariphagu*s, and *Chilo tumidicostalis* in Thailand. Augmentative releases of *C. flavipes* increased borer parasitism rate although effects on borer infestations were not always observed. However, an economic analysis revealed that monthly releases of 1,250 adults/ha increased farmer net income.

Three presentations addressed biological control in India. One presentation reported that 10 releases of *Trichogramma chilonis* maintained *C. auricilius* below damaging levels. In another presentation, the standardized mass-rearing and release of *T. chilonis* and *T. howardi* for *C. sacchariphagus* control cost US$16/ha and resulted in increased cane yield by 6.5 t/ha (US$250/ha). Another presentation highlighted that spiders are generalist predators participating in the biological control of *C. infuscatellus*, *Pyrilla perpusilla*, and *Arboridia* sp.

Two presentations reported on the biological control of *S. nonagrioides* and *S. cretica* in Iran. Augmentative releases of the native egg parasitoid *Platytelenomus hylas* were associated with reductions >50% in the percentage of bored internodes five years after the releases were initiated. Releases of *Telenomus busseolae* resulted in 65-80% parasitism of *Sesamia* spp. eggs, with some variations among commercial sugarcane varieties.

One presentation focused on *C. sacchariphagu*s in Réunion, where *T. chilonis* was selected for augmentative releases. Field releases of the egg parasitoid were associated with 15-25% yield increases and economic gains of €1,400-1,600/ha. However, intra-guild predation by the ant *Pheidole megacephala* was reported as a problem. Parasitoid production relying on partnerships with private companies, and the use of cold storage and timed releases for improved biological control were also discussed.

Three presentations addressed parasitoid production. A laboratory study in Indonesia showed that parasitoid egg cards can be stored at 10°C for as many as 3 days without impact on the emergence and sex ratio of *T. chilonis*. Another laboratory study in China showed that *T. chilonis* strain and the number of generations reared in an insectary affected fitness of the parasitoid. In Colombia, *Trichogramma exiguum* was produced by private insectaries for the management of *Diatraea* spp., causing the greatest levels of egg parasitism. However*, Trichogramma atopovirilia*, *Trichogramma pretiosum*, *Trichogramma lasallei*, and three undetermined species were also found parasitizing *Diatraea* spp. eggs. Thus, the control of species composition for mass produced *Trichogramma* spp. was important.

Biological control of aphids, beetles, whiteflies, and mealybugs

One presentation reported that as much as 90,000 ha of sugarcane production in India were successfully managed for *C. lanigera* infestations using augmentative releases of predators such as *Dipha aphidivora* and *Micromus igorotus*. These releases decreased reliance on insecticides and increased farmer confidence in biological control. Additional presentations focused on potential biological control agents for longhorn borers (*D. buqueti*) in Thailand, whiteflies (*Neomaskellia andropogonis*) in Iran, and mealybugs (*Saccharicoccus sacchari*) in China.

Use of entomopathogens

Nine presentations (6.7% of entomology presentations) addressed the identification and use of entomopathogens, primarily *Beauveria* spp. and *Metarhizium* spp.

The development of a commercial formulation of *Metarhizium anisopliae* for *D. albohirtum* management in Australia was summarized in one presentation. Control was ≤60%, emphasizing the need for complementary tactics. In addition, efficacy against other whitegrub species was limited, emphasizing

the need for complementary entomopathogens like *M. anisopliae* var. *lepidiotum*, which was effective against *Lepidiota negatoria*. Another presentation summarized the impact of *Beauveria brongniartii* for *Hoplochelus marginalis* management in Réunion. The nematode *Heterorhabditis indica* killed all stages of the white grub *Holotrichia serrata* in India, reducing pupa numbers and adult emergence in treated fields.

Three presentations focused on laboratory and field evaluations of *Metarhizium flavoviride* in Indonesia and *M. anisopliae* in Thailand for the management of *Dorysthenes* sp. Local isolates of the entomopathogens caused 30-35% mortality, which was associated with a measurable yield increase.

Two presentations reported that traps baited with corrugated cardboard and treated with *Beauveria bassiana* or baited with eucalyptus wood pieces and treated with *M. anisopliae* had potential for control of termites infesting sugarcane fields in Mexico (*Heterotermes tenuis*) and Thailand (species not reported), respectively. In another presentation, isolates of the two pathogens were tested in bioassays, with *B. bassiana* NBCRCBB001 having the potential to be used for control of *Yamatotettix flavovittatus*, a leafhopper vector of sugarcane white leaf disease in Thailand.

Host-plant resistance

Eleven presentations (8.1% of entomology presentations) specifically focused on host-plant resistance to moth borers. All presentations except one addressed non-transgenic resistance.

Five presentations focused on *D. saccharalis* in the USA and Argentina whereas another presentation focused on *Diatraea* spp. in Venezuela. Results of laboratory, greenhouse, and field research were reported, showing that *S. spontaneum* and *Erianthus* are possible sources of borer resistance. Additional presentations included field and laboratory studies screening germplasm, including commercial varieties, to understand mechanisms of resistance and identify genotypes for use in breeding efforts. Results of comparable studies on *Sesamia* spp. in Iran (2 presentations) and *C. infuscatellus* in India (1 presentation) were also reported. One presentation summarized studies investigating the biochemical basis of resistance to *E. loftini*, but also *M. sacchari*, in commercial varieties in the USA, suggesting that concentrations of free amino acids played a role.

Two presentations focused on sugarcane resistance to *E. saccharina* in South Africa. One presentation described a potential strategy to inhibit necrophytic *Fusarium* colonization of sugarcane stalks associated with *E. saccharina* injury by using “synthetic bacterial consortia” promoting the growth of endophytic *Brevibacillus*. Another presentation summarized efforts supporting the regulatory approval of transgenic sugarcane, which included the study of potential gene flow, the assessment of refuge’s role in mitigating insect resistance development, and an educational program targeting sugarcane scientists and farmers.

Insecticides

Eleven presentations specifically focused on the effects of conventional synthetic insecticides on insect population and injury levels whereas another presentation focused on the effects of an insecticide on sugarcane plants in the absence of insects (8.9% of entomology presentations).

Four presentations reported results of insecticide studies for moth borer management. In the USA, tebufenozide effectively controlled *D. sacccharalis* with little to no effects on beneficial arthropods and without flaring *Sipha flava* populations. In Iran, fipronil reduced *S. cretica* injury and infestation levels; however, differences in efficacy were observed with different formulations. In China, an application of chlorantraniliprole or chlorantraniliprole+thiamethoxam controlled a complex of moth borers including *C. infuscatellus*. In South Africa, alpha-cypermethrin was effective against *E. saccharina*.

Three presentations summarized research on organophosphates and potential alternatives for soil insect control. In Australia, a controlled-release formulation of chlorpyrifos was effective again white

grubs, including *D. albohirtum*, and represented >90% of insecticide use for grub control by the end of the 1990s. Imidacloprid, which became commercially available in 2001, was an effective alternative to chlorpyrifos when applied into or beside cane stools using coulters. In the USA, thiamethoxam applied in open furrows at planting protected young sugarcane from *Melanotus communis* feeding, representing an alternative to phorate.

In other presentations, soil and foliar applications of imidacloprid controlled *Fulmekiola serrata* in South Africa. In Brazil, fipronil or endosulfan applied 40 cm deep during soil preparation controlled *Migdolus fryanus*. In another study, fipronil, imidacloprid, and thiamethoxam applied at planting did not decrease *Sphenophorus levis* infestations. In Fiji, cellulose bait stations with fipronil attracted *Coptotermes gestroi*, suggesting that these stations might be used for termite management. In Japan, a field study showed that fipronil treatments had a phytostimulatory effect, increasing sugarcane growth and yield in the absence of insect pests.

In addition to the 12 presentations focusing on conventional insecticides, one presentation described laboratory studies showing that cashew nutshell extraction waste had potential as a bioinsecticide against *Lepidiota stigma* in Indonesia, causing >95% mortality. Another presentation described laboratory results in Argentina showing that the application of the biostimulant PSP1, which contains a defense-inducing protein of fungal origin, decreased the number of *D. saccharalis* neonates feeding on young sugarcane plants.

Cultural practices

Five presentations specifically focused on cultural practices potentially influencing sugarcane arthropod population and injury levels. Nitrogen fertilization increased *D. saccharalis* infestation levels in Argentina whereas irrigation did not have an effect. In addition, leaving trash on the soil surface or burning it after harvest did not affect *D. saccharalis* injury levels and egg parasitism rates.

The application of silicon sources also affected sugarcane pests. In Indonesia, bagasse furnace ash applications reduced *Scirpophaga nivella intacta* infestations, increasing cane yield by as much as 40%. In Iran, the application of three different sources of silicon reduced numbers of *Oligonychus sacchari*, but not below economically damaging levels, suggesting that silicon might complement miticide use. A study in Iran suggested that sugarcane plants passively and actively absorb and accumulate silicon, increasing resistance to moth borers.

Pheromones, behavioral manipulation, and SIT

Five presentations focused on the use of pheromones for sugarcane insect management.

In Japan, laboratory and field studies suggested that mating disruption using synthetic sex pheromone dispensers decreased mating success of *Sesamia inferens* females, subsequently decreasing infestation levels. In China, a field study showed that a sprayable slow-release formulation of the *Chilo venosatus* sex pheromone caused mating disruption for up to 30 days.

In Fiji, field studies showed that traps baited with pheromone lures allowed monitoring of *Rhabdoscelus obscurus* populations. Results also suggested a potential increase in yield associated with mass trapping. In India, a trap combining a light and a pheromone lure was effective for the monitoring and mass trapping of *Holotrichia consanguinea* adults. In Florida, USA, pheromone trapping of *Spodoptera frugiperda* determined that >85% of moths collected were of the “rice strain”, which is generally more susceptible to insecticides than the “corn strain.”

Two presentations described research on *E. saccharina* management in South Africa. In a laboratory study, compounds attracting or repelling the insect were identified and isolated. These compounds extracted from the plant *Melinis minutiflora* might be included in an areawide IPM approach using a push-pull approach. In an additional series of studies, the feasibility of SIT was investigated. An artificial

diet for mass rearing was developed, the biology of irradiated moths was studied, and the effect of transport on irradiated moths was determined. Results suggested that SIT has the potential to control *E. saccharina*.

Integrated Pest Management (IPM)

Twenty presentations focused on aspects of IPM, including the integration of multiple management tactics, the monitoring of pest population levels, and the use of models to assist with decision making.

Management of moth borers

Eight presentations summarized the pest status of moth borers, as well as management approaches integrating multiple tactics.

In Louisiana, USA, the use of chlorantraniliprole, adoption of high-yielding resistant varieties, and mechanized harvest decreased *D. saccharalis* infestations. For *E. loftini*, the same practices contributed to management. Minimizing crop stress with irrigation, also decreased *E. loftini* infestations. In Brazil, at-planting applications of imidacloprid or clothianidin decreased predatory ant populations and were associated with increased *D. saccharalis* infestations, highlighting the role of conservation biological control.

In India, the combination of insecticides applied to the whorl and *Trichogramma* releases provided the highest level of control of *C. infuscatellus*. For *C. sacchariphagus*, the combination of relatively less susceptible varieties and entomopathogens had potential for control. In Indonesia, crop rotation and a combination of silicon applications and *Trichogramma* spp. releases suppressed *C. sacchariphagus* populations below economic injury levels. In Papua New Guinea, the application of carbofuran for *Sesamia grisescens* management disrupted natural enemies whereas lambda-cyhalothrin and parasitoid (*C. flavipes*, *Pediobius furvus*) releases provided effective IPM.

For *E. saccharina* in South Africa, a comprehensive review of proven and potential tactics for bio-intensive IPM was provided. Tactics included soil-applied silicon, habitat management with a push-pull strategy, the use of elicitors to induce resistance, the breeding of varieties producing “SOS volatiles” attracting parasitoids, the use of *Wolbachia* to decrease reproductive success, and inhibition of endophytic *Fusarium*.

Management of armyworms, longhorn borers, whiteflies, planthoppers, leafhoppers, wireworms, and mites

Eight presentations focused on insects and mites other than moth borers. In Mauritius, field experiments identified effective insecticides for *Mythimna* spp. management; however, beneficial caterpillars feeding on sugarcane leaves forming the trash blanket were also negatively affected. Trash removal was an ineffective control tactic. In Indonesia, the combination of cultivation and application of entomopathogenic fungi substantially decreased *Dorysthenes* sp. infestations and increased cane yield by 25%. In Iran, the combination of parasitoid releases, cultural practices, and insecticide applications led to the successful management of *N. andropogonis*.

In Thailand, *Y. flavovittatus* and *M. hiroglyphicus* transmitted the sugarcane white leaf phytoplasma. Population dynamics of these vectors suggested that the production of non-infected seed and planting date avoiding peak populations should be the main control tactics. In Ecuador, mechanized collection of *Perkinsiella saccharicida* decreased delphacid numbers by 80% in young cane. In addition, varieties with reduced infestations, conservation of natural enemies, and insecticide use assisted in decreasing delphacid numbers.

For *M. communis* infesting sugarcane in Florida, the estimation of an economic threshold was described. Because sampling methods were too labor intensive, cultural practices minimizing wireworm infestations were recommended to complement insecticide use.

In Iran, the mite *O. sacchari* was controlled with the application of acaricides, conservation of natural enemies, planting of least susceptible varieties, control of alternative hosts, application of water sprays creating a wet environment, and application of vinasse on roads to reduce dust formation. In mainland China, *Aceria sacchari* was reported for the first time, and the implementation of plant material inspection and quarantine, as well as hot water treatment of seed cane, was recommended to prevent the spread of the mite.

Additional IPM considerations

One presentation reported on an areawide program monitoring larval infestations of *E. saccharina* in South Africa to identify problematic areas and assist with management decisions. In three presentations developed by French scientists, DECIPESTS, an interactive model enabling the identification of the cause of pest infestations and proposing management solutions was described. Modelling efforts addressed *E. saccharina* in Senegal and *S. flava* in Tanzania.

Biosecurity and educational efforts

Two presentations summarized proactive work conducted to address the threat of exotic pests of sugarcane potentially being introduced into Australia. This biosecurity work, which focused on moth borers, involved the development of identification tools, including sequencing of mitochondrial DNA (COII and 16S) and the implementation of pheromone trap monitoring. Response plans were developed, including plans for the importation of natural enemies and for insecticide emergency exemptions.

Three presentations specifically addressed educational efforts aiming to disseminate research results for increased impact and to improve insect identification for better management. In Australia, comprehensive “GrubPlan” workshops were conducted in the early 2000s to train growers and crop advisers on how to manage grubs, resulting in substantially lower damage. In Thailand, 602 farmers participated in a training program promoting the use of parasitoids, predators, and entomopathogens for management of moth borers and longhorn borers. In addition to providing courses, the program included demonstration plots and provided beneficial organisms to farmers. After completing the program, 94% of farmers asked for more beneficials to continue biological control efforts. In another presentation, the development of a mobile application using image processing techniques to identify sugarcane pests and diseases in Thailand was discussed.

PROMINENT CONTRIBUTORS

Many scientists have contributed to entomology applied to sugarcane production as shown by their contributions to presentations of the entomology section at ISSCT congresses since 2001.

François-Régis Goebel, France. At ISSCT congresses, he was the presenting author for five presentations (including 1 workshop report) and was a co-author for 15 presentations (including 1 workshop report). He contributed to studies focusing on the biological control and IPM of moth borers such as *C. sacchariphagus* in Réunion, *E. saccharina* in Ivory Coast, *C. sacchariphagus*, *C. auricilius*, and *S. excerptalis* in Indonesia, *Sesamia* spp. in Iran, *D. tabernella* in Panama, and *D. saccharalis* in Argentina.

Wiwat Suasa-ard, Thailand. At ISSCT congresses, he was the presenting author for four presentations and was a co-author for two presentations (including 1 workshop report). He contributed to research and education efforts in Thailand for the control of *Chilo* spp. using parasitoids and predators, and of *D.*

buqueti using *M. anisopliae.* He also contributed to the study of the biology and natural enemies of *D. buqueti* and *C. lanigera*.

R. Stuart Rutherford, South Africa. At ISSCT congresses, he was the presenting author for two presentations and was a co-author for one presentation. Dr. Rutherford contributed to innovative research for bio-intensive IPM of *E. saccharina* in South Africa.

IMPACT OF THE RESEARCH

The 135 entomology presentations included in the past eight ISSCT congresses exhibited the breadth of research and education efforts conducted internationally to improve the management of sugarcane arthropod pests in the early 2000s.

The assessment of losses caused by arthropods was conducted in sugarcane industries worldwide, providing a basis for the development of pest management strategies. For example, comprehensive studies determined the pest status of *D. saccharalis* infesting sugarcane in Argentina.

The many examples of successful biological control programs and entomopathogen use reduced reliance on chemical control while mitigating losses. For example, *C. flavipes* releases in Thailand actively involved farmers in a biological control program to manage moth borers. In Indonesia and Thailand, *Metarhizium* spp. was used to control *Dorysthenes* sp.

The development of cultural practices such as the application of silicon, the improvement and adoption of resistant varieties, and the use of safe and highly effective insecticides provided examples of diverse management tactics integrated with biological control to reduce reliance on chemical control. Successful examples of IPM included *C. sacchariphagus* management in Indonesia, and *D. saccharalis* and *E. loftini* management in the USA.

To complement traditional IPM approaches for increased sustainability, entomologists also conducted research to develop highly innovative techniques. For example, research for *E. saccharina* management in South Africa investigated a push-pull technique, elicitors to induce resistance, *Wolbachia* to decrease fitness, the inhibition of necrophytic *Fusarium*, insect-resistant transgenic sugarcane, and SIT.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Pathology 1924-1938

Jeffrey W Hoy

JHoy@agcenter.lsu.edu

INTRODUCTION

The International Society of Sugar Cane Technologists held six congresses during the initial period from 1924-1938 until World War II interrupted the cycle. Pathology studies were an important component of the congresses from the beginning, and this paper highlights the focal points and advances in this area and key contributions of four individuals. The format evolved from issue-based general discussion sessions to submission and presentation by researchers of specific study results as knowledge increased and methodology advanced. A cooperative approach based on sharing of information to advance the common good was evident from beginning. Attention during this period was focused on causes of root problems, preventing the mosaic pandemic from destroying the developing industry, etiology of bacterial diseases, the importance and most effective means for quarantine to minimize movement of pathogens during the essential sharing of germplasm, and how to evaluate and screen for host resistance.

RESEARCH ADVANCES

1924 Honolulu, Hawaii

The first ISSCT Congress was held in Hawaii. Only 10 countries were represented with 46 delegates, 72% of which were from the US, with 29 of the 33 from Hawaii. North (Australia) served as the Pathology Section Chair. The level of participation, structure, and depth of the ISSCT congresses evolved during the early meetings. At the first congress, no formal, detailed research presentations were submitted nor published as proceedings. Instead, there were multiple discussion sessions, each centered on an issue deemed to be of particular importance, and these choices revealed the areas of greatest concern to the pathologists in attendance.

Diseases with the potential to cause major losses had already been recognized and described in many locations. However, causal agents and details of the etiology, epidemiology, and effective control measures were unknown to many. Four main subjects were important to the pathologists at the first Congress. Interestingly, root rot, the first subject discussed, does not receive much attention today. A discussion on the need for knowledge about diseases and their occurrence in different countries, with detailed descriptions of some specific diseases, followed. The group then focused on developing quarantine regulations and procedures to reduce new disease incursions that could result from the essential germplasm sharing. The last subject receiving major attention was the importance of resistance and how to produce disease-resistant varieties. There was little discussion of the subject that would dominate the subsequent congresses: mosaic.

There was widespread recognition of the importance of a healthy root system and that rots of the roots were an important constraint to sugarcane production. However, it was also recognized that understanding of the causes and factors affecting severity was at present limited, and thus, there was an urgent need for research in this area. Considerable attention was devoted to the cause(s) of Lahaina

disease which was important in Hawaii at that time. It was thought likely that roots were being affected by multiple diseases, but the edaphic factors like high soil salt and acidity, and damage from animals, such as snails, were suspected to be contributing factors.

Discussion of specific diseases focused on an effort to develop lists of diseases in different countries. The bacterial diseases, gumming, and leaf scald, were recognized to have widespread importance along with mosaic, various stalk and top rots, and leaf and sheath diseases.

The group visited the quarantine station in Hawaii. Precautions that could be taken to prevent the movement of diseases between countries while sharing germplasm were considered. It was recognized that no practical quarantine could provide absolute protection against the entrance of insects and diseases but that the effort was needed and valuable. It was acknowledged there was an urgent need to develop successful direct disease control measures.

The breeding session focused on methods for successful crossing but recognized that parent selection would involve consideration of resistance/susceptibility to diseases to realize yield potential. Disease resistance was recognized as a trait of importance from the beginning of sugarcane breeding programs. Delegates from multiple countries outlined efforts to develop varieties with resistance to various diseases and discussed whether crossing resistant parents would yield a higher frequency of resistant progeny. It was also recognized that the focus could not be on only one disease but would need to account for multiple diseases.

1927 Havana, Cuba

The II congress had some research papers on diseases but most of the proceedings consisted of descriptions of papers published elsewhere and extensive discussion. Johnson (Cuba) was the Pathology Section Chair. The mosaic pandemic was underway and of great concern to all, so the majority of the papers presented addressed this issue. However, the first discussion again focused on root rot problems that continued to be an important concern worldwide. There was again general recognition that root health was affected by multiple edaphic, environmental, and pathogenic factors. A first mention was made of nematodes as one pathogenic factor adversely affecting growth (Agee; Edgerton), and *Pythium* was first suggested to be a significant pathogen causing root rot under cool wet conditions (Bourne; Rands).

Mosaic was recognized as a catastrophic problem. Multiple delegates presented research findings related to mosaic in multiple crops, the possible involvement of multiple different viruses, and the probable existence of different strains of mosaic. Roguing was described as a possible control measure, although some suggested it was helpful/feasible while others thought it futile, along with healthy seedcane selection and time of planting. Research was presented on the key role of aphids in transmission and the effects of weather on mosaic incidence and aphid population fluctuations. Resistance in other species, such as *Saccharum spontaneum*, was reported.

There were additional presentations on other diseases, including some that might pass through quarantine without symptoms. The US quarantine was described and reported to now be a clearing house for varieties of experiment stations worldwide.

1929 Soerabia, Indonesia

At the III congress, Wilbrink (Java) was the Pathology Section Chair. Only six papers were presented on diseases of sugarcane. Two addressed root rot with Rands reporting on fungi associated with rots of sugarcane in the US in which *Pythium arrhenomanes* was identified through extensive pathogenicity testing as the most aggressive species and Carpenter reporting on Pythium root rot in Hawaii. Bolle (Java) presented a descriptive paper on different forms of top rot. North (Australia) reported research results related to gumming and leaf scald. Finally, two papers addressed mosaic. Wilbrink reported on

the mechanical transmission of mosaic and Rosenfeld (USA) presented a review paper “The decline and renaissance of Louisiana’s sugar industry” focused on the mosaic epidemic.

A continuing Committee on Protective Sugar Cane Quarantine presented a report: *Quarantine Practice in Relation to Inter-regional Movement of Sugar Cane Propagating Material*. The USDA quarantine procedures were outlined along with practices in other countries. The value and effectiveness of quarantines were again extensively discussed.

1932 San Juan, Puerto Rico

At the IV congress, Cook (Puerto Rico) was the Pathology Section Chair. The proceedings were more extensive than in previous congresses. Papers of widely varying lengths were included. Sometimes papers were read aloud by non-authors and sometimes simply discussed without any presentation.

Cook presented the results of an international survey of diseases of sugarcane commissioned by ISSCT that garnered responses from 12 countries but purported to cover 40. The results reported addressed mostly fungal diseases. Some cultures were submitted to the Central Bureau von Schemmel cultures in the Netherlands, and it was suggested this be a standard practice. A list of 44 sugarcane pathologists was prepared, and it was decided that there was a need for a committee to consider common names for recognized diseases. The Committee on Protective Sugar Cane Quarantine advocated for active, stringent quarantines and a compilation of quarantine practices in different countries.

The 31 pathology papers presented covered a wide range of subjects. Considerable attention was still given to mosaic with nine presentations. The papers revealed that much had been learned about the disease, but many aspects remained poorly understood. Despite this, mosaic was considered to be largely under control in many industries – with an ongoing threat of outbreaks. The use and value of roguing was still under debate along with the effects of weather and climate on the rate of spread and aphid population dynamics.

Root rot, a focus of interest in previous congresses, was the subject of only two papers, including a study addressing the adverse effects of nematodes in Hawaii (Zweluwenburg). The focus on soilborne problems had shifted to sett rots and stubble deterioration (Abbott; Cook; Tims and Edgerton).

An excellent, thorough paper on resistance screening methods was presented by Bell (Australia). Guidelines and considerations for successful resistance screening trials were reported. The last most important requirement was that trials should be conducted and reported in a manner that results could be understood and utilized by pathologists in other countries. It was suggested that a committee be appointed to formulate principles and methods for guidance in investigating varietal resistance, including international check varieties. This continued to be a subject of ongoing interest in later congresses. It was the focus of the first Pathology Workshop in 1984.

1935 Brisbane, Australia

At the V congress, Bell (Australia) was the Pathology Section Chair. Twenty-two papers were presented, covering a wide range of subjects. The length and depth of papers again varied widely.

The Committee on Protective Sugar Cane Quarantine was discontinued since changes in procedures were now not sufficiently rapid to warrant a permanent committee. However, a paper was presented on the Hawaiian system of cane quarantine (Agee). In addition, an excellent paper by Cottrell-Dormer (Australia) on the existence, source, scale, and significance of variability in all types of plant pathogens pointed out the implications for quarantine operations and for disease resistance screening.

Six papers were presented on varietal screening for resistance, and one was presented on large-scale inoculation methods. There continued to be a focus on research addressing virus diseases with nine papers on mosaic and other virus diseases, including one on chlorotic streak that was thought to be

caused by a virus (Martin). A paper by Pemberton (Hawaii) catalogued the known vectors for virus diseases of sugarcane, including distribution by geographic area. Brandes reported on transmission of new strains of mosaic and presented a retrospective on virus disease research during the previous 20 years.

1938 Baton Rouge, USA

Twenty-seven papers related to pathology were presented at the meeting addressing varied subjects, including reviews of diseases in different countries; specific fungal, bacterial, and viral diseases; alternative hosts for pathogens; variation in pathogenicity and strains; variety screening for resistance; diseases of roots, setts, and stubble; disease control measures; quarantine programs; and results of exotic germplasm collection trips to find new sources of disease resistance. Papers again varied widely in depth and length.

Advances in understanding and knowledge of diseases and pathogens were evident in many of the studies presented at the sixth congress. Identification of different strains of mosaic and additional vectors, identification and recognition of the role of alternative hosts for important pathogens, identification of new sources of resistance, beginnings of exploration for and understanding of mechanisms of resistance, appreciation of effects of edaphic and weather factors on disease severity, and unraveling of complex problems, such as root rot, sett rot, and stubble deterioration, were examples of the progress that was being made in pathology research.

PROMINENT CONTRIBUTORS

Many pathologists from different countries participated in the early congresses and made significant contributions to the advancement of knowledge about diseases of importance and how best to manage them. Several made extensive, particularly noteworthy contributions during this period, including E.W. Brandes, D.S. North and R.D. Rands. Gerharda Wilbrink deserved recognition for her work especially for her work on suspected virus diseases and other pathogens. She will be remembered for her development of Wilbrink's medium that is still used to isolate xanthomonad pathogens today. These individuals are all examples of pathologists who were willing and able to effectively address multiple types of diseases as needed and contributed to the Society's functions.

Elmer Brandes, Chief of the Office of Sugar Plant Investigations of the United States Department of Agriculture, played a prominent role in research on most important issues in sugarcane pathology and led discussion during all of the first six congresses, ultimately serving as the General Chairman for the sixth one during 1938 in Louisiana. He advocated breeding and selection for disease resistance as representing an important disease control method. He presented an extensive evaluation of the potential utilization of resistance to mosaic in other species, particularly *S. spontaneum*, and the possibility of natural selection for resistant forms of noble canes in Papua New Guinea. He presented the results of wild germplasm collecting trips that obtained good sources of resistance to mosaic and root rot. In addition, he reported extensive research on mosaic etiology focused on aphid transmission and about greenhouse quarantine facilities of the USDA that would allow safer importation and sharing of varieties. Brandes was elected an ISSCT Honorary Member and received additional special recognition for his contributions to research on mosaic. During the first six ISSCT congresses, Brandes served as a leader in multiple critical research areas, advocated effectively for quarantine programs, and served the Society in multiple capacities.

David North, Colonial Sugar Refining Co., Australia, served as the Pathology Section Chair at the first congress, and he was an active participant and contributor in widely varied research areas at subsequent congresses. As the chair, he indicated the need for knowledge about diseases in different countries and advocated for the preparation of lists of diseases of significance. He presented detailed descriptions of leaf scald and gumming, observed aerial transmission of leaf scald and recognized the threat of disease spread via symptomless carrier varieties. North also addressed Fiji disease,

presenting information on resistance trials, methods of infection, incubation periods, and transmission studies.

Robert Rands, USDA, was an active participant and contributor at multiple congresses focusing on root rot but also addressing other problematic diseases such as mosaic and red stripe. He was the clear leader in the research effort to address the evident widespread concerns about root rot. Rands presented research demonstrating that *Pythium* was a significant pathogen causing root rot and recognizing disease severity was enhanced by cool, wet soil conditions. This research was particularly noteworthy because it was the first in any crop to demonstrate that *Pythium* was capable of causing damage to plants through root rot as well as damping off, *P. arrhenomanes* being the most aggressive species. He reported further results on root rot identifying *S. spontaneum* as a source of resistance and evaluating pathogenic specialization in *P. arrhenomanes*. He cooperatively compiled a list of major and minor sugarcane diseases in the US.

Recognition is due to these outstanding scientists, but some recognition is also due to the highly impactful agencies that employed them. The contributions of the Dutch in Java are of legendary status. The first congress being held in Hawaii was not an accident. The research conducted by Hawaiian Sugar Planters' Association had an outsized impact for a long time. Brandes and Rands both worked for the USDA along with multiple other researchers that featured prominently in our history during the period of this report and continuing after. Finally, North worked for Colonial Sugar Refining, but he was joined by researchers, such as Arthur Bell then many others who worked for the highly effective Bureau of Sugar Experiment Stations.

IMPACT OF THE RESEARCH

What were the major accomplishments and impact of the first six congresses? The foundation was laid during these early congresses for the essential elements of effective disease management in sugarcane. The congresses quickly became a focal point for cooperative interaction, and there was one episode that immediately demonstrated the positive impact that could be accomplished through the ISSCT. The coordinated, sustained, cooperative effort that led to the successful control of the devastating mosaic pandemic illustrates what could be and can be accomplished through the ISSCT. The development of the mosaic-resistant interspecific hybrid POJ varieties in Java and their shared distribution led to not only successful control of mosaic but also to worldwide, multifaceted research efforts to effectively develop and deploy varieties with resistance to other diseases of importance at different geographic scales. This approach became and remains the most important method for managing diseases in sugarcane and continues to be one of the most active areas for research today.

The early congresses saw sustained advocacy and coordinated efforts to develop quarantine procedures and programs to minimize the spread of diseases during needed germplasm exchanges. This was another foundational step that has had a positive, long-term impact on sugarcane industries worldwide.

From the beginning, the ISSCT has provided a forum for communication and cooperation among scientists to effectively address shared problems. The early congresses, and all subsequent congresses, have facilitated a steady advance of understanding of all the diseases of sugarcane and the pathogens causing them to minimize potentially large negative impacts on industries worldwide. Brandes in his Presidential Address at the sixth congress in Louisiana stated his view of the ISSCT as a "scientific fraternity drawn together from all parts of the world by mutual interest to meet the need of humanity for an indispensable food".

Travel and communication were both difficult during the period when the ISSCT started to function. We owe a debt of gratitude to the early sugarcane researchers who made a persistent effort to make the ISSCT a successful forum for the exchange of research results and mutual deliberations on their significance and best practices to promote industry productivity. The focus was always on research, not

economics, at the congresses, but the advances achieved certainly helped make the production of sugar from sugarcane a profitable, sustainable endeavor worldwide.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Pathology 1950-1974

Philippe Rott

philippe.rott@cirad.fr

INTRODUCTION

Nine congresses (VII to XV) were held during 1950-1974 and 208 communications were presented in sugarcane pathology during this period. While only 11 communications were given in sugarcane pathology at the VII congress in Brisbane, Australia, this number rose to 33 at the XII congress in San Juan, Puerto Rico. These communications covered general reviews of diseases but foremost various aspects of 35 diseases, including economic importance, etiology, epidemiology, and control. Of the 208 communications, 39 covered sugarcane diseases in general, while the other ones covered specific diseases, with the three most investigated being ratoon stunting, mosaic, and red rot. These three diseases were the only ones that were, on average, the subject of at least two papers per congress. Fifteen communications focused on quarantine and exchange of plant material, especially in 1959 at the X Congress in Honolulu.

In addition to the congress presentations, ISSCT pathologists also produced the first comprehensive compendium in sugarcane pathology comprising two books *Sugar cane diseases of the world*. The first book (Volume I) was edited in 1961 by Martin and collaborators, and volume II was published three years later by Hughes *et al*. (1964). In 1968, ISSCT pathologists also produced the first issue of a newsletter to rapidly disseminate information on sugarcane diseases.

RESEARCH ADVANCES

Updates on known sugarcane diseases, description of new diseases and their geographical distribution

At the VII congress in 1950, Martin presented a paper entitled “Sugar cane diseases and their world distribution”. Because references to the occurrence of diseases in some countries were not available or surveys were not conducted, this first list was rightly considered incomplete. Consequently, a resolution was adopted at the plenary session of the VII Congress to appoint a standing committee for the purpose of maintaining a list of all cane diseases of the world that would be reported at each future congress. A revised list was further discussed at the VIII congress in 1953 and revised listings were officially presented and published at the ISSCT congresses starting in 1956 until the early 1990s.

As mentioned in 1956, “Sugarcane diseases are not static….”. “A current or up-to-date listing of sugar cane diseases and their world distribution is invaluable to countries in relation to interchange of varieties, disease control, and collecting expeditions, and also to universities and other scientific institutions.” In 1962, a list of 74 sugarcane pathologists worldwide was also established to promote closer cooperation between them. Martin chaired the standing committee on sugarcane diseases until 1962 and Antoine (the 1962-1965 chair of this committee) outlined the outstanding contribution of Martin. A comprehensive list of sugarcane nematodes of the world, including more than 50 species and 13 genera was also presented at the XIII congress (Winchester 1968). The nematode fauna recorded in 1974 in Cuba comprised 124 species, 108 in the soil and 88 in sugarcane roots (Razjivin 1974).

Additionally, several new diseases or pathogenic variants of causal agents of known diseases were reported at the 1950-1974 congresses such as the first report of Sembur in Java (Hes 1953) and the first report of white leaf in Taiwan (Matsumoto 1969).

Ratoon stunting

With 32 communications, ratoon stunting disease or RSD was the most discussed disease at ISSCT congresses from 1950 to 1974. Initially considered as a specific disorder of sugarcane in 1944-1945, RSD was first recognized as a disease of this crop in Queensland, Australia in the late 1940s thanks to the investigations conducted by Steindl and was brought into prominence at the VII congress (1950). Besides a comprehensive description of symptoms of this new disease, Steindl reported the first mechanical transmission of RSD from diseased to healthy plants, which was strong evidence for the presence of a pathogen in cane juice. In addition to growth reduction, RSD was also identified by a yellow-orange to red coloration of the vascular bundles at the nodes of mature stalks and a diffuse salmon-pink discoloration of the nodal area in young shoots. These diagnostic symptoms were used for many years in Australia but also in other countries where the disease was found. However, these internal stalk discolorations were not always found satisfactory or reliable for the diagnosis of RSD or for testing resistance to the disease (Ricaud 1974; Steib 1974).

Steindl also performed the first hot-water treatment (HWT) assays to eliminate the pathogen in infected stalks or cuttings. After further improvement in several locations, HWT (2 hours at 50°C) soon after proved to be an efficient control method of RSD, which is nowadays still in use to combat the disease in numerous countries worldwide. Interestingly, as early as in the mid-1950s, plants showing RSD symptoms in quarantine in Taiwan were not destroyed as they could be rendered disease-free using HWT (Chu 1959). In 1954 in Taiwan, 18,421,272 two-bud seed cuttings were hot-water treated with mobile and stationary units and then used to plant 858 ha of nurseries (Chu 1959). Thanks to this control program that was carried out until 1959, the incidence of the disease was reduced in plantation farms from 60.6% (55/56 crop year) to 13.4% (66/67 crop year) with only 6.4% in 62/63 (Chu 1968). A treatment of seed cane for 8 hours at 58°C using a commercial hot air oven was used for the control of RSD in Louisiana since the late 1950s (Tantera 1971). Similarly, a hot-air seed cane treatment plant was developed in India for the elimination of both the RSD pathogen and the causal agent of grassy shoot (Menon 1971; Sandhu 1974). In the early 1970s in Australia, the standard practice was to soak entire sugarcane stalks in hot water for three hours at 50°C. About 3000 to 4000 t of cane were treated annually for the production of disease-free plots on a farm scale (Steindl 1974).

For a long time, RSD was considered to be caused by a virus for which resistant varieties were sought. Treating soil with bromoethane was thought to attenuate a soil-borne virus (Steib 1965) and a species of rabbit failed to transmit the RSD virus (Bourne 1965). At the XV congress in Durban (1974), Gillaspie and collaborators from the USA and Teakle from Australia, both reported the association of a small bacterium with RSD-affected sugarcane. This bacterium, currently known as *Leifsonia xyli* subsp. *xyli*, was indeed the causal agent of the disease. Because of its fastidious nature, it was successfully isolated in pure culture and checked for pathogenicity only 6 years later by Davis and collaborators.

Based on Steindl's description of RSD, the disease was also diagnosed in Louisiana in the early 1950s by Abbott, and later in Mauritius (Antoine 1959), Taiwan (Chu 1959), Hawaii (Martin 1959), Mexico (1959), Sri Lanka (Egan 1962), Réunion (Hoarau 1965), Dominican Republic (Liu 1965), Puerto Rico (Liu 1965), Mozambique (Rosario Noronha 1971), etc. As stated by Hughes in 1962 when summarizing three decades of sugar-cane pathology: "Perhaps the most interesting recent discovery in the whole realm of sugar-cane pathology is that of ratoon stunting disease. This insidious disease with its entire lack of specific, external symptoms, offered a possible explanation of the mysterious 'running-out' of varieties which has been such a feature of the cane scene for so many years." RSD was reported in 27 countries in 1961 (Martin *et al.* 1961) and in the early 2020s in more than 60 countries. In Australia, it was estimated to cause 10-30% yield losses (Hughes 1974). The highest yield losses were associated with diseased sugarcane subjected to water stress (Rossler 1974).

Mosaic

Mosaic was the second most discussed disease at ISSCT congresses between 1950 and 1974. Only two papers were presented on mosaic from 1950 to 1959, but this disease was the subject of 22 papers from 1962 to 1974. This phenomenon was largely due to the development of new strains of the virus and the breakdown of varieties previously considered resistant. In 1962, it was reported by Abbott and Todd that resistance to mosaic among clones of *S. spontaneum* was not as universal as previously thought. Screening sugarcane varieties and seedlings for resistance to mosaic by mechanical inoculation was performed in several countries (Dean 1965; Liu 1965; Kolobaev 1974). Replacement of susceptible varieties by resistant ones resulted in a great reduction of mosaic incidence and even eradication in commercial fields.

In Louisiana, identification of the spreading periods of SCMV suggested that control of mosaic could be improved by roguing of virus-infected stools of sugarcane at specific months of the year (Steib 1968). Serial heat treatments proved to be efficient in eliminating the virus from infected stalk cuttings (Benda 1971). This concept of repeated hot-water treatments was new as heat therapy of sugarcane against pathogens generally consisted of a unique exposure to a given temperature.

New grass hosts of sugarcane mosaic virus, such as *Stenotaphrum secundatum* which can be common around sugarcane fields, were identified (Nolla 1965). Reciprocal transmission of the virus between sugarcane and other grasses was also demonstrated (Forbes 1971). Elimination of weed host plants near sugarcane fields in Louisiana did, however, not result in a significant reduction of the spread of SCMV (Zummo 1968).

The occurrence of synergetic effects of mosaic and red rot on cane germination, sucrose content, and yield were highlighted in Louisiana where the two diseases sometimes occurred in the same plants (Koike 1974). When sugarcane plants of CP61-37 were affected by both mosaic and RSD, the yield reductions were higher than for each disease taken separately.

Three additional insects were identified as vectors of the sugarcane mosaic virus (Abbott and Charpentier 1962). Furthermore, it was first demonstrated that the corn-leaf aphid becomes rapidly viruliferous (within 5 minutes) after feeding on sugarcane infected by SCMV and that the virus was transmitted by these viruliferous insects within 15 minutes after feeding on healthy plants (Zummo 1965). Similarly, the sowthistle aphid (*Hyperomyzus lactucae*) acquired SCMV within 15 minutes of presence on infected plants and transmitted the virus within 15 minutes after being placed on virus-free sugarcane plants (Zummo 1968).

At the dawn of the serological diagnosis of plant pathogens, SCMV was purified from diseased plants, antisera against SCMV strains were produced, and serological tests were developed to diagnose sugarcane mosaic (Gillaspie 1971; Handojo 1971). The availability of laboratory diagnostic tools later proved to be essential for the detection of viruses and other pathogens in asymptomatic plants, especially in quarantine. Disappearance and reappearance of mosaic symptoms were shown to be affected by temperature (Perdomo 1968). Strain F of SCMV was first reported in India (Bhargava 1971). It should be noted that this strain would later be assigned to a new virus species, *Sugarcane streak mosaic virus*, the causal agent of streak mosaic. The first occurrence of SCMV strains L and M was described in Louisiana (Zummo 1974).

Red rot

Red rot was the third most discussed disease at ISSCT congresses from 1950 to 1974 with 18 communications. Although red rot is nowadays mainly a disease impacting commercial production of sugarcane in India and Pakistan, this disease was a serious disorder in several countries starting in 1925 (Singh 1956). In the 1950s, the use of resistant varieties in India was limited because of resistance breakdown after a certain period of cultivation (Kar 1956). Variation in pathogenicity was described between isolates of the red rot pathogen in India (Singh 1956). It was suggested to test sugarcane for

resistance to red rot using a mixture of isolates of the fungus to improve the selection of resistant varieties (Abbott 1956). In contrast to India, red rot was no longer a major problem in Louisiana since the early 1950s as the growing of resistant varieties prevented the development of severe epidemics on the remaining commercial susceptible varieties (Abbott 1962). Nevertheless, fungicides were tested in Louisiana for the control of red rot (Anzalone 1971).

The degree of resistance of parents appeared to have little effect on the percentage of resistant seedlings in a progeny (Azab 1959). While red rot was mainly associated with germination failure of sugarcane cuttings, the disease was affecting standing crops in India, thus the need to develop other resistance screening methods (Srinivasan 1965). Different inoculation methods were developed to screen for red rot resistance, including the nodal infection method (spraying of fungal spores on nodes) and the plug inoculation method (puncturing of standing cane) (Kar 1974). Investigations into the disease cycle of the red rot pathogen in a sugarcane plant revealed that perithecial build-up in summer contributes to the fungal inoculum in the field (Sanchsz-Navarrete 1965).

Blossoming of methods to test and rank varieties for their resistance to diseases

Although planting resistant varieties was recognised by sugarcane technologists since the occurrence of the first disease epidemics like mosaic, Fiji disease (now called Fiji leaf gall), the initial identification of resistant clones relied on natural infections and observation of disease symptoms. Numerous artificial inoculation methods and experimental procedures were developed from 1950 to 1974 in locations worldwide for testing the reaction of sugarcane to major diseases (Antoine 1965; Anzalone 1965; Wismer 1965). These diseases included chlorotic streak (Egan 1965), downy mildew (Chu 1968), mosaic (Abbott *et al.* 1965), eye spot (Osada 1968; Wismer 1965), leaf scald (Egan 1965, 1968, 1971; Koike 1971; Wismer 1965), Fiji disease (Husain 1965, 1971; Daniels 1968), Pythium root rot (Koike 1965), red rot (Abbott 1965; Srinivasan 1965; Wismer 1965), RSD (Abbott 1965), smut (Byther 1974; Rivera 1965), and white leaf (Leu 1974).

In the 1960s, varieties approaching the commercial stages in Australia were tested on a pathology farm that was remote from cane-growing areas. These varieties were either artificially inoculated or exposed to diseased plants for natural infection. Although resistance to some diseases can be tested in specific trials, it was recommended to not underestimate the observation of disease reaction from the seedling stage to commercial production (Hughes 1965).

Breeding for resistance was considered not difficult when only one strain of a pathogen was present and when suitable resistant parents were available. Breeding was made more difficult by the breakdown of resistance to several diseases such as red rot, mosaic, and leaf scald, and the development of new strains of the pathogens. Martin (1965) published the first comprehensive list of commercial sugarcane varieties of the world and their resistance and susceptibility to major diseases. At the XIII congress in Taiwan, Hutchinson (1968) proposed a numerical system for disease resistance rating with 10 subdivisions ranging from 0 (= immune) to 9 (= highly susceptible). The major advantages of this new system were the prevention of language difficulties in interpreting shades of meaning and the production of data immediately available for statistical analysis.

Dissemination of knowledge under the auspices of ISSCT besides ISSCT congresses

Besides congress proceedings, additional literature was produced under the auspices of ISSCT. This literature includes the first two books on sugarcane pathology mentioned above but also the *Sugarcane Pathologists' Newsletter* (SPN). The first issue of the SPN was published in September 1968 and the goal of this newsletter was to disseminate information, usually short notes, to sugarcane pathologists and provide a forum for discussion of various topics on sugarcane diseases. The first issue edited by Hutchinson (CSR, Sydney, Australia) and Srinivasan (SBI, Coimbatore, India) also contained a list of an international collection of slides illustrating sugarcane diseases. Hutchinson in Australia maintained this collection of initially 139 colored transparencies. The supplement to SPN number 7 (November

1971) listed 215 color slides featuring many aspects of sugarcane pathology. Copies of slides were available from Hutchinson (up to 25 were supplied free of charge and additional slides were charged at cost, 25 cents each). The final issue of SPN was published in November 1982 (Number 29).

PROMINENT CONTRIBUTORS

The 208 communications presented at the ISSCT congresses from 1950 to 1974 were authored or coauthored by 180 people. Ten of these authors were associated with at least seven congress papers, namely E.V. Abbott, S.J.P. Chilton and R.J. Steib from Louisiana (USA), R. Antoine from Mauritius, B.T. Egan, C.G. Hughes, P.B. Hutchinson and D.R.L. Steindl from Australia, J.P. Martin and C.A. Wismer from Hawaii (USA). Among these, Abbott, Hughes and Steindl stand out as great scientists who made tremendous contributions to ISSCT and sugarcane pathology in general. They produced numerous and highly valuable writings for their local and international sugar communities.

While E.V. Abbott was superintendent at the US Sugarcane field Station in Houma, Louisiana, the mosaic virus-strain identification work in Louisiana was made under his direction. He identified new aphid vectors of sugarcane mosaic virus (1962). Abbott was a member of the ISSCT disease standing committee for several years and was an editor of the first two books on sugarcane diseases in which he authored 22 chapters.

C.G. Hughes (Australia) was chair of the pathology section in 1962 and in 1971. While he was holding this position, he organized each time a symposium on international exchange of varieties. Hughes was a member of the ISSCT disease standing committee for numerous years. He was also an editor of the first two books on sugarcane diseases in which he authored 15 chapters. The notable scientific achievements of Hughes (and Steindl below) include the elimination of gumming and downy mildew in Australia and the reduction of Fiji leaf gall (formerly Fiji disease) to low levels.

D.R.L. Steindl (Australia) was the first to describe bacterial mottle caused by *Pectobacterium chrysanthemi* (initially named *Pectobacterium carotovorum* var. *graminarum*) in Queensland, Australia in 1957. He was the first to propose a long hot-water treatment (presoak of 24 hours followed by 3 hours at 50°C) against *Xanthomonas albilineans* in infected sugarcane setts (Steindl 1971). Nevertheless, his most remembered work was his research on RSD. Steindl laid the foundation work for many discoveries on this disease that proved to be a major constraint to sugarcane production worldwide.

IMPACT OF THE RESEARCH

The major impact of the advancements in sugarcane pathology from 1950 to 1974 was the improved control of diseases that resulted in the reduction of the yield losses caused by these diseases. The screening of varieties for disease resistance in specific trials, setup of disease surveillance systems, application of newly developed fungicides, heat therapy, and production of clean seed in specific nurseries all contributed to this result. The sugarcane industry is highly dependent on disease-resistant varieties (Hutchinson 1971). Nevertheless, obtaining resistant varieties is a long-term goal, and other options are sometimes needed (Hughes 1950; Daniels 1971). The integrated disease management concept was developed in several countries, such as Australia, where varieties were no longer discarded because of their susceptibility to a disease but rather withheld from areas with high disease incidence (Steindl 1965). Although the first clean-seed scheme dates back to the beginning of the 20th century in Java, the discovery of RSD and its possible control using heat treatments resulted in the establishment of this approach in numerous countries where the disease was found. Later, clean-seed schemes were also promoted to control other diseases such as Fiji disease in Australia (Egan 1974).

In the 1950s the innovative concept of testing local varieties against diseases occurring only in foreign countries emerged. Hawaiian varieties were screened against Fiji disease and downy mildew in Fiji (Robinson 1956). Cane varieties of interest to Mauritius where Fiji disease does not exist were tested for their reaction to this disease in Madagascar (Wiehe 1962). This allowed the industry to be aware of

the potential risk of growing susceptible varieties and to know which resistant varieties could be cultivated in case of the appearance of a specific new disease, thus limiting its impact. To limit the risk of introduction of new diseases, especially those spread by infected cuttings, more secure circulation of germplasm was promoted via quarantine systems. In all the 10 quarantine programs described at the 1959 congress, only visual inspections were performed to identify diseases, except the quarantine in Mauritius where latent mosaic infections in imported material were tested by spindle inoculations on a susceptible variety (Wiehe 1959). This was going to change during the next ISSCT era thanks to the development of serological diagnosis of pathogens and especially of viruses (Gillaspie 1971). Although biotechnologies did not have a major impact on the advancement of the sugarcane industry as is the case nowadays, it shall be noted that the 1950-1974 period witnessed the first use of molecular methods to better understand or control sugarcane diseases. Ultraviolet radiation was used to obtain mutants of the red rot pathogen (de Carvalho 1968) and gamma radiation was performed to obtain sterile males of the leafhopper vectoring Fiji disease (Ayub Husain 1968).

In addition to technical improvements, the sugarcane industry also benefited from better diffusion of knowledge. As stated by Hughes (1962) when summarizing three decades of sugarcane pathology: “In conclusion I should like to draw attention to an important ISSCT activity which I feel has not received the publicity it warrants. I refer to the two-volume work on sugar cane diseases of the world. Volume I was prepared….. These volumes will prove an invaluable source of reference for all connected with sugar cane….This ISSCT book will also prove of the greatest value to workers in crops other than sugar cane…. I feel that all ISSCT members should be aware of this book and of its value to laymen and scientists alike.”

1950-1974 was an intense period of disease descriptions, identification of causal agents, their geographical distribution, their transmission, and control. This includes a description of quarantine procedures in various countries to limit the risk of introducing diseases (and living pests) with imported setts or fuzz. During this period, quarantine procedures involved essentially visual observation of plants, which required a good knowledge of disease symptoms, and progressively hot water treatments to eliminate some pathogens (Gillaspie 1974). Consequently, the years 1950-1974 constitute a very rich period in sugarcane pathology, from new discoveries to successful extension work, including the production of extensive literature for ISSCT members. The most significant disease discovery is undoubtedly the description and transmission of RSD in Australia, which was subsequently followed by the detection of this disease in numerous sugarcane production areas worldwide. Hot air and hot water treatments were developed, thus providing the first very efficient method to limit the effect of RSD on sugarcane yields.

Finally, the following quotes by CG Hughes at the plenary session of the XIII Congress in 1968 may reflect the feelings of sugarcane pathologists and entomologists about their contribution in the 1960s to increasing sugarcane yields by disease and pest control: “The politics of disease control are no less tortuous than those of other brands!… Unless the correct measures are taken, there can be serious losses to diseases and pests. There are no great obvious gaps in our knowledge of the measures needed, but there are very serious gaps in the dissemination and application of our knowledge…. It is up to all concerned, whether they be cane breeders, farmers, millers, or makers of laws, to play their part. Awareness that a problem exists is the first step to its solution, the next step is to learn something about it.” One may wonder if these quotes are still relevant.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Pathology 1975-1999

Jack Comstock

sugarcanedoc@gmail.com

INTRODUCTION

Eight congresses (XVI to XXIII) were held from 1977 to 1999 and 130 oral presentations were presented on a variety of subjects of sugarcane pathology. There was an average of just over 16 presentations per congress ranging from nine in India in 1999 to a high of 36 in South Africa in 1980. The communications covered all aspects of sugarcane pathology with an emphasis on understanding the disease, the pathogen and control methods. Several papers on specific diseases; ratoon stunt (10), mosaic (14), brown rust (15), smut (13) and leaf scald (14) emphasized their importance and spread of the pathogen on a global scale. Brown rust was first reported in Hawaii (1982) and the Western Hemisphere in 1978, and smut was first reported in Hawaii (1971) and the Caribbean Region in 1974 although it was in Argentina since the 1940s. Most papers on brown rust and smut followed the introduction of these pathogens to new geographical regions. Also important is when the disease was first reported at a congress, indicating the recognition of a new disease in a new area. Communications on Pachymetra root rot in Australia (1989), bacilliform virus (1992) yellow leaf (1999), and leaf yellow (1999) were all reports of recently described diseases of sugarcane.

An innovation of ISSCT was the initiation of subject matter workshops, with the first Pathology Workshop held in the USA in 1984. These workshops between congresses have provided an excellent mechanism of scientific exchange. The pathology section committee under Chair Philippe Rott worked to publish *A Guide to Sugarcane Diseases* in 2000.

RESEARCH ADVANCES

1977 Congress

The 1977 Congress in Brazil had four serological papers to assist in pathogen detection and identification of ratoon stunt (Damann *et al.* 1977), leaf scald (Ricaud *et al.* 1977; Oliveira *et al.* 1977), sugarcane mosaic diseases (Gillaspie *et al.* 1977) and streak virus Ricaud and Felix 1977). In subsequent years, serology became more important, in sugarcane pathology research. There were methodology papers for screening varieties for resistance to red stripe (Chinea *et al.* 1977) and on inoculating true seed with smut (Duarte and Tokeshi 1977) that offered a new approach to screening for resistance. Still, due to the need for microscopic evaluation of the young seedlings, it later appeared to be labor intensive.

Two papers dealt with very different aspects of hot-water treatment, one as a disease control practice (Benda and Ricaud 1977) and the other investigating if the hot-water treatment (Bailey, 1977) and other factors increased the susceptibility of seedcane to subsequent infection. Results suggested this but were not conclusive. Aspects of rind disease (Liu *et al.* 1977), sugarcane streak (Ricaud and Felix 1977), and pokkah boeng (Higgy *et al.* 1977) were presented.

Overall, the serological papers had important contributions to pathogen detection and identification. Furthermore, they demonstrated the importance of serology and predicted its use in the future.

1980 Congress

The 1980 Congress in Manila, Philippines, had a record number of pathology papers. There were eight on sugarcane mosaic covering epidemiology (Farrag *et al.* 1980), strains (Gillaspie *et al.* 1980; Dosayla and Benigno 1980), sources of resistance (Koike 1980), methodology of detecting yield impact (Benda 1980), the effect of hot-water treatment on control (Farrag and Kandarsamy 1980), and induction of virus strain variation (Farrag *et al.* 1980). The topic diversity indicated the importance of mosaic and the desire to understand the disease.

Seven papers on sugarcane smut dealt with aspects of screening, determining and evaluating variety resistance (Ferreira *et al.* 1980), and the infection process and whip production (Alexander and Ramakrishnan 1980). Two papers from Brazil described techniques to collect sufficient inoculum (Tokeshi *et al.* 1980), and on using a vacuum for inoculating sugarcane caryopses (Bleicher and Tokeshi 1980). A new smut strain was described in the Philippines (Latiza *et al*. 1980) and the status of smut in Belize and Mexico was outlined (Flores and Osada 1980).

Papers on rust (brown rust) were presented in response to its introduction to the Caribbean Region and the Western Hemisphere in 1978 reporting on its occurrence and evaluating the resistance of varieties (Bernard 1980; Liu and Bernard 1980); Bernard and Liu 1980). A paper by Brian Egan from Australia reviewed the worldwide distribution of brown rust (Egan 1980).

There were two papers on ratoon stunt disease from Brazil; the first discussed the use of microplots to evaluate tolerance (Masuoka 1980) and the other discussed factors that influenced the evaluation of resistance using water flow techniques (Valarini and Tokeshi 1980). Both these papers indicated the difficulties in determining varietal resistance with ratoon stunt because of its lack of external symptoms.

Two papers on the fungi found in sugarcane true seed and the floral parts were presented. The first was on the fungi present (primarily genera of *Curvularia, Fusarium* and *Helminthosporium*) (Sanguino and Tokeshi 1980) and the second was on control of infections during germination of true seed, with the fungicide Thiram offering the best control (Sanguino and Tokeshi 1980). These papers were important because reports on fungi on sugarcane true seed (fuzz) are rare. The feasibility of using fungicides to control yellow spot disease in Mauritius was presented (Autrey and Sullivan 1980). The control of rind disease using systemic fungicides was also discussed (Mansour 1980).

A group of single papers discussed a range of diseases and pathology topics; a paper on Fiji disease (now called Fiji leaf gall) showed that inoculated-resistant plants did not provide the Fiji virus to the leaf hopper vector (Reddy 1980), such that they could infect susceptible varieties, indicating resistant varieties were not carriers of the Fiji disease virus. A unique paper on wallaby ear of sugarcane in Australia was presented where it appeared that the maize wallaby ear virus caused gall symptoms of sugarcane (Ryan *et al.* 1980). Evidence was presented that, although the galls were somewhat similar to Fiji galls; they were morphologically different.

Three vastly different control methods were discussed. First, the Australian cold soak/long hot water treatment used in conjunction with a clean seed program to control leaf scald was described (Egan and Sturgess 1980). Second, surveys showed higher nematode populations in lighter sandy soils with *Helicotylenchus, Pratylenchus, Meloidogyne,* and *Criconemoides* as the most common and nematicide treatments increased yield (Handojo *et al.* 1980). Thirdly, red rot severity caused by *Colletotrichum falcatum* was reduced by prior inoculations with *Fusarium moniliforme* and the proposed mechanism was mechanical blockage of the xylem (Liu *et al.* 1980).

Miscanthus sp. in Taiwan was resistant to both smut and downy mildew and might offer a new source of resistance for sugarcane (Lo *et al.* 1980). Another paper reported that some *Saccharum* spp. had

resistance to sugarcane mosaic strains H and I (now known to be sorghum mosaic virus) but a majority did not possess the virus after inoculation (Koike 1980).

1983 Congress

The 1983 Congress in Havana, Cuba, had 13 papers each on a different disease. A paper on sugarcane white leaf studied the host range of the disease using the leafhopper *Matsumuratettix hiroglyphicus* in an insectary method of virus transmission (Chen 1983). White leaf infected sugarcane varieties and *Saccharum spontaneum, S. officinarum, S. robustum* and *S. endule.* A discussion of sugarcane mosaic strains A, B, C, D, and E from Egypt and a general status of strains of the virus was presented (Farrage and Nour 1983). In Papua New Guinea, downy mildew was controlled on a susceptible variety by a presoak in the fungicide acylalanine (Ridomil 25 WP) in plant crop (James 1983). Rhizosphere fungi and actinomycetes present in sugarcane roots showed that pathogens reduced germination, while some actinomycetes were slightly antagonistic (Mansour and Haamdi 1983). The integrated control program for yellow spot in Mauritius was described, demonstrating the use of resistance and the supplemental use of fungicides when environmental conditions allowed higher severity levels of disease to develop (Ricaud *et al.* 1983).

Three papers described the screening for resistance for each one of these diseases: eye spot (Kolobaev *et al.* 1983), brown spot (Wang and Lee 1983), and red rot (Singh *et al.* 1983). A paper from Cuba described screening for leaf scald and gumming disease resistance and the differences in the distribution of the two pathogens (Rivera *et al.* 1983). A final paper discussed multiple diseases for the entire variety development program (Kolobaev *et al.* 1983). Together these papers allowed comparing different rating scales and screening techniques for the different diseases.

The biological and physiological aspects of *Puccinia melanocephala* and *Ustilago scitaminea* (now named *Sporisorium scitamineum*) were presented separately in two different papers. These papers gave optimal environmental conditions for pathogen spore germination and disease development (Sandoval *et al.* 1983; Chinea *et al.* 1983). The paper on rust indicated more severe disease development in plants between 5-7 months of age. The paper on smut described differences in teliospore germination either hyphal or sporidia (Handojo and Legowo 1983). The papers provided significant information for anyone dealing with these diseases.

1986 Congress

The 1986 Congress in Indonesia had 15 papers on a wide range of sugarcane diseases and topics with most diseases covered by only a single paper. Aerial fungicide application to control yellow spot in Mauritius gave partial control and was necessary when infection was approximately 20 % in April (Autrey *et al.* 1986). A comparison of the transmission of white leaf in Taiwan and grassy shoot in Thailand was done to help determine if the two diseases were the same or different and the inability of the white leaf vector in Taiwan to transmit grassy shoot suggested that they may be different (Chen 1986). In Mauritius, race 3 of gumming pathogen was shown to produce significant yield losses in sucrose content, sugar per sample and growth on varieties M 1314/64 and M 377/56 (Autrey *et al.* 1986). A paper from Indonesia described a reddish-brown leaf spot caused by *Curvularia eragrostidis* that occurred in Java (Handojo *et al.* 1986).

Several reports, each describing the biology of different diseases, were presented. Eye spot pathotypes in Cuba were determined using a toxin produced by the pathogen (Izquierdo *et al.* 1986). Basal stem rot is a disease of plants under stress and is usually not studied, but the perfect state of the pathogen was described (Fang *et al.* 1986). Cultural characteristics of the yellow spot pathogen *Mycovellosiella koepkei* were discussed with isolating being best on Czapek yeast agar and culture maintenance being best on cane leaf agar (Autrey and Saumtally 1986). Seven sugarcane mosaic strains from Indonesia were identified based on symptomology on sweet sorghum cv. Rio and sugarcane varieties (Gillaspie *et al.* 1986).

Two technique papers were presented where ratoon stunt inoculated sugarcane uprights had reduced growth as compared to uninoculated uprights (Benda 1986). Although the experiment was not designed to measure yield, it suggested a reduced yield. A needle bud puncture method of inoculating sugarcane clones for smut reaction evaluation identified highly susceptible clones (approximately 20%) while being rapid and economical (Matsuoka *et al.* 1986).

A paper on brown rust on the use of fungicides to limit rust development showed that fungicide-treated plots had an increase of sugar by 45% and an increase in cane yield by 48% in a susceptible variety (Taylor *et al.* 1986). Another paper on the same disease demonstrated an increased severity of the disease on 6-month-old plants regardless of the time of year (Comstock and Ferreira 1986).

There were three excellent papers on ratoon stunt, each covering a different aspect of control (Victoria *et al.* 1986). A paper on hot-water treatment evaluated the value of pretreatment soak and different treatment temperatures and durations. A 10 min pretreatment soak at 50 °C followed by treatment for 2 h at 50 °C and using shorter setts gave the best control. A related paper on production of disease-free seedcane demonstrated that the use of tissue culture-produced seedcane was free of the pathogen in plant crops and was more productive than grower-produced seedcane (Anderlini and Kostka 1986). The final paper on ratoon stunt evaluating disinfectants for cane knives found that Vavodine (complex of iodine-ethanol, nonyl-phenol-poluethylene-propylene) gave the best control, but it had no residual action (Victoria *et al.* 1986).

1989 Congress

The 1989 Congress in Sao Paulo, Brazil had 12 pathology papers of which five were on topics concerning brown rust, two on root diseases, and the remainder on other sugarcane diseases and pathology aspects.

A paper comparing resistance to brown rust and yield components showed greater severity on variety B4362 plants derived from calli and axillary buds than those obtained from cuttings (Bravo *et al.* 1989). Another paper looked at the application of serological methods in evaluating early disease interaction during rust infection (Hernandez 1989). A comparison of brown rust infection of tissue-culture-derived plantlets and bud-derived plants using foliar inoculation showed no differences and either plant source could be used to rate rust infection (Peros *et al.* 1989). A brown rust genotype-environment interaction experiment using 12 varieties and five locations in Colombia showed that pustule type was highly stable and determined mainly by variety (Victoria *et al.* 1989). The last paper on rust was on fungi and hyperparasites found in rust pustules which was very interesting because it is seldom discussed in the literature (Sandoval and Lopez 1989).

The remaining papers each covered different topics. In Taiwan, there were two sugarcane mosaic strains: SCMV-A mainly in Taichung and SCMV-A and SCMV-D in the Hwalien area (Chen and Hsieh 1989). In Morocco, sugarcane bacilliform and sugarcane mosaic viruses were identified, and the quarantine system was discussed (Autrey *et al.* 1989). Leaf scorch trials in Indonesia were conducted and identified resistant varieties (Suranto and Harsanto 1989). Fungicide trials also demonstrated yield losses when the susceptible variety Ragnar was infected at 5 months of age. Serological methods for detection of *Xanthomonas albilineans* were compared and latent infection was detected only by direct ELISA (Autrey *et al.* 1989). There were two papers on root diseases: one on *Pachymetra* root rot (Croft and Magarey 1989) and the other on *Pythium* stubble decline in Louisiana (Hoy and Schneider 1989). The final paper was a survey of quarantine procedures adopted and used in 16 countries that import and is valuable because it compiles all the standard quarantine practices in one paper (Autrey *et al.* 1989).

1992 Congress

The 1992 Congress in Bangkok, Thailand had 10 pathology papers of which four concerned leaf scald and two were on smut. The remaining papers were on other diseases. One leaf scald paper was on a selective media modified from Wilbrink's media with the addition of antibiotics and fungicides that allowed stalk blots to determine if stalks contained the pathogen, *Xanthomonas albilineans* (Davis *et al.* 1992) The second paper determined pathogenic races (Autrey *et al.* 1992). Another described a leaf scald seedling inoculation that eliminated susceptible seedlings early in the program and prevented carrying susceptible clones through to the final stages (Hoffman and Tokeshi 1992). The last leaf scald paper provided evidence of aerial transmission (Autrey *et al.* 1992).

The first of two smut papers discussed the epidemiology in subtropical conditions in Louisiana where smut-infected stools are less likely to survive the severe winters, and the spring regrowth synchronizes the smut development in both plant crops and ratoons (Hoy and Grisham 1992). The second paper discussed different mechanisms of resistance (Hector *et al.* 1992).

The wide distribution of sugarcane bacilliform virus was reported; this virus was reported in the late 1980s, but it had probably been undetected for years and has a wide distribution particularly on noble canes (Autrey *et al.* 1992). Vector transmission of sugarcane mosaic strain-A was spread in Taiwan by several aphids with *Rhopalosiphum maidis* being the most efficient (Yang *et al.* 1992).

In Indonesia, brown rust was reported to have a maximum infection at 3 to 5-months in plant crop and caused yield losses. Treatment with fungicides mancozeb and mancozeb plus carbendazim were most effective in control of the disease (Suranto *et al.* 1992).

1995 Congress

The 1995 Congress in Cartagena, Colombia had 13 papers of which one was a review of the pathology section activities. Four papers were on leaf scald, two on ratoon stunt, two on yellow spot, and the remaining on various pathology topics.

Strain variation in the leaf scald pathogen, *Xanthomonas albilineans*, was discussed in two papers, based on colony and cell morphology, serology, and genomic variation (Mohamed *et al.* 1995; Rott and Davis 1995). Pathogen populations differed in apex with a susceptible variety having the highest population (Saumtally *et al.* 1995). Aerial transmission was discussed in one paper with detection, mechanical transmission, and control practices in the other paper (Saumtally *et al.* 1995). The two papers on ratoon stunt looked at pathogen population and yield reduction, finding a highly significant correlation between bacterial population and yield parameters Victoria *et al.* 1995). The other paper used a serological tissue blot assay to screen varieties for ratoon stunt resistance eliminating very susceptible clones in the second vegetative propagated stage in the selection program based on relative pathogen populations (Comstock *et al.* 1995). One paper on yellow spot described the main impact of the disease occurring later in the crop during the sugar accumulation stage (Ouvanich and Srisink 1995). The other paper concerned yellow spot inheritance of resistance finding that resistant progeny can be obtained when one parent is resistant (Ramdoyal *et al.* 1995).

A paper on diseases in Papua New Guinea at a sugar estate in Ramu Valley, a major center of diversity of *Saccharum* spp., observed Ramu stunt, Ramu orange leaf, Ramu scorch, and Ramu streak; these may be unique diseases not found elsewhere (Magarey *et al.* 1995). A review of root diseases in Australia was presented covering *Pachymetra* root rot, a disease unique to Australia, and *Pythium* root rot (Magarey and Croft 1995). A quantitative method determining brown rust resistance evaluation based on the number of uredinia was presented (Daugrois and Letourmy 1995). A paper from Taiwan on *Xylaria* cf *warburgii*, the causal agent of root and basal stem rot was presented indicating the pathogen is heterothallic with several genes controlling compatibility. This paper was extremely interesting because the pathogen is rarely studied (Fang and Lee 1995).

A review of the Pathology Section activities was given as a paper at the Congress and demonstrated a significant interaction of the committee and sugarcane pathologists around the world. Yellow leaf syndrome was associated with luteovirus and maybe a new disease (subsequently named yellow leaf) (Autrey 1995).

1999 Congress

The 1999 Congress in New Delhi, India had nine pathology papers of which one was a report from the Pathology Committee. A paper from Australia reported the presence of sugarcane smut in Western Australia, a first report of the disease on the continent (Riley *et al.* 1999). A paper on the incidence of ratoon stunt in southern and central Africa indicated variation in the disease incidence in some countries with over 50 % of the fields being infected (Bailey and McFarlane 1999). A paper from Colombia presented data on production of disease-free seedcane giving treatments and their effectiveness in eliminating the common seedcane-borne pathogens; plus, the increase in cane yields of using disease-free seedcane commercially (Victoria *et al.* 1999). A paper on the detection of the bacilliform virus in the World Germplasm Collection in Cannanore, India reported that over 60% of the *Saccharum officinarum* clones were infected and some clones of *S. barberi, S. sinense* and *S. robustum* were also infected (Viswanathan *et al.* 1999). At that time the leaf yellowing symptoms of yellow leaf syndrome were being clarified and four papers were presented. Two papers (from Florida and Mauritius) associated a luteovirus with the yellow leaf symptoms and identified varieties that contained the virus. The paper from Florida determined the incidence in clones from the seedling stage (1.6 %) until the final stage prior to release as varieties (66 %) (Comstock *et al.* 1999). A paper from South Africa determined the association of the luteovirus was poor but found a phytoplasma associated with the symptoms (Cronje and Bailey 1999). A paper from Brazil cautioned the association of the virus and the disease because symptoms occurred late in the season under stress conditions, particularly in poorer soils. It was noted that SP71-6163, which had severe yield losses, was not suited for growing under these conditions (Matsuoka and Meneghin 1999). The status of yellow leaf syndrome as a disease was not resolved at the Congress.

A report from the Pathology Section Committee was given showing much activity (Bailey 1999). The Third Pathology Workshop in conjunction with the Molecular Biology was held in South Africa. The 7th International Congress of Plant Pathology met in Edinburgh in 1998 and there was a ratoon stunt workshop there, and a yellow leaf syndrome workshop at Rothamsted before the International Congress. These additional meetings helped stimulate research on these pathological problems. The joint Pathology Molecular Biology Workshop was beneficial in bringing the scientists together to share technology.

PROMINENT CONTRIBUTORS

During this quarter of a century, three pathologists made significant contributions.

The first is Brian Egan (Australia) for his constant scientific and leadership contributions to the Pathology Committee and ISSCT. Brian's outstanding knowledge, experience and strong personality played a major part in the progress made during this period.

The second is Jean Claude Autrey (Mauritius) for his prolific contributions of papers to ISSCT Congresses and his leadership to the Pathology Committee of ISSCT.

The third pathologist is Jorge Victoria (Colombia) for his in-depth pathology papers on ratoon stunt, brown rust and disease control through clean seed programs. Jorge also served on the Pathology Committee.

IMPACT OF THE RESEARCH

The papers presented at the Congresses reflected the disease situation and pathology problems occurring in the home countries of pathologists giving the presentations. Single papers may be because there is a disease-causing problem in that country such as gumming disease in Mauritius. Multiple reports on a disease may be for several reasons. It may be because of an introduction into a new geographic region such as multiple reports on brown rust in the Congresses after 1978 when it was first reported in the Western Hemisphere. It may be a disease such as ratoon stunt that may cause significant yield losses in multiple countries. Finally, the availability of new technology allowed research such as the polyclonal antisera developed by Ben Lockhart and Erik Mirkov through the support of the International Consortium for Sugarcane Biotechnology and distributed in the 1999 Congress and elsewhere.

Research developments clearly showed progress in understanding and control; a prime example was the ratoon stunt, where its incidence had been documented to be decreasing.

A major advancement impacting the Pathology Section was the initiation of Workshops with the first one being held in Beltsville, Maryland, USA in 1986. The workshops stimulated cooperation and the exchange of information.



The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Pathology 2000-2023

Jean Heinrich Daugrois

jean-heinrich.daugrois@cirad.fr

INTRODUCTION

In 2000, CIRAD and ISSCT published a book entitled *A Guide to Sugarcane Diseases* that was very useful for sugarcane pathologists and technologists involved in sugarcane production. This book edited by Philippe Rott, Roger Bailey, Jack Comstock, Barry Croft and Salem Saumtally gathered many changes in sugarcane pathology at the end of the 20th century. Information on known diseases was updated, new diseases were described and identified, and new diagnostic assays based on molecular biology were included. In contrast to the previous books on sugarcane diseases published by ISSCT in the 1960s and in 1989, this guide did not include exhaustive disease descriptions but provided sufficient and updated information regarding the scientific knowledge and practical aspects of disease control. Each disease was described by its causal agent(s), geographical distribution, symptoms, transmission, host range, epidemiology, and economic importance. Information regarding strains of the pathogen, diagnosis, and control was also provided. Key references from the literature were cited and color pictures illustrated each disease. An interactive CD-ROM of the book, D-CAS 1.2, with additional photos and supplementary information was also produced.

Since then, eight congresses (XXIV Brisbane to XXXI Hyderabad) were held from 2001 to 2023, and 147 communications were presented in sugarcane pathology, including 86 oral presentations and 61 posters. The number of communications in sugarcane pathology ranged from 12 at the XXVI Congress in Durban to 29 at the XXX Congress in Tucumán. These communications covered various aspects of 27 diseases and quarantine procedures and disease reviews.

Disease aspects included first reports, resistance, economic importance, etiology, epidemiology, genetic diversity, pathogenicity, diagnosis, control, biocontrol, bio-stimulants, high-throughput sequencing, disease management, functional genomics, and proteomics.

The three most investigated diseases were yellow leaf, orange rust and ratoon stunting. Yellow leaf was the only disease that was covered at all eight congresses, with an average of four communications per congress.

The most frequent theme of the congress communications was disease diagnosis, with 36 communications at seven congresses. Interestingly, this theme progressively shifted over the years from conventional to molecular diagnosis, resulting in 18 communications describing molecular diagnosis of pathogens, 10 with conventional diagnostic methods (serology, etc.), and eight with both types. Only five communications reported the use of metagenomics for sugarcane disease diagnosis or pathogen identification. The second most frequent theme was resistance to diseases, with 34 communications describing plant resistance heritability and breeding for resistance. The least frequent themes were disease management (based on the use of pesticides, thermotherapy, meristem tip culture, or biocontrol; 29 communications) and epidemiology (especially disease incidence; 20 communications).

RESEARCH ADVANCES

New and surprising revelations regarding chlorotic streak

This period of eight congresses was marked by the presentation made in 2016 at the XXIX Congress in Chiang Mai by the Australian team led by Kathy Braithwaite who reported the pathogen causing chlorotic streak was a Cercozoa, 87 years after the discovery of the disease. This pathogen was subsequently identified as a Cercomonad and named *Phytocercomonas venanatans* by the same team. *P. venanatans* is the only cercomonad known to cause a disease in sugarcane and in any other plant species. The identification of the causal agent of chlorotic streak will help to develop specific diagnostic tools and improve the management of this disease.

Sugarcane disease diagnosis

Disease diagnosis tools are essential as they permit the identification of pathogens when symptoms are insufficient or to ensure that sugarcane material is not infected. During the eight ISSCT congresses from 2000 to 2023, 31 oral presentation papers described the application of diagnostic tools. Accurate diagnosis is needed to determine the susceptibility of plants to diseases during breeding, for example, and the impact of these sugarcane diseases on yield, as well as to protect borders with quarantine facilities and to avoid the introduction of new diseases or new strains of a pathogen already present. In addition, limiting local disease impact by planting disease-free material may reduce disease impact on yields. Quarantining needs accurate diagnosis to ensure safe germplasm movement or introduction.

At the beginning of the 21st century, quarantine diagnosis was performed using pathogen isolation, immunoassays, as well as PCR or RT-PCR assays depending on the type of pathogen (Guinet 2013; Victoria 2007). To develop more accurate or informative diagnosis, a quantitative-RT-PCR protocol was developed to detect sugarcane yellow leaf virus (SCYLV) genotypes in quarantining canes (Joomun 2016) and metagenomic protocols were set up to detect viruses in imported sugarcane (Mollov 2016) or used to search for non-diagnosed virus in quarantine material (Fernandez 2019). Similarly, pathogen detection in cleaned tissue-cultured plants switched from immunological diagnosis to optimized molecular PCR or RT-PCR protocols that allowed the detection of lower levels of pathogens, thus resulting in the implementation of safer nurseries (Noguera 2013). Tissue-blot immuno-assays were used to (i) evaluate field incidence of SCYLV and *Leifsonia xyli* subsp *xyli* (Lxx) (Bertani 2023; Bertani, 2019; La O 2013; Rassaby 2001), (ii) to identify resistant varieties in breeding programs (Sood 2023) or parental collections (Bertani 2019), (iii) perform transmission studies, and (iv) test for a pathogen after sugarcane cleaning (Lehrer 2001). RT-PCR was also often used to diagnose SCYLV in addition to TBIA for evaluation of field incidence or to control genotype identities (Edon 2007).

PCR amplification and sequencing of the bacterial 16S RNA gene was used to study the diversity of endophyte and epiphyte ice nucleic bacteria causing frost damage (Rezamahalleh 2023). Metagenomics was used (i) to identify a so far unknown pathogen, the causal agent of chlorotic streak, (ii) to describe the genomic diversity of viruses such as *Ramu stunt virus* in Papua New Guinea (Braithwaite 2019), and (iii) to implement transcriptomics for identification of pathways promoting resistance to red rot (Naveen Prasanth 2023). Metagenomics also contributed to identifying new viruses infecting sugarcane, which resulted in 2023 in a list of 24 viruses from 10 different families (Daugrois 2023). This result was a significant jump compared to the “only” seven viruses described in 2000 in *A Guide to Sugarcane Diseases*

Control of diseases by plant resistance

The most efficient disease control is growing resistant varieties obtained by breeding. Research developed to evaluate resistance to diseases and nematodes was presented in 26 oral communications. Two concerned red rot, one dealt with identification of resistance in wild germplasm in Louisiana (Hale 2010) and the second described a more accurate methodology to screen varieties

against red rot in India (Sugeshwari 2013). Brown rust (*Puccinia melanocephala*) resistance was also well studied since the identification of the major resistance gene *Bru*1. Data obtained during this period showed that sugarcane has other resistance genes besides *Bru*1. In Argentina, *Bru*1 was present in only 16% of brown rust-resistant varieties (Racedo 2013) and additional brown rust resistance genes (Hoy 2016) and markers (Rincon 2023) were described.

The local sugarcane industry focused again on resistance to orange rust *(Puccinia kuehnii*) in Australia when a new strain infected the main commercial variety (Magarey 2001). However, with outbreaks of orange rust occurring in the Americas in the late 2010s, other countries started to look for disease resistance. Resistance to orange rust determined by natural infection is well correlated with the one assessed by artificial inoculation of plants (Sood 2013). To limit epidemics in Colombia, varieties have been selected in this country for resistance to orange rust since 2011 (Angel 2016). Furthermore, inheritance of resistance to orange rust showed that crossing susceptible varieties may lead to relatively high levels of individuals in the progeny that are resistant to orange rust (Sood 2016). To identify resistance markers, methods and conditions to inoculate plants with brown rust and orange rust were studied (Rincon 2023).

Resistance to SCYLV was also improved and progeny analyses showed that susceptible x resistant crosses could result in resistant progenies (Victoria 2005). A narrow heritability of resistance to SCYLV showed a good correlation between parental resistance and the progeny resistance values (Hoareau 2016). Furthermore, resistance to transmission of SCYLV by its aphid vector was highlighted (Garces 2019). A molecular marker correlated to SCYLV resistance was found in the proximity of a putative resistant gene (Izquierdo 2013).

Following a recent spread of streak mosaic in Java, caused by sugarcane streak mosaic (SCSMV), commercial varieties were tested by artificial inoculation for resistance, and only one-third of the tested commercial varieties were resistant to SCSMV (Putra 2013). Planting resistant varieties was recommended.

Control of diseases by integrated management

Limiting the development of diseases is crucial to secure sugar yields, and different types of management were described during these congresses. Cleaning sugarcane from pathogens by thermotherapy followed by meristem tissue culture was effective for Lxx and *Xanthomonas albilineans* (Guevarz 2005), but less effective for SCYLV as hot-water treatment was ineffective against SCYLV (Moutia 2001) and SCSMV (Putra 2013). However, true tip meristem culture was efficiently used to clean sugarcane from SCYLV (Lehrer 2001). Cleaning techniques resulted in the setup of healthy nursery schemes to minimize Lxx impact (Hoy 2001), or other main local diseases (Nogera 2013). Heat therapy and meristem tip-based tissue-culture techniques were also tested to manage white leaf and sugarcane grassy shoot phytoplasma but had moderate success in reducing the disease impact on yields (Rao 2023).

The use of chemicals to limit yield decline due to fungal pathogens was investigated with the selection of fungicides to minimize the impact of rust diseases (Margarey 2001, 2010; Raid 2013; Rott 2016). Similarly, the elimination of nematodes by soil fumigation in addition to crop rotation was also studied (Stirling 2001).

Proteomics was used to identify potential targets in *Colletotrichum falcatum* and its inhibitor with the objective of limiting the effects of red rot in India (Malathi 2023). Better ‘green’ management was investigated using bacterial communities to identify bio-promoters limiting diseases, such as rhizobacteria (Afghan 2019), or to assess diversity of endophytic and epiphytic bacteria to identify bacteria antagonistic to plant pathogenic microbes (Moazzen 2019).

A large range of resistant or tolerant varieties should be used whenever possible. Most cited effective management practices to reduce disease impact involved the use of healthy seed cane produced in certified nurseries.

PROMINENT CONTRIBUTORS

The 147 communications presented at the ISSCT congresses from 2000 to 2023 were authored or coauthored by 401 people. Among these authors, the top three personalities (ranked by the author of this paper in alphabetical order and not by order of merit) were J.C. Comstock, P. Rott, and A.S. Saumtally. These three pathologists investigated sugarcane diseases and helped to improve their control for several decades. They were not only involved in sugarcane disease research but also produced numerous and valuable writings for the sugar community worldwide, and they made tremendous contributions to ISSCT and sugarcane pathology in general.

Jack Comstock was born in Detroit, Michigan, USA. He received his Ph.D. degree in plant pathology in 1971 from Michigan State University. Jack was a research associate in the Botany and Plant Pathology Department at Iowa State University from 1971 to 1974. From 1974 to 1989, he was an associate sugarcane pathologist at the Experiment Station of the Hawaiian Sugar Planters' Association, Aiea, Hawaii. From 1989, he has been a research plant pathologist at the USDA-ARS Sugarcane Field Station in Canal Point (CP), Florida, where he became research leader in 2004. Jack published numerous papers including research and extension articles, as well as book chapters. He served as a member (1988–2005) and chair (2005–2010) of the Sugarcane Pathology Committee of the ISSCT and is the only person who attended all 13 ISSCT Sugarcane Pathology Workshops that started in 1986. He retired from USDA in January 2017 and started a new occupation as a sugarcane consultant. At the XXIX congress in Chiang Mai, Thailand (2016), Jack was appointed an Honorary Life Member of ISSCT.

Philippe C. Rott was born in Strasbourg, Alsace France. He received his Ph.D. degree in phytopathology in 1984 from the University of Paris XI, Orsay France. Philippe was hired in 1984 by CIRAD-IRAT as a plant pathologist and worked in Martinique and Montpellier, France, on bacterial diseases of tropical plants until 1988. From 1988 to 1993, he conducted research in sugarcane pathology in Guadeloupe, and in 1993-1994, Philippe was a visiting professor at University of Florida. In 1994, he joined CIRAD in Montpellier as manager of the sugarcane quarantine until 2000, when he became head of CIRAD's sugarcane crop protection project. From 2007 to 2009, Philippe was a Marie Curie Fellow at the Plant Pathology Department of the University of Florida in Gainesville. In 2010, he returned to CIRAD in Montpellier as Director-elect of a mixed research unit in plant pathology (UMR BGPI, CIRAD-INRA-Montpellier SupAgro) and was director of this unit from 2011 to 2013. In 2013, Philippe moved to the University of Florida (Belle Glade) as a Professor of Plant Pathology for six years. Since 2019, he has been working as a research director in sugarcane pathology at the Plant Health Institute (UMR PHIM) of Montpelier, France. Philippe has authored numerous publications on sugarcane diseases including research papers, book chapters, and extension papers. Member of the ISSCT since 1988, he has occupied various positions in this society: Member (1992-2005) and Chairman (2001-2005) of the Pathology Section Committee; Biology Commissioner (2005-2007); Member (2007-2019), Vice-chair (2013-2016) and Chair (2016-2019) of the Executive Committee. At the XXXI congress in Hyderabad, India (2023), Philippe was appointed an Honorary Life Member of ISSCT.

Abdess Salem Saumtally holds a PhD degree in Plant Pathology from the University of Reading, UK. He dedicated nearly three decades (1983–2012) in the Pathology Department of the Mauritius Sugarcane Industry Research Institute (MSIRI), and internationally, making significant contributions to the understanding of sugarcane diseases and their management. He authored numerous research publications and book chapters on sugarcane disease. A committed member of the ISSCT since 1994, he played a leadership role in the Pathology Section, serving as its Chairman from 2010 to 2016. From 2007 to 2010, he also represented the Society as Deputy Commissioner (French). His research, on gumming, leaf scald, yellow leaf, leaf yellows, and various other diseases, is well documented in ISSCT Proceedings. Since 2016, he has continued to contribute to the Society as a member of its Executive Committee.

IMPACT OF THE RESEARCH

All the research and techniques that were presented at ISSCT congresses during 2000 to 2023, to characterize and manage sugarcane diseases have had a positive impact by minimizing disease effects not only on sugarcane and sugar production but also on breeding programs.

Controlling sugarcane variety entries and protecting borders are essential tasks to avoid new diseases spreading in a country on varieties that were previously not confronted with them, thus preventing potential high yield decline. However, this will not stop some pathogens, such as fungi, from being disseminated by wind or other atmospheric movements without direct human involvement. After having been confined to Asia for over a century, sugarcane orange rust has spread across the Western Hemisphere in the last two decades, thus illustrating the permanent risk of the development of new disease epidemics. Additionally, the jump of species of pathogens from other crops such as maize or wild grasses to sugarcane may also happen and needs to be taken into consideration.



The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Factory Engineering 1924-1938

Juliusz Lewinski, Sergio Guzman and Manuel Enriquez Poy

jlewin@prodigy.net.mx

INTRODUCTION

The period from 1924 to 1938 marks the beginning of all subsequent ISSCT congresses, during which technicians and scientists involved in the industry presented various new developments in processes and equipment. The presentations and discussions reviewed here were related to the subjects corresponding to the Engineering Section within its definition by the ISSCT Factory Commission.

RESEARCH ADVANCES

1924 Congress

As it was the first congress, the important recommendation was to adopt a uniform system to report chemical control data, obtained from the processes, so that the figures reported may be understood by technicians in all countries.

The important subjects were:

1. Grooving with reference to managing returned settings from the Petree process. The problem was solved by replacing the customary 60° grooving with grooves of 37.5° angle and 0.5” inch pitch. The extraction was higher than before the use of the Petree process, but moisture in bagasse was increased to above 50%.
2. Milling under Cuban conditions considered capacity as the main factor, so double crushers with 60° grooving and 3” pitch on the first and 1.5” pitch on the second, together with comparatively coarse grooving on the following units were found to be the best solution. The author discussed the importance of having Krajewski crusher rolls properly adjusted.
3. Milling practice in Fiji and Australia. The type of shredder known in Hawaii as the National was used in many mills.
4. Under the subject of milling practice in Hawaii, the advantages of the Searby shredder were discussed.
5. Extraction by a combination of milling and diffusion. In some factories, long maceration baths were used between milling units. In others, large annular drums having revolving rakes were installed between the mills. In both cases, the apparatus was kept partly filled with maceration water. The partly crushed cane averaged about 15 minutes in passing through them. The maceration baths were kept hot to prevent bacterial action and lime was added to reduce inversion.
6. To improve mill sanitation, replacement of the old slat conveyors with the Ewart, Ramsey, and Meinecke types and the installation of juice pans with steep sides under the mills was proposed. The use of antiseptics around the mill, including returning the juices used as maceration without straining, using anti-clogging pumps for this purpose and the Peck strainer, were presented.

1927 Congress

The important subjects in milling were:

1. Cane knives had been in use for at least 20 years. Originally, they consisted of a single set of slow-running and widely spaced knives, but later the practice was to put in two sets. One set was placed halfway up the carrier, running on the upper layer of cane; the other was placed at the carrier head with knives 2" (5 cm) apart, having their points set to within 1" (2.5 cm) of the carrier boards. The most successful type of construction was the "Ramsay" swing blade knife to prevent the breakage of the blades.
2. National shredders were reported to be removed from the factories due to disc breakages and the Searby shredders started to be more common. In Cuba, the Maxwell shredder started to become popular, combining the shredder with one crusher before the mills.
3. Crushers were still extremely popular in Cuba for cane preparation as double or even triple crushers. Three-roller crushers were also used. The Fulton and Krajewski crushers were compared in reference to the shape of roller surface and milling capacity. In Hawaii, most of the Searby shredder installations were preceded by Krajewski crushers. Searby was much in favor of the Krajewski type of crusher as a feeding device.
4. Experiences in different countries were presented in relation to rollers' grooving and the general conclusion was that Messchaert grooves, with proper installation, ought to make a reduction in the moisture of bagasse leaving the mill.
5. Three main types of pressure application over milling rolls: hydraulic regulators, toggle regulators and rigid or solid housings without relief were discussed, but most factories were using the hydraulic regulators. In Java, most of the mills used hydraulic pressure. There were, however, a small number of factories that had mills with rollers with fixed distances between them. Toggle regulators were often used on the crusher.
6. The old apron or slat-type conveyors were entirely discarded in Hawaii. They were replaced by the Meinecke chute, by the Ewart type, or by the Ramsay type (the latter of which is like the Ewart. but placed at an angle). With the Meinecke type, maceration was at first unsatisfactory and it seemed as if good extraction might be difficult to obtain.
7. Strictly speaking, "imbibition" was understood as simply spraying or pouring dilute juice or warm or hot water on the bagasse; "maceration" was the method used in Australia where the bagasse is drawn through a bath of water or dilute juice with around 20-minute retention time between one mill and the next, during which it is totally submerged.

The important subjects regarding the boiler plant were:

1. During the sessions, different thermal topics were discussed, such as the difference between water tube (with additional new units in recent years) and fire tube boilers, evolving design general arrangements, types of furnaces, use of superheaters, air preheaters, control systems and better maintenance schemes.
2. A comparison was made between water-tube and fire-tube boilers, their overload capacity of up to 175% and the effect of the use of bagasse mixed with other fuels like wood, molasses, and sugarcane leaves. Furnace design became important, principally regarding the Cook (hearth) (and its capacity of up to 1,040 kW (1,400 HP) per unit, with cleaning every 24 to 48 hours.
3. There were some discussions about the quality of water with trends toward the use of evaporator condensates (including all effects) to increase boiler efficiency.
4. The main factor for good combustion was how to feed the bagasse. The use of gas analyzers for measuring CO_2 and CO, and the installation of high chimneys and induced draft fans were just starting to be used. The measure of temperature and mass flow in flue gases is important to improve efficiency using water heaters, combustion air heaters or drying bagasse. The use of the Ljungström air preheater was an important alternative (developed for locomotives) capable of improving efficiency between 15% to 20%.

5. In ordinary bagasse-burning boiler plants, with bagasse of 49% moisture, 2.45 pounds (1.1 kg) of evaporation from and at 212 °F (100 °C) per pound (0.45 kg) of bagasse was considered decent work. The factories that made white sugar burnt additional fuel.
6. In many Cuban factories (160 psig) the use of superheaters was usual, obtaining from 75 to 125 °F (24 to 52 °C) above saturation with best efficiency in steam machines, reducing the steam consumption by 5%. Another advantage of superheat is that there was no condensation in the steam pipes, hence no loss of hot water drips.

1929 Congress

The algebraic method developed by Noël Deerr to evaluate the extraction of juice in mills and the considerations on which it is based were presented. In the final discussion, it was stated that the method has some base points that are ideal and that there is no basis for them, although it was proposed that they can give a goal that always guides improvement. A summary statement “Our work cannot be governed by probability or accident. More global knowledge is needed to do scientific work in industry” is still relevant.

Sun-dried bagasse was used in some places for boilers, but the use of wet bagasse was already common. Java had not changed from the "step-grate" grid, but its construction and dimensioning had greatly improved. There were tests to dry bagasse with chimney gases, but they had not been successful, being replaced by air preheating with better results. Direct steam was also being evaluated to reuse vapors from evaporation to feed it again.

In factory operation and chemical control:

1. A complete study was made based on the approach to the behavior of bagasse cells during grinding.
2. The bagasse cells resume their shape after compression and absorb air, affecting the effectiveness of maceration by decreasing the penetration of the liquid.
3. The extraction of the juice is a function of two factors: bagasse porosity and the ability to increase pressure in the juice present.
4. Extraction of juice from living cells can be by diffusion or by hot maceration.
5. Use of hot maceration, including the use of about 10% of the steam used in the factory, in a semi-closed carrier, had shown improvements in juice extraction, with temperatures between eighty to ninety degrees Celsius.

The world had seen that the use of shredders improves both preparation and capacity. A common maceration method was to pour the juice or water into a curtain or with nozzles over the bagasse. This approach would change in the near future to more efficient forms, such as hot maceration or interleaved diffusion between mills. In Egypt, the first designs of a bagasse diffuser were introduced. There was also a similar process in Queensland using intermediate carriers.

There were three figures proposed to analyze the milling operation: Pol extraction, normal juice (undiluted) lost in bagasse on fiber and percentage of fiber in the last bagasse. The concept of normal juice lost in bagasse, raised by Noël Deerr, began to appear. The Deerr performance factor proposal was not accepted because of difficulties in making good comparisons among countries, because the effect of higher imbibition tends to show worse performance.

1932 Congress

Haan in the paper “Electric Mill Drives” stated that for the electrification of sugar mills the following systems must be considered:

1. The three-phase AC system with wound rotor motors and variable speed generator.
2. The DC system with DC shunt motors and five variations:

a. DC generators with variable voltage.
b. AC to DC rotative converter with variable voltage transformers.
c. AC motor moving DC generator.
d. Individual generator for each mill.
e. DC generator moved by steam turbine.

The choice of the system was ruled by many factors, the weight of which was often determined by local conditions. In general, three factors exerted greater influence:

1. The initial and maintenance costs,
2. The requirements for speed change and
3. The influence on the steam and fuel economy.

In the paper “The Comparison of Cane Milling Results” Deerr proposed as criteria for international comparison in cane milling operation the following variables:

1. The extraction,
2. The fiber in the last mill bagasse (f), and
3. The reduced extraction at 12.5% fiber, where e is observed extraction and V is the undiluted juice lost in bagasse percentage fiber, being connected by the expression:
   $V = \frac{(1-f)}{f} \times (1 - e)$ that for f equal to 12.5%, converts to $V = 7 \times (1 - e)$

Schreiber, in the paper “The Control of The Sugar Mill”, concluded that the increase in milling efficiency lowers the juice purity.

1935 Congress

In a paper on milling practice, Marriott described the development of circular diffusers (removed after testing), long maceration carriers, levelling knives, mechanical pushers, and other equipment, used in connection with the combined crushing and diffusion (lixiviation) process for extracting sugar from the cane at the Colonial Sugar Refining Company's Mills. A brief description of the new crushing station and a flow of the maceration circuit at Hambledon Mill was given.

Schreiner and McKaig described a three-roller mill used in sugar-cane experimental fieldwork; a hydraulically equipped experimental sugar-cane mill used by the Division of Soil Fertility in its investigations at Houma, Louisiana. The crusher and whole milling extraction data were presented to indicate that the experimental milling was comparable with commercial operations; the crusher juice extraction obtained with hydraulic equipment was more uniform than was obtained with less flexible pressure regulation. Chemical examination of the crusher juice revealed satisfactory agreement between experimental and commercial crusher juice, in the case of soluble components, but greater differences in insoluble components in the juices of the whole cane.

1938 Congress

A paper by Behne and Jenkins on Present Practice in Raw Sugar Manufacture in Queensland could be regarded as an index to the technological developments in this country during the previous few years. While there had been few major changes in the crushing plants of the mills, the average crushing rate had steadily increased from year to year, without any sacrifice in milling efficiency as judged by values for extraction and lost undiluted juice percent based on fiber. The better results indicate that considerable thought and attention had been given to details of construction and operation, thus enabling better performances to be obtained.

In Queensland, the standard preparation equipment consisted of two sets of levelling knives, followed by a shredder (National or Searby). One set of knives was placed near the bottom of the carrier with a

clearance of approximately one foot, trying to prepare a uniform blanket to provide a high degree of extraction. The second set of knives was usually set as close to the carrier slats as practicable (approximately one inch) and was intended to give the maximum disintegration. Mill settings and ratios were adopted from Mackay region and proved very satisfactory.

With the higher tonnages crushed, the need for well-designed feed hoppers and pushers at the mills had been emphasized. The general practice in those Queensland factories in which the mills were fitted with hydraulics was to load the accumulators to such an extent that the top roller lifts only in extreme cases or when foreign substances (e.g., iron pieces) are passing. In several mills, maceration had been applied intensively, using efficient drainage and recirculation with anti-clogging pumps. The maceration water was applied by well dispersed sprays directed onto the bagasse as it was dragged up by the inclined part of the intermediate carrier. The performances of these mills compared very favorably to those of other mills and so emphasized the considerable benefit obtained from the proper application of maceration.

An interesting boiler installation which showed results of a very high standard was that at Kalamia mill, where two Babcock and Wilcox boilers, each of 8,646 ft^2 (803.2 m^2) heating surface, supplied practically the full steam requirements of a mill, crushing 80 t/h. Each boiler was provided with an air heater, two-step and chain grate furnaces, and a large combustion chamber with provision for removal of ashes from both parts while the plant was in operation. Automatic bagasse feeders, flat suspended arches, and a high firebridge were provided with secondary air ports in both sides.

Dennis outlined new equipment for improving the efficiency of mills. He presented a stress diagram based on vectorial analysis of a typical three-roll mill was presented. The comparison of an old type bearing with a Munson bearing was made and the Munson hydraulic system was discussed. The combination of Munson Top Brasses with Munson Air Operated Hydraulics on each bearing plunger assured maintenance of the pressure force p (pressure between top roll and cane roll at AD line) and np (pressure between top roll and bagasse roll at AE line), thus securing even results in extraction and elimination of shock from the entire mill equipment, as well as more constant and reduced power output from the prime movers.

Kelsey talked about electric drives for cane mills and pointed out that it is better to operate continuously with changing milling rates to keep pace with the cane supply rather than to run out of cane and shut down the mill. A change in speed could be made by changing the voltage of the direct current generator or with alternating current by changing the frequency, as well as the voltage of the system. For making the required speed adjustments, direct current was ideal because of the greater relative speed range of advantage with widely varying fibre, but a compromise could be made with the simpler, less expensive system.

A brief history of the bagasse furnace practice was described by Seeling. The characteristics, use and applications of the different bagasse furnaces were analyzed: the Cook forced draft furnace supplied with pressurized air between one to two water inches, using turbine-driven blowers, the Ward single pass furnace and the compound blower.

In conclusion, there were, frequently, sugar mills in which the line of selection between steam and electric drive for the auxiliaries was not clearly marked, or in which the determining factors fluctuated due either to varying seasonal conditions or to other periodic variations, making it very difficult for the engineer in charge to decide upon the nature of the motive power for the blowers or other auxiliaries.

Waddell reviewed technical progress made in the Philippines islands during the previous 3-5 years. Factory "lost time" figures showed a significant improvement during the past 5 years. There had been several changes in the design of return bars, such as the lowering of the back to about one-half inch to relieve the power load on prime movers. There were numerous attempts to improve drainage and reduce wear; but a plain, unobstructed way was still most popular. Another innovation was an arrangement that removed part of the weights on the hydraulic pressure by lowering them past a certain point. This approach promptly reduced the pressure on the top roll when soft or short-fibered cane was

being milled, the full pressure being applied again by pumping up the weights when better feeding cane entered the mill. Automatic forced-feed lubrication to mill bearings had also been established at many mills.

The bailing of surplus bagasse had become almost universal practice throughout the Philippines. The bales, as a rule, were piled under the shelter of sheds of wooden framework with painted corrugated iron or straw roofs. After storage for 2-6 months, the bales were used as fuel for locomotives, lime kilns, domestic purposes, or for returning to the fireroom during the offseason for power, light, distillery use, etc. The chimney soot nuisance had been relieved at some mills by the installation of water scrubbers, some at the base of the smokestacks, others at the top. However, this approach was recognized as a temporary necessity since there were several modern furnace settings in operation which did not require any external removal of soot.

PROMINENT CONTRIBUTORS

Noël Deerr, an English historian, and technologist of the sugar industry. His major work was *The History of Sugar* edited in London in 1949. He was also the author of the first sugar manual published in 1911 and 1921 and known for his concepts related to the definition of the criteria for international comparison in cane milling operation including reduced extraction definition used until today.

Francis Maxwell, author of many patents related to sugar factory equipment and of the famous book *Modern Milling of Sugar Cane* in 1932.

William Searby, developer of the concept of the hammer shredder for sugarcane preparation (Searby shredder) used until today and the promotor of using the crushers as convenient feeder for three-roll mills what gave the idea of development of actual five- and six-roll mills.

IMPACT OF THE RESEARCH

The period was marked by understanding the necessity for good data on milling performance as well as many innovations in machinery and equipment. ISSCT Congresses provided the forum for interchange of ideas and reflection on changes in the industry.

It is remarkable to observe that many ideas currently regarded as innovative by technicians were already documented in papers and patents from earlier times. This reinforces the validity of the old saying: “What is considered new have two options: or is not new or is not good".



The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Factory Engineering 1950-1974

Geoffrey A Kent

g.kent@qut.edu.au

INTRODUCTION

The advancements in factory engineering that occurred in the period 1950 to 1974 are reviewed through the lens of the proceedings of the International Society of Sugar Cane Technologists (ISSCT). In 1950, ISSCT contained a single Manufacturing section which covered both Factory and Co-products commission activities. By 1953, Manufacturing had a Factory section and a By-products section. By 1956, Engineering had its own section. Some judgement has been used to identify Engineering papers in the period to 1956 and the distinction between Engineering and Manufacturing/Processing has been quite subjective in the subsequent period. The main focus of this review is on papers submitted to the Engineering section and, in particular, topics that were the subject of at least five papers in the 1950 to 1974 period.

RESEARCH ADVANCES

Cane preparation

The 1950 to 1974 period saw a transition from primarily using knives for cane preparation to utilising shredders or, more broadly, hammer mills, for cane preparation. Buchanan *et al.* (1965) and Serna Silva (1965) both reviewed factory data to conclude that better factory performance was achieved when a shredder was employed for cane preparation.

While knives continued to have a purpose in cutting whole stalk cane and were generally used as a pre-processing step before shredding, Ducasse (1974) reported on a chopper-fiberiser that did not require pre-processing by knives.

The introduction of the continuous diffusion process for sucrose extraction, particularly the cane diffusion process that requires better preparation, confirmed the benefits of utilising a shredder (Townsley and Cheatham 1965; Schaer 1974). Moor (1974) provided a useful review of the cane preparation options.

Renton (1974) reviewed cane preparation stations across South Africa and provided useful guidelines on the power requirements for cane preparation and on the relationship between power consumption and cane preparation, as measured by the preparation index.

To help understand the cane preparation process by using a small-scale shredder, Shaw (1971) and Cullen and McGinn (1974) observed the action of a hammer striking the cane and observed the cane movement from the point of contact through the grid section. Cullen and McGinn (1974) provided insights on the effect of hammer mass, hammer design and grid design.

Milling

In 1950, the three-roll mill was the most common mill design in use. Several refinements to the basic design were made. Most significantly, Fitzhugh (1950) reported on the use of hydraulic cylinders on both ends of the top roll to provide the capability to keep the top roll level by utilising different hydraulic pressures on each end. Murray (1950) reported on the use of roller bearings on mills.

Considerable advances in capacity and performance were achieved through the introduction of a range of feeding devices. Clayton (1953) and Hollywood and Clarke (1962) discussed the continuous pressure feeders that were developed in Australia and provided capacity and extraction benefits. Buchanan *et al.* (1965) discussed the introduction of vertical closed feed chutes and underfeed rolls on South African milling units.

The 1950-1974 period saw a large amount of research undertaken on small-scale mils at the University of Queensland and the Sugar Research Institute in Australia.

Jenkins (1956) used a press to explore mill power requirements.

Bullock (1956) explored the feeding of a two-roll mill with prepared cane. He measured the effect of contact angle, and also how cane rate and juice extraction varied with mill speed. Bullock and Murry (1959) furthered that work by developing a relationship between roll load and extraction and exploring the effects of compaction and preparation on roll load and extraction. Murry (1959) reviewed previous experiments to better understand the effect of preparation on extraction, cane rate and power consumption. Crawford (1962) extended the research by examining the crushing of bagasse and the effect of imbibition.

Murry and Holt (1962) and Shann (1962) focussed on the application of the learnings from the experimental mills on factory milling units. Murry and Holt (1962) developed dimensionless numbers to scale up their theories to larger diameter rolls. Shann (1962) conducted tests at a factory to measure the effect of fibre rate on extraction and power consumption. Haines and Hughes (1962) reported on a factory experiment to measure the effect of imbibition parameters on extraction.

Murry and Holt (1962) sought a deeper understanding of the extraction process, utilising a pressure pin to measure the pressure of prepared cane on the roll surface through a two-roll mill, finding that pressure peaks before the nip. Crawford (1959) and Shaw (1971) sought to better understand the extraction process, focussing on the mechanisms of reabsorption and the pressure distribution through a mill.

Understanding and modelling the extraction processes in a milling process was a focus for Douwes-Dekker (1959) and Shaw (1971). Gouws (1974) used a dynamic extraction model to examine imbibition control.

Other papers focussed on various design aspects. Gasper (1962) considered mill capacity. Buchanan (1965) and Shaw (1971) discussed mill setting. Cullen and Allen (1968) reported on an investigation into roll shaft failures.

Diffusion

During the 1950-1974 period, continuous diffusers were introduced into the sugarcane industry as an alternative to and as a supplement to a milling tandem.

Many different diffuser designs were introduced. The designs include the DDS (Payne 1962; Weng and Brüniche-Olsen 1965), Kelvin (De La Calle 1962), D-C (Díaz-Compain 1965), Egyptian (Tantawi 1965), Ring (Townsley and Cheatham 1965), De Smet, BMA, Burnett (Foster and Shann 1971), auto-diffuser, DC Segura, Saturne (Barre 1971; D'Espaignet and Rivalland 1974), FS and Huletts designs. Wu (1968) and FitzGerald and Lamusse (1974) provided reviews of the status of diffusion technology.

These early diffuser designs practised both cane and bagasse diffusion. By the end of this period in 1974, the South African industry, where adoption of diffusion technology was greatest, was moving away from bagasse diffusion and towards cane diffusion (FitzGerald and Lamusse 1974).

The first substantial investigation on the operation and performance of a diffuser was reported to ISSCT by Payne (1962) who explored the effects of cane preparation, processing rate, juice level, temperature and pH on diffuser performance. He compared diffuser juice to mill juice from juice clarification, sugar crystallisation and sugar refining perspectives.

Further experiments on the effect of operational parameters on diffuser performance were reported by Bjerager and Brüniche-Olsen (1968) who investigated the effects of pH, temperature and retention time and Graham et al. (1968) who investigated the effects of pH and temperature.

Efforts were also made to develop theory to describe diffuser operation. The earliest attempt at theory presented to ISSCT was by Freund (1968) who adapted the Silin formula for sugar beet leaching to cane diffusion. Payne (1968) took a fundamental although qualitative approach to describe the diffusion process. Rein (1971) described a mathematical model of the extraction process in a diffuser, accounting for temperature and preparation effects.

Spoelstra (1968) considered the effect of the diffusion process on bagasse moisture content and considered what can be done in dewatering mills to achieve a satisfactorily low bagasse moisture content.

Evaporation

Noel (1953) reported on the adoption of mild steel bodies for evaporator vessels, replacing the traditional cast iron material. He also reported the practice of vapour bleeding from the first and second effects as a means of reducing steam consumption.

Serbiá and Balsa (1965) and Frew (1971) both reported on new designs of entrainment separator.

De Krijger (1965) explored the heat transfer process from steam to juice across the tube wall and developed design modifications to improve the heat transfer.

Crystallisation

Venton (1950, 1953) described the types of pans in use in Queensland, Australia, being coil pans, Webre pans and calandria pans. Unlike today where calandria pans are widespread, the preference in the Queensland industry was for coil pans.

Hamill (1956), promoting calandria pans, discussed a wide range of design considerations, including the type of sugar to be produced, the purity and brix of the massecuite, the purity, brix and temperature of material to be boiled, the preferred method of forming grain, the massecuite production rate, the steam pressure, the condenser design and the type of control. Madsen (1971) described the design and construction of the Danish Sugar Corporation pan. An (1974) also discussed pan design.

Hugot and Jenkins (1959) described vacuum pan design criteria to ensure satisfactory circulation. Considerations included the diameter of the calandria compared to the diameter of the pan and the number and dimensions of the tubes.

Steam generation

Noel (1953) reported on the replacement of low-pressure (6 bar) boilers in Mauritius. The low-pressure boilers were being replaced with higher pressure (10 bar to 22 bar) boilers operating at temperatures

between 250 °C and 375 °C, and capacities of 20 t/h to 35 t/h. Arnold (1956a) discussed the introduction of air heaters, economisers, forced draft fans and water walls for higher pressure and higher efficiency, while Mathur (1968) also discussed superheaters.

Coombes (1962) discussed the problem of fly-ash separation. He discussed the introduction of water sprays to remove fly-ash and screening to remove particles from the water effluent. Cullen and Ivin (1971) reported the development of a new type of wet scrubber design and the influence of air rate, furnace pressure and fuel/air ratio on its performance. Flood *et al.* (1974) discussed the issue of meeting emission standards and the issue of dewatering fly-ash.

Summers (1956), Hall (1974) and Magasiner (1974) provided reviews of sugar factory boiler designs of the time.

Steam turbines

During the 1950s, steam turbines became recognised as promising alternatives to steam engines. Savoie and Vought (1950) reported on their installation on mills at two factories in Louisiana. Arnold (1956, 1959) and van der Linden (1965) discussed the merits of the steam turbine.

Steam usage

The importance of a steam balance between the production of steam in boilers and the consumption of steam for power production and for juice processing was well established (Constandse 1956; Singh 1956; Lu *et al.* 1968, McGinn 1971). The objective of achieving a steam balance was to reduce the need for extraneous fuel and to save bagasse for value-adding opportunities. Constandse (1956) and Batstone (1971) also discussed the importance of vapour bleeding to reduce process steam consumption.

Batstone (1971) introduced the concept of computer modelling of a factory steam system and used it to assess various vapour bleeding strategies to reduce process steam consumption.

Automation

Following the development of control technology, the 1950-1974 period saw improvements in automation in sugar factories. Hu (1968) described the concept of closed-loop automatic control for a process, that compares a signal to a setpoint and takes action depending on the error or difference between the two.

The main focus of the automation was to automate the cane carrier by automatically varying its speed (Nicklin 1956; Desmarais 1959; Gunn 1959; Hu 1968). While it was recognised as desirable that the #1 mill feed chute should be kept full, it was also recognised that there was a need to ensure that the motors of the preparatory devices were not overloaded. Hence, the early carrier controllers focussed on slowing down the carrier when the load on the preparatory drives was high.

Hu (1968) discussed automation of other factory processes. He discussed the control of steam supply and juice level and Brix in evaporators, controlling the feed into vacuum pans using conductivity, temperature control of crystallisers and automatic controls for boiler steam pressure, water level, and bagasse feed and draft. Quintero (1968) gave an overview of the range of control opportunities across the sugar factory. Sloane and Lui (1968) considered the potential applications of automation for the future.

McWhinney and Murry (1968) discussed the principles of control system design and used them to describe the development of a simulator of milling tandem performance.

Other topics

Apart from the main topics discussed above, presentations to ISSCT were made on a wide range of other topics, including cane receival, cane sampling, cane cleaning, tramp iron separation, processing soft cane, electric motors, conveyor chains, juice pump design, screw presses for dewatering bagasse, lubrication, noise, use of stainless steel, alternative extraction processes, juice heater performance, clarifier design, condenser specifications, sugar dryer design, bagasse scales, bagasse storage and handling, and electricity generation.

PROMINENT CONTRIBUTORS

The 1950-1974 period saw substantial contributions to knowledge in the fields of cane preparation, milling and diffusion.

The main contribution to cane preparation came through the experimental work of Rod Cullen in Australia (Cullen and McGinn 1974), through their experimentation with a small-scale shredder and the associated photographic analysis.

Rod Murry in Australia conducted experiments on a small-scale two-roll mill and produced models that form the basis of modern milling theory (Bullock 1956; Bullock and Murry 1959; Murry and Holt 1962; Shaw 1971).

There were many contributions to the new sugarcane processing field of continuous diffusion, with the most significant contributions in the 1950-1974 period being made by John Payne in Hawaii and whose contributions covered both factory investigations and theoretical development (Payne 1962, 1968)

IMPACT OF THE RESEARCH

Probably the biggest impact in the 1950 to 1974 period was the widespread adoption of feeding devices on milling units. Vertical feed chutes and underfeed rolls are now widely used. Many milling units are also fitted with pressure feeders. These feeding devices have enabled substantial increases in milling unit capacity and, in many cases, improvements in extraction performance.

There was a major transition in cane preparation from primarily using knives to primarily using hammers. Improved performance in terms of sucrose extraction was demonstrated through the use of shredders fitted with hammers.

Another major impact was achieved with the introduction of the continuous diffusion process as an alternative to a milling tandem for extraction of juice from sugarcane. Diffusers have been documented as having lower capital, maintenance and operational costs than milling tandems. The South African sugar industry has achieved widespread adoption of the technology and there are many other diffuser installations around the world. Improved extraction performance has been reported in many instances.

Although out of favour today except for driving generators, steam turbines offered substantial benefits in the 1950 to 1974 period, compared to both steam engines and DC electric motors. Turbines were widely utilised on cane preparation devices and milling units as well as for boiler auxiliaries. Turbines offered better control, enabling better factory performance.

The 1950-1974 period saw the early adoption of process control for automation of many factory processes. Cane carrier control was an early automation target.

The period also saw substantial developments in the factory engineering field. Shredders became the preferred technology for cane preparation and knowledge of shredders was substantially advanced by Rod Cullen and Jim McGinn. Milling technology improved substantially through the introduction of feeding devices such as the vertical feed chute, underfeed roll and pressure feeder and the

development of milling theory primarily by Keith Bullock and Rod Murry. Continuous diffusion was introduced to the sugarcane industry and knowledge of its operation and performance was developed principally by John Payne and Peter Rein.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Factory Engineering 1975-1999

Peter W Rein

peterein@gmail.com

INTRODUCTION

Factory Engineering and Factory Energy were two separate sections up until 1999 when the two were combined into Factory Engineering and Energy. Both are covered in this section. The separation into Engineering and Processing has been fairly subjective over the years, and some aspects of engineering papers find their way into the processing section and vice versa. This review excludes the relevant engineering papers in the processing section.

The 1980 and 1986 Engineering sections were relatively short on engineering contributions. The latter may have been partly because South Africans were prevented from attending for political reasons. The congress in Cuba in 1983 was not unexpectedly dominated by Cuban contributions.

The 1992 meeting addressed the declining standards of ISSCT papers and undertook to introduce measures to improve quality. This quality improvement has been achieved over subsequent years.

RESEARCH ADVANCES

The Australian technologists have regularly reported results of their experiences with milling. Their work on cane preparation and particularly heavy-duty shredding led the way, as encapsulated by Cullen's paper in 1986. This paper provided useful design insights, following earlier work published in 1974. Work was also reported on different designs of pressure feeder as well as the milling operation itself. Milling torque and power consumption also received some attention.

Various factors that affect mill capacity were dealt with in detail by Cullen and McKay in 1992. They showed that careful attention to many factors is required if the design capacity is to be achieved at the desired level of extraction. The physical size of the milling unit is the prime determinant of capacity; feeding arrangements, and power installed also play a very significant part.

The introduction of independent drives on mill rolls was introduced in this period by Farrell *et al.* (1995) in Australia and Vivas *et al*. (1999) in Colombia.

Tosio in 1992 introduced a new design of flexible coupling on mill tandems, which replaces conventional tail bar couplings. It has eliminated the problems associated with tail bar couplings and has over the years proved of substantial benefit in many cases around the world.

The cast steel perforated roll, termed the Lotus Roll, was first reported on by Bouvet in 1980. The concept of draining juice more effectively, particularly from the top roll, was claimed to improve capacity and extraction performance. Butt in 1986 reported successful use of Lotus rolls, but experience elsewhere subsequently in the longer term showed that none proved consistently successful in practice, due to the eventual clogging of the drainage holes. The concept has however been successfully resurrected in present times, with some modifications to overcome the blockage problems.

Diffusers were receiving more attention, having been given much attention in 1974. In 1980 Love and Rein presented modelling and design data to characterise flow conditions in a diffuser, based on pilot plant and industrial diffusers. Van Hengel in 1986 pointed out the advantage of diffusion in requiring less HP steam, showing that the introduction of diffusion can avoid the necessity for high-pressure boilers and matching turbogenerators, while at the same time achieving an increase in extraction efficiency. Matthesius reported on juice flow behaviour in 1986, a topic which still sometimes confuses engineers. However, Rein and Ingham in 1992 described a system for controlling interstage juice flow rates at optimum levels, by measuring liquid levels in the bagasse bed and varying the points of application of the interstage juice flows.

Wright and Valdes published information on the design of tubular heaters and direct contact heaters. The latter were neglected for many years until efforts to improve steam economy became important.

Investigations into the use of falling film evaporators in a cane sugar mill to reduce juice residence times have been considered by Bhagat and by Tobe in 1995. Poor heat transfer performance reported by Bhagat and others did not have the effect of encouraging their widespread use. The advantages of using long tube Kestner evaporators were outlined by Rein and Love in 1995 based on extensive experience in South Africa. In one instance the lower juice residence time achieved when first-effect Robert vessels were replaced by a Kestner was shown to have reduced undetermined loss by 1 %.

Developments in continuous vacuum pans have been regularly addressed. Papers on this subject have been allocated to Engineering and Factory Processing sections over the years, with no clear criteria for where they should be allocated. Langreney was one of the first to report on developments in the cane sugar industry. His 1977 paper describes all the pilot plant work done before the development of an industrial scale pan. This design had some significant subsequent adoption in the form of an annulus and found application mainly in Central America.

Broadfoot in 1986 reported on an SRI-designed continuous pan in Australia. Bosse in 1986 first reported on the BMA vertical continuous pan, now widely employed in the beet industry, but with minimal adoption in the cane sugar industry.

Rein in 1992 outlined the requirements for the successful implementation of continuous pan boiling. Techniques of continuous pan boiling have now been developed to a stage where a widespread swing to the installation of continuous vacuum pans instead of batch systems is underway. Many advantages are realized, which ultimately lead to reduced overall costs of production.

Steam economy and energy efficiency have been ongoing themes. Interestingly, in 1977 Leibig said the following: '*The world's future for energy supply does not look very bright*". Quite true in present times. Contributions varied in scope and purpose; Mason in 1992 reported on Australian concerns to ensure the energy balance did not result in a bagasse surplus expensive to dispose of, while Larsen *et al.* (1989) reported energy studies which could significantly reduce process steam and make large quantities of power available for export. The industry which first invested in large-scale export of power was Hawaii. The sugar industry there sold about 50 % of the electrical power generated, even after high internal use of power for irrigation and in cane washing plants, reported by Idehara in 1992.

Design of boilers received significant attention. Mason *et al.* in 1986 investigated boiler tube wear. They showed that gas flow velocity was a significant factor in determining the rate of wear and that the increase in local velocity as the gas passed around baffles where fitted exacerbated the problem. The use of metallic tube shields was found to be the most effective solution to this wear.

Drying of bagasse ahead of burning in boilers has been a consistent theme from 1977 onwards. Dixon and Edwards incorporated the idea of swirl burners on boilers, which can also reduce bagasse moistures. In spite of many efforts, widespread use of bagasse dryers has not been evident, because energy efficiency improvements in feed water and flue gas handling have generally been more cost-effective.

PROMINENT CONTRIBUTORS

In terms of the number of papers contributed, Vic Mason (Australia) leads the field with seven contributions in the eight Congresses considered. What is impressive is the range of topics associated with his papers, from boilers to milling to sensors/measurements and energy.

The leader in the field of extraction was Rod Cullen (Australia). His contributions on cane preparation were extensive and had a significant effect on the industry. His contributions on milling have also been most valuable.

As third leading contributor I designate Peter Rein (USA) on the basis of all technical inputs he made to ISSCT in Engineering.

IMPACT OF THE RESEARCH

Between 1977 and 1999, research in factory engineering provided tangible gains in extraction efficiency, throughput and energy management. In milling, advances in cane preparation, most notably heavy-duty shredding and optimized pressure feeders, combined with the introduction of independent drives on mill rolls and Tosio's flexible tandem couplings, increased capacity and reduced mechanical downtime. Innovations in juice extraction, such as controlled inter-stage flow systems and modified Lotus Rolls, further improved extraction performance, while diffuser refinements demonstrated that diffusion could boost extraction without requiring higher-pressure steam. In the evaporation and crystallization stages, replacing first-effect Robert vessels with long-tube Kestner evaporators cut undetermined sugar losses by about 1% and encouraged the widespread adoption of continuous vacuum pans, which lowered production costs by moving away from batch boiling. Concurrent energy-balance studies ensured mills avoided costly bagasse surpluses and, in some cases, most notably Hawaii, enabled the export of up to half their generated power, underscoring both economic and technical returns. Collectively, these engineering contributions streamlined operations, enhanced yield and paved the way for modern, energy-efficient mill design.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Factory Engineering 2000-2023

Boris Morgenroth, Harjeet Singh Bola and Saiedeh Wicht

Morgenroth@ipro-bs.de

INTRODUCTION

The Engineering section of the International Society of Sugar Cane Technologists (ISSCT) is dedicated to advancing the engineering technologies associated with the design, operation and maintenance of sugar factory equipment including cane & biomass transportation and handling, juice extraction, and power plants. Its core activities include conducting research on the development and optimization of plant machinery and processing sugar cane. By organizing workshops and webinars, the section promotes knowledge sharing among professionals, facilitating the exchange of innovative practices and emerging trends. Additionally, the section actively publishes technical papers and reports to disseminate research findings, ensuring accessibility to the broader community. Networking and collaboration are also emphasized, providing platforms for engineers, researchers, and industry experts to connect and foster partnerships that drive innovation. The inter-commission exchange at international conferences helps to achieve innovative progress in the cane sugar industry. Until 2005 the “Engineering” section was still known as “Engineering and Energy” section.

Over the 23 years, 116 papers for oral presentation, and 49 papers for poster presentation have been published in the Factory Engineering section.

RESEARCH ADVANCES

2001 Congress, Brisbane

Environmental concerns and advancements in agricultural practices have led to increased efforts to recover and utilize sugarcane trash in more sustainable ways. Hassuani made an initial approach to utilize trash that marks an important step from environmental awareness to implementation in sugar production.

Kent and McKenzie published measurements on the distribution of torque in a three-roll mill and highlighted the loss of torque via the trash plate. In this congress, several papers on further investigations and developments of mills as well as various parameters and their impact on energy consumption were analysed and presented.

A new technique was also brought up by Jensen on how filtration in cane sugar factories can be replaced by mud recirculation to the extraction station.

Other papers and posters presented related to:

- Electricity cogeneration (Mason, Australia)
- Maximising revenue from sugar extraction and cogeneration through imbibition rate regulation (Kong Win Chang and Wong Sak Hoi, Mauritius)
- Changes in green cane harvest residue during storage (Briceño and Torres, Colombia)
- Auto setting mill concept, design and plant performance (Gangavati *et al.,* India)

- Development of the Bundaberg two-roll mill (Batstone *et al.,* Australia)
- Effect of fibre and soil content on shear and friction coefficients of sugarcane bagasse (Ferraz and Pierossi, Brazil)
- Measurement and modelling loads and power consumption in Colombian sugar mills (Gómez and Echeverri, Colombia)
- How much sugar to produce efficiently in one year by (Luna *et al.*, Colombia)
- Economic maximisation of grower and miller sugar cane profits: Optimising the length of milling season at South African sugar factories (Moor and Wynne, South Africa)

2005 Congress, Guatemala City

A paper presented by Journet came at a time when the falling-ilm evaporator was emerging in the cane sugar market, highlighting optimization parameters to adapt it from the beet to the cane industry. Numerous similar publications from that period helped establish the falling-film evaporator as today's industry standard.

The study by Echeverri compared massecuite fluid flow analysis from a CFD model with experimental results from a lab-scale test rig for both batch and continuous pan operations. Findings suggested that the numerical model overestimates flow velocities compared to the experimental data.

Gómez *et al.* found that costs related to sugar losses and increased energy consumption caused by worn hammer tips are much higher than maintenance costs. Carbide volume fractions were measured in samples and specific materials were tested as hard facing alloys.

Papers were presented regarding bagasse boiler operation. For example, the paper by Lora *et al.* addressed the boiler efficiency, more precisely the optimum flue gas outlet temperature, in relation to the cost of fuel and the income from the sale of bagasse and electricity surplus. It was made clear that at the time, a flue gas temperature of 120-130 °C is optimal and well below the values measured in practice. It is particularly interesting that flue gas temperatures are still far too high in many factories today and that there is still enormous potential for optimisation in many factories.

Mann *et al.* explored the optimization potential of conservatively designed bagasse-fired boilers using CFD simulations to enhance performance and reduce maintenance costs. Their developed tool can identify and correct inefficiencies, such as airflow non-uniformities, contributing to the design of a new generation of efficient, low-cost boilers. Teixeira and Lora investigated the influence of the operating principle of boilers on the NOx concentration in the flue gas. At that time, regulations on NOx in flue gas did not apply everywhere.

Other papers and posters presented related to:
- Numerical and experimental study of the flow in vacuum pans (Echeverri *et al*., USA)
- Development and prospects for drying bagasse by steam (Morgenroth and Batstone, Germany and Australia)
- Increasing the reliability of top roll shafts (Coronado *et al.,* Colombia)
- Electro-hydraulic assist drives for sugar mills (Lewinski, México)
- Wear on top roll shaft journals (Rivas *et al.,* Colombia)

2007 Congress, Durban

The paper by Moor contained the challenges faced by sugar factories in meeting stricter environmental regulations concerning flue gas emissions from bagasse-fired boilers. It reviewed various flue gas cleaning technologies, noting that traditional methods like dry cyclones often fail to comply with new particulate emission limits. Wet scrubbers, particularly sieve plate scrubbers, have proven to be the most effective and practical solution for reducing emissions, with operational data from multiple countries supporting their superior performance. The wet and dry electrostatic precipitation

technologies were also briefly discussed for their ability to remove very fine particles at low-pressure drop. However, these technologies were extremely expensive at that time and not many references were available in the cane sugar industry. The results underline the importance of adapting to evolving environmental regulations, as compliance is critical to the sustainability of the sugar industry.

Other papers and posters presented related to:

- Cane tracking and sampling equipment (Calboutin and Naidoo, South Africa)
- Sintered alloy powder carbide and tungsten carbide materials for shredder hammer tips (Duttagupta and Rama Mohan, India)
- Fibre extracted with juice from mills – an omission in milling theory (Moor, South Africa)
- Conversion of a BMA diffuser to a Bosch projects chainless diffuser—the first season's experience (Schröder et al., South Africa)
- Detection of sugar traces in the Tongaat Hulett refinery condensates by NIR spectroscopy (Lionnet *et al.*, South Africa)
- Detection of sucrose in boiler feed water (Gooch and Wienese, South Africa)
- Integrated beet and cane sugar processing with high cogeneration efficiency (Avram *et al.*, Germany)
- Unique two-roller mill combination: The CMR mill (Nikam and Nikam, India)
- Measurements and CFD simulation of the flow in vacuum pans (Echeverri *et al.*, USA)
- Characterisation of polluting emissions from sugarcane bagasse boilers and their removal (Teixeira *et al.*, Brazil)
- Hard faced welded tips in shredder hammers (Gómez *et al.*, Colombia)
- Steady-state simulation of a complete sugar mill with an ethanol plant (Gómez *et al.*, Colombia)
- Torque signatures in crushing mills (Gómez *et al.,* Colombia)
- Economical means of improving the juice extraction performance of four-roll mills (Kent and Zapatero, Australia and Argentina)
- Cleaner production assessment in a sugar factory (Gunness *et al.,* Mauritius)
- Milling and diffusion extraction (Kent, Australia)

2010 Congress, Veracruz

Prabhakar *et al.* explore the potential of sugarcane dry trash as biomass fuel. Deccan Sugars' approach of harvesting and processing trash with sugarcane makes it suitable as boiler fuel by washing away alkali and silica, known to cause slagging and fouling. This method resulted in a 20% increase in biomass but incurred higher transportation costs, offset by the greater fuel quantity for cogeneration. The study highlights the need for further research to optimize this approach while addressing alkali-related boiler inefficiencies. Overall, crushing cane with trash offers a viable solution for enhancing power generation and reducing environmental impact.

Olivério and Ferreira examined cogeneration and bioelectricity as emerging business opportunities for sugar and ethanol mills in Brazil, particularly following government support in 2003. It discussed the Brazilian government's 2002 Proinfa initiative, which promoted investment in alternative energy sources and led to the development of three generations of technologies for efficient power generation. The paper also outlined strategies to enhance energy utilization from sugarcane, reduce energy consumption, and maximize surplus electricity production. Furthermore, it emphasizes the retrofitting potential of existing plants, which can achieve a payback period of 4-5 years, while noting the growing interest in biomass energy auctions as an indicator of the program's success.

Other papers and posters presented related to:

- Sugar mill operation with individual drives (Lewinski *et al.,* Brazil, Sweden)
- The world's largest sugarcane diffusers (Voigt, South Africa)
- Hydraulic motor of high torque with cylinders and crankshaft (Arias-Polo, Cuba)
- Comparison of diffusion and milling at a cane sugar plant (Mullapudi, India)

- Factory concepts for very low steam demand and status of implementation (Morgenroth and Pfau, Germany)
- Engineering properties of sugarcane fibres (Rodriguez Ramirez and Mendez Lagunas, México)
- Cane preparation – optimised technology (Inskip, England)
- Sugar-mill coupling developments since 1987 (Tosio, South Africa)
- Effect of added water temperature on milling train operation and performance (Kent, Australia)
- Improvements to a sugarcane road transportation system (Gómez *et al.*, Colombia)
- Ethanol dehydration system by SIFTEK™ polymeric membrane (Olivério *et al*., Brazil)

2013 Congress, São Paulo

Voigt and Bellam examined the evolution of cane preparation equipment, focusing on comparing shredders used in diffuser operations. Different regional practices were reviewed, including Brazilian, whole-stick, and Tongaat-type shredders. The study found that Tongaat-type shredders offer better cane preparation and extraction efficiency for diffusers due to more complete fibre breakdown, while whole-stick shredders are more energy-efficient but leave unprepared chunks of cane. For bagasse diffusers, longer fibres from whole stick shredders are preferred for improved juice percolation. Recommendations prioritized diffuser performance, excluding investment and maintenance considerations.

Batstone and Morgenroth investigated superheated steam drying to improve the calorific value of bagasse, enhancing its use in renewable energy and other applications. Over 9 years, full-scale trials in Australia demonstrated effective moisture control below 12%. Modelling suggested improvements to increase drying capacity. Superheated steam drying supports processes like pelletising, torrefaction, and pyrolysis, potentially increasing bagasse's value in energy production. The study concluded that this drying method could significantly boost the economic returns from sugarcane processing when integrated with milling systems.

Lehnberger *et. al* introduced a 5-effect falling-film evaporator system for a sugar factory in India, aimed at reducing steam consumption and increasing power output. Falling-film technology improves heat transfer and efficiency but requires careful cleaning to manage scaling. The paper also included the handling of non-condensable gases and the formation of scaling including chemical cleaning for the individual stages. The system reduced steam usage to 30-33% on cane.

Other papers and posters presented related to:
- Thermo-economical optimisation of a cogeneration plant of a sugarcane factory based on the marginal cost concept (Castillo, Perú)
- Effect of chute level on mill capacity (Kent, Australia)
- Advanced computer simulation of the milling process (Thaval and Kent, Australia)
- Torque and power consumption in four roll sugar mills (Lewinski *et al*., Sweden)
- Tribology for enhancing the life of sugar mill roll bearing and journal (Kharbanda and Pandey, India)
- Testing cane varieties for processability in a diffuser (Loubser *et al.,* South Africa)
- Juice extraction systems: Mills and diffusers (Oliverio *et al.,* Brazil)
- Cogeneration issues in a greenfield project (Sabadi *et al.*, Cuba)
- Determining the material properties for heavily over-consolidated bagasse through parameter estimation (Plaza, Australia)
- Innovative energy efficient milling train (Goel and Kharbanda, India)
- Reducing sugarcane juice reabsorption in sugar mills using mill rolls with internal drains (Sanchez and Chavarro, Colombia)
- On-line fibre on cane estimator for imbibition water control (Montoya *et al.,* Colombia)

2016 Congress, Chiang Mai

Lewinski *et al.* presented a method for optimizing milling operations by employing individual electrohydraulic drives for continuous torque measurement in four-roll mills. The analysis revealed that the torque in the fourth roller accounts for less than 5% of the total torque, indicating its minimal contribution to the overall load. Continuous torque monitoring serves as a practical tool for predictive maintenance and helps identify mechanical issues affecting mill performance. This approach offered a potential pathway for improving efficiency in milling operations.

Van Belzen gave an overview of project management by examining the application of multiple business models to enhance engineering project management (PM) practices, ensuring projects are completed on time, within budget, and to quality standards. Utilizing frameworks such as the Project Management Maturity Model and the McKinsey 7-S Model, the study formulated a change-management action plan based on data from literature reviews, surveys, and stakeholder interviews. The findings identified critical success factors for effective PM and proposed a conceptual model to foster a project culture aligned with predefined KPIs, emphasizing stakeholder involvement for continuous improvement.

Other papers and posters presented related to:

- Strategies for increasing availability and milling performance at Colombian mills (Cobo *et al*., Colombia)
- A classification scheme for wear and corrosion (Davy and Kent, Australia)
- Applications of CFD (computational fluid dynamics) modelling on boilers (du Toit and van der Merwe, South Africa)
- Today´s production requirements – how material selection and innovative design contribute to their fulfilment (Geyer and Lehnberger, Germany)
- Improved design of a falling-film tubular evaporator with a maintenance-friendly novel juice distributor (Goel *et al.,* India)
- Exporting electricity of 100 kWh/t of clean cane while producing white sugar (Joshi et al., India)
- Six-roll sugarcane mill: mathematical model, finite element analysis and its validation by strain-gauge measurement (Kharbanda *et al.,* India)
- Increasing sugarcane juice extraction using microwaves (Latifaltojar *et al.,* Iran)
- Enhancing milling efficiency and throughput through control philosophy (Lopez and Bhosale, Guatemala)
- Process energy value chain (Loubser *et al*., South Africa)
- Role of the JPMA mill coupling in energy conservation (Sundaram *et al.,* India)

2019 Congress, Tucumán

Kent focused on automating the control of milling tandems in sugar production using straightforward algorithms. Key components of the control system include chute-level control, added-water rate control, and the regulation of speed and torque for each mill drive. Effective factory-rate control is achieved by managing the cane level in the chute of the first mill and adjusting its speed based on factory capacity constraints. Additionally, the added-water rate should be maintained at a consistent ratio to the cane-fibre rate, with adjustments made to enhance extraction during periods of high sucrose content in the cane.

Ospina presented strategies for enhancing combustion efficiency in Colombian sugar mills, which have increased their cogeneration capacity through bagasse combustion in steam boilers. It identified key efficiency losses due to unburned fuel, high flue gas temperatures, and instabilities in steam generation, and proposed solutions through operational data analysis and Computational Fluid Dynamics (CFD) simulations. Three case studies demonstrated improvements achieved by optimizing air distribution and increasing secondary air temperature. The results highlighted the critical role of air distribution and temperature in boosting combustion performance and overall boiler efficiency.

Zamora Rueda *et al.* characterized the energy content of sugarcane bagasse, a key waste product in Tucumán's sugar-alcohol industry, used as fuel for thermal and electrical energy generation. Analysis of bagasse samples collected during the 2017 and early 2018 harvests revealed significant moisture, ash, volatile solids, and calorific values, following standard methodologies for accuracy. The findings provide valuable insights for designing and optimizing steam boiler systems to enhance energy efficiency in sugar production.

Other papers and posters presented related to:

- Vinasse incineration with bagasse as a supporting fuel (Awasthi *et al.*, India)
- Evaluation of control strategies in sugarcane mills through dynamic simulation (Pantoja, Colombia)
- Enhancement of mill performance by adopting low-speed milling in the sugar industry (Chandgude and Patil, India)
- Fibrous sorghum as an alternative fuel during the off-harvest sugarcane season in Tucuman, Argentina (Cruz *et al.*, Argentina)
- The 2015 Pongola Silo Failure and the use of cascade sugar drying to re-establish refined sugar conditioning capacity (Lawlor and McAdam, South Africa)
- Analysis of milling operation with electro-hydraulic individual drives in the Ferrari sugar mill (Lewinski, Sweden)
- Improvements to bagasse combustion (Mann, Australia)
- New sugarcane-mill misalignment coupling (Matosevic and Veljovic, Croatia)
- Process design and equipment selection for optimized steam and power concepts – the “zero” process steam sugar factory (Morgenroth *et al.,* Germany)
- Design and implementation of a starting system for a sugarcane shredder (Munoz, Colombia)
- Implementation of a variable-frequency drive for a fibrizer to achieve the ideal preparatory index (Patil and Chandgude, India)
- Improving energy efficiency in an existing sugarcane factory (Ramaru *et al.,* South Africa)
- Experience gained from perforated mill rolls in Réunion (Roussel *et al.,* France)
- Use of filtering nozzles in sugar mill XM-type rolls (Sanchez and Chavarro, Colombia)
- Reduction in bagasse moisture and improvement in mill extraction by controlling reabsorption of juice in mills (Sundaram *et al*., India)

2023 Congress, Hyderabad

Foxon presented a shortcut method for estimating boiler steam costs for steam bleeds that can effectively estimate the impact of an increase in a single utility stream and predict how changes in steam quality in another process will affect boiler steam demand, with an accuracy of 5%. This method is suitable for quick assessments of energy costs and savings; however, it should not be used as a substitute for a comprehensive energy analysis when a design change or investment is being considered.

Other papers and posters presented related to:

- A new sugar complex designed to provide maximum raw material to a paper industry (Awasthi *et al.,* India)
- Implementation of a first-mill cane-feeding control strategy based on a cane-harvest system (Pantoja *et al.,* Colombia)
- Degradation modelling of and optimising the timing of replacements for batch vacuum pans (Horner e*t al.,* Australia)
- Low-temperature dryers in the cane sugar industry (Kimmenauer and Szymkiewicz, Switzerland)
- Application of a hydrostatic transmission in cooling crystallisers (Lewinski *et al.,* México)
- Effect of imbibition water temperature on tandem mill extraction (Munoz *et al*., Colombia)
- Power generation in the Indian sugar industry using segregated urban dry waste as an auxiliary fuel (Raskar and Kshirsagar, India)

- In-house C massecuite reheater: a successful development for Le Gol sugar factory (Riviére *et al.*, France)
- Influence of two-roller mills in enhancing the efficiency of conventional milling tandems (Sakhardande *et al.*, India)
- Modelling the extraction performance of a diffuser station (Thaval, Germany)
- Engineering concept for combined refinery operations with cane sugar milling (Thaval, Germany)
- An innovative hybrid dryer for bagasse incorporating waste-heat recovery and flue-gas cleaning (Verma *et al.,* India)
- Evaporation and concentration at low temperatures using plate-type evaporators based on a mechanical vapour-recompression system (Verma, India)
- Low-temperature bagasse applications for fuel saving and power export (Wicht *et al.*, Germany)

PROMINENT CONTRIBUTORS

Many authors have made significant contributions during 2000-2023, whose importance for the cane sugar industry has been assessed accordingly.

Geoff Kent made an outstanding contribution with a focus on the topic of extraction with mills and diffusers with 10 publications as an author or co-author as well as in his role as chairman and member of the Engineering Section.

Boris Morgenroth contributed outstanding publications (six papers) on innovative process operation schemes and new technologies as an author or co-author as well as chairman and member of the Engineering Section.

Juliusz Lewinski contributed five outstanding publications on the subject of mill drives as well as in his roles as ISSCT Factory Commissioner and chairman and member of the Engineering Section.

IMPACT OF THE RESEARCH

This most recent period of ISSCT history introduced a range of innovations. The period saw the introduction of falling-film evaporators into the sugarcane industry and shredder designs for both whole-stick and billet cane.

Energy efficiency has become much more important for the design of factories with steam on cane around 30%. Energy efficiency technologies such as superheated steam drying of bagasse have been investigated. The use of bagasse for cogeneration and the collection of trash to enhance cogeneration have also been discussed.

In terms of improved understanding of the process, considerable advances have been made in milling through the understanding of mill behaviour through individual roll drives and through improved control. Advances in understanding boiler operations have also been made leading to improved and more efficient combustion and lower emissions.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Factory Processing 1924-1938

Steve Davis

sdavis@smri.org

INTRODUCTION

Although the structure of the 1924-1938 congresses was somewhat different to the current structure, papers dealing with topics relevant to factory processing in the "Manufacturing Section" were identified, and the highlights are presented here. The increasing interest in and attendance at the ISSCT Congresses over the years is evident from both the steadily increasing numbers of papers presented and the increasingly detailed technical content.

RESEARCH ADVANCES

1924 Congress, Hawaii

One session was held on "Factory Operation and Control in Sugar Cane Factories", the processing section of which mostly concerned juice clarification and various methods and chemical additives employed to produce good quality juice. There was also some discussion about methods of calculating the performance of factories and assessing cane quality in terms of "Pure Obtainable Sugar Content" in cane, at the end of which it was resolved that it was desirable to establish and adopt a uniform system of calculating and reporting factory data.

1927 Congress, Cuba

Clarification of juice was again a major topic of interest, with representatives from the Hawaiian, Puerto Rican and Philippines industries discussing current practices. There was particular interest in how to deal with "refractory" juices, and the use of electrical instruments to determine best flocculation practices and liming control through pH measurement. A further discussion was held on methods of boiling sugar, a perennial subject that covered various boiling schemes and their benefits, as well as methods of seeding pans. The schemes used varied from country to country, with some using a two-massecuite system and others a three-massecuite system. Concerns with keeping qualities of raw sugars were also discussed, where most raws had polarisations in the range 96-97°Z. False grain and poor filterability appeared to be the major concerns, which were often associated with high moisture levels.

1929 Congress, Indonesia

This congress included an extensive report from the Special Committee on Uniformity in Reporting Factory Data, chaired by Dr FW Zerban, in which recommendations for reporting calculations and definitions were proposed, including standard sugar processing definitions and terms in English, Dutch, French and Spanish. There was also some discussion about juice clarification methods for pol analysis, followed by a request to re-establish the Committee on Uniform Methods of Sugar Analysis (predecessor of ICUMSA), which had last met in 1912. Furthermore, it was resolved that all sugar

producing countries should adopt the metric system for field and factory measurements, and that all ISSCT publications should use the metric system.

Pieter Honig presented a paper discussing various non-sugars present in sucrose crystals, specifically iron and calcium salts and colour impurities, and how they were incorporated into the crystals. Related to this, Kees Douwes Dekker gave a detailed description of the formation of colour from reducing sugars under alkaline conditions – this remains a valuable record of the chemistry of these reactions.

1932 Congress Puerto Rico

One of the highlights of this congress was an extensive symposium on crystallisation held over two days, at which several “bulletins” were presented, leading to much discussion. Noel Deerr presented, in Bulletin 2, a derivation of the well-known “SJM” formula for calculating the split of sucrose between sugar and molasses, which is still used every day in factory calculations. There were some discussions about the effects of impurities on sugar crystallisation and the impacts on filterability of sugar solutions, perennial topics that are still of relevance today.

“Recent progress in evaporation” was discussed by Webre who had the contract for additional boiling house apparatus as part of the Clewiston sugar factory rebuild in the USA. The factory engineer could consider this to be “a distinct step backward”, as the previous quadruple effect system had been replaced with a triple effect system. However, there was an overall improvement in steam balance, with the vacuum pans now operating on lower pressure vapours, resulting in better steam economy and less colour formation because of lower boiling temperatures. Detailed process flow diagrams and results were presented to substantiate the claims.

A comparison of the two-strike and three-strike boiling systems in Peru was presented by Neumann, with detailed calculations to show that the three-strike system was far superior. Other papers discussed sucrose supersaturation and methods of monitoring and controlling it during pan boiling, especially with regard to impure solutions. Harman of the Colonial Sugar Refining Company in Australia discussed a method of determining saturation temperatures and supersaturation coefficients, comparing it with previously published methods, and noting that its use in factories had benefit in improving cooling rates in crystallisers.

In an early semi-commercial paper (Bulletin 103), Powe of Oliver United Filters discussed various types of filters used in sugar factories and refineries, in particular comparing the commonly used plate-and-frame filters with the continuous Oliver-Campbell Cachaza Filter. Detailed performance and cost comparisons were presented by way of demonstrating the benefits of continuous filters.

Another perennial topic of debate among sugar technologists, molasses exhaustion, was expounded upon by Davies of the Trinidad sugar industry (Bulletin 121). A review of literature on the topic was followed by results of detailed experimental work that had been undertaken, and it was concluded that correlation of exhaustion with water content was most reliable, and that other proposed correlations based on glucose/ash ratio or ash percent non-sucrose were unreliable due to the great variations in the nature of ash in molasses. It was acknowledged, though, that the correlation derived was of most use in monitoring a single factory’s performance and was of limited use in comparing different factories.

Zerban reported (Bulletin 125) in detail on the work of the Special Committee on Uniformity in Reporting Factory Data, with emphasis on the boiling house and analytical methods. It is noteworthy that the report included the statements “It is hardly necessary again to repeat the now commonplace statement that the entire control should be based on sucrose rather than pol figures.” and “The committee is unanimous that sucrose should be determined and reported for mixed juice and for final molasses.” Ninety years later, pol is still being used in many factories! Various definitions of boiling house and overall recovery were discussed and recommendations made which should be adopted. Also discussed were recommended methods of weighing and sampling various factory products and streams, while noting that methods of weighing bagasse was an important problem that had still not been solved.

In an early example of the type of review paper that is always welcomed by sugar technologists, Farnell gave a comprehensive review of the various types of massecuite crystalliser in use worldwide at the time with detailed drawings (Bulletin 129). These were all horizontal water-cooled types, some of which may still be in use today, such as the Werkspoor design that the author favoured, but the diversity of designs at the time was interesting.

1935 Congress, Australia

The Manufacturing Section was opened by Simmons of the Colonial Sugar Refining Company, Australia, who provided details about the development and testing of a method for controlling lime addition to mixed juice using on-line pH measurement, in those days using a combination of calomel and antimony electrodes. The results presented showed reasonably good pH control in the days before advanced electronics and control systems were available. This was followed by a paper from Khainovsky discussing methods of liming control that were tested in the Javan industry. Several technical problems encountered were listed, mostly relating to the unreliability of electrical components at the time. The accuracy of pH control achieved in the factory did not seem to be as good that reported by Simmons in Australia.

Further work on the exhaustion of final molasses was presented by Micheli and de Gyulay, also of the Colonial Sugar Refining Company, including details of the experimental exhaustion procedure and the effect of the impurity/water ratio on equilibrium molasses purity. Fifteen molasses samples from various sources were tested, which confirmed that the nature of the impurities has a significant effect on the exhaustibility of the molasses.

A symposium on sugar boiling was held, consisting of four separate papers dealing with methods of controlling boiling with different grades of massecuites and various methods of seeding pans. The use of the relatively new technique of conductivity measurement to monitor and control pan boiling in Queensland was discussed at some length, which was concluded to have delivered great benefit to the mills that had tried it. This was followed by a review of the Java experiences with the method by Honig, who emphasised the need for skilled sugar technologists to get the best out of pan boiling.

One of the core unit operations of sugar factories, evaporation and steam usage, was discussed at length by Neumann in terms of an extensive factory trial that he had carried out. Detailed mass balances were presented to show the effect of increasing the crushing rate on the evaporator station performance and proposed additions of “pre-evaporators” to achieve the required evaporation rate. Considerable debate ensued and there was some disagreement about the conclusions. This was followed by an exposition of the influence of hydrostatic head on boiling in evaporator and pan tubes by Webre, who started with a statement to the effect that “It is much easier to bring about the adoption of entirely new ideas than it is to cause revisions of generally adopted concepts after these have proven to be totally unsound.” Webre concluded that many pans may experience local undersaturation due to a poor understanding of the principles, leading to unsatisfactory massecuite quality.

A second symposium was held on the refining quality of raw sugar, during which four authors presented their experiences with determining causes of poor-quality raw sugar and changes made in respective raw sugar mills to improve quality. Good clarification was highlighted as essential, along with the need for good pan boiling practices to achieve clean and uniform sugar grains, although the negative consequences of poor-quality sugarcane were also mentioned. The symposium concluded with an extensive discussion on the most meaningful analytical tests to determine juice and sugar quality.

1938 Congress, Louisiana

The Milling Section opened with the report of the Special Committee on Uniformity in Reporting Factory Data, chaired by Dr Zerban. There were various updates reported, and a re-emphasis by Deerr that sucrose-based rather than pol-based or mixed sucrose and pol-based control was strongly

recommended. There were further discussions on the always contentious pol in bagasse measurement method, with no firm conclusions being reached. Later in the session, Kelly and Newman of Australia presented a paper outlining their investigations into the use of a conductimetric method of soluble ash determination, with very promising results. This was followed by an interesting paper by Kopke of the USA demonstrating a graphical analysis of sugarcane milling operations, showing profit/loss as a function of tonnes of cane crushed, taking into account the various operating costs and factory efficiencies. Several cases were presented, showing the impact of different scenarios.

Clarification of mixed juice, especially refractory juices extracted from “problem” cane varieties, was the subject of two papers. The first, by Davies of Trinidad, reviewed the chemistry of clarification and what impurities were associated with poorly clarifying juices. Low phosphate content was identified as a major factor, as was high silica content. He then presented results of the use of the Fractional Liming and Double Heating process that had been used to benefit in several countries where refractory juices had been encountered, concluding that this process was preferable to others in such cases. This was followed by a paper by Moore of Antigua describing how automatic pH control of liming in the Fractional Liming and Double Heating process had been successfully applied in Antigua. Several challenges were encountered with both the electrical and mechanical systems, but these were successfully overcome by the ingenuity of the factory technologists and engineers, and the factory was able to achieve reasonably good clear juice pH control and a reduction in ash in final molasses.

Continuing a discussion from the 1935 Congress, Webre of the USA described benefits to be achieved using a two-boiling system, noting that the three-boiling system was in almost universal use “in the tropics”. In particular, he advocated full seeding of A-pans, rather graining on B-magma and the use of ground sugar as seed rather than collected sugar dust. He also included several practical suggestions for good pan operation, illustrated with a diagram of what he considered to be the ideal pan, although the audience did not consider that anything really new had been presented.

Deterioration of final molasses in storage was the subject of two papers, one from the Egyptian industry and the second from another renowned sugar technologist, Prinsen Geerligs. Various mechanisms and causative factors were suggested, but principal among them were concentrating the molasses to high brixes and high storage temperatures. In some cases, this led to slow deterioration of the sucrose and glucose, but in other cases, rapid decomposition was noted, leading to violent gas emission and ultimately charring. Although the reactions were not detailed, these were examples of Maillard and decarboxylation reactions, well known and feared among modern sugar technologists.

Deterioration of a different kind was the subject of a paper by McCalip and Hall of the USA, in which they outlined the effects of the bacterium *Leuconostoc mesenteroides* on the frosted cane crop of 1937. The bacterium was responsible for the loss of sucrose and production of dextran, leading to severe processing problems in the factories. Samples of infected cane were transported to a microbiology laboratory in Washington, DC, where detailed investigations were undertaken. Various chemical agents were tested for their efficacy in clarifying synthetic juices with added dextran. Various methods of determining the effect of dextran on viscosity were discussed, and the sharp increase in viscosity with increasing dextran content was evident, and at least a partial explanation of the difficulties encountered in boiling high dextran massecuites. A gummy syrup from a Louisiana factory was shown to have a viscosity four times higher than a second sample of the same syrup from which the gums had been removed. Although various procedures were tested, it was shown that removal of dextran from juices using variations of typical clarification methods was not effective, and no cure could be offered.

On a similar topic, Micheli and de Gyulay of Australia presented the results of a detailed investigation into the relationship between the viscosity and supersaturation of sugar syrups and molasses over a range of temperatures and concentrations. Suggestions were offered as to how the data presented could be used to make informed decisions with respect to the treatment of low grade massecuites prior to centrifugalling.

Fort of the USA presented a comprehensive analysis of the relationships between impurities in syrups and impurities in the sugars produced from them, including colour, soluble ash components and silica.

The effect of washing sugars on impurity concentrations was discussed, and it was noted that the effectiveness of washing was dependent on the individual impurity. Meade of the USA then reviewed the use of phosphoric acid in cane sugar manufacture and refining, noting the importance of the quantity and quality of the phosphates added for good clarification.

A comprehensive discussion of centrifugalling of all grades of massecuites was presented by Stevens of the USA. This probably represents the state of the art in centrifuge operation at the time and the detailed results included would have been very useful to the industry in those days. Later in the session, Waddell of the Philippines shared the results of factory trials that had been undertaken to investigate various ways of treating low grade massecuites prior to curing, while noting the difficulty in conducted well-controlled trials in an operating factory. Several practical observations and recommendations were presented for those trying to improve final massecuite exhaustion.

PROMINENT CONTRIBUTORS

This era stands out as the heyday of many well-known sugar technologists who left a considerable legacy of their work, such as Noël Deerr, Kees Douwes Dekker, Pieter Honig, George Meade, Charles Perk, H.C. Prinsen Geerligs and Frederick Zerban.

Three significant contributors to the advancement of sugar processing knowledge during this time are considered to be the following.

Frederick Zerban: For much of this period, he chaired the Special Committee on Uniformity in Reporting Factory Data, which worked hard between congresses to discuss, develop and introduce uniform methods of measurement, analysis and calculation of factory performance figures. This work led to better understanding of factory performance and benchmarking of operations, leading to improved recoveries.

Pieter Honig: Well-known to sugar technologists worldwide through his multiple volume handbook “Principles of Sugar Technology”, Honig was stationed in the Java sugar industry during this review period. He was a regular contributor to ISSCT congresses, sharing his extensive knowledge of the principles and best practices of the clarification, evaporation and pan boiling sections of the factory.

Alfred Webre: He had a special interest in evaporation, pan boiling and crystallisation and was a regular author of papers on these topics at ISSCT congresses. He was not afraid to challenge conventional wisdom, but his ideas were always backed up with sound science and calculations. He also designed a type of batch pan that was named after him, with multiple stirrers to ensure good massecuite circulation throughout the boiling process.

IMPACT OF THE RESEARCH

The Special Committee on Uniformity in Reporting Factory Data by F Zerban introduced consistent definitions, calculation methods, and metric measurements for all factory stream practices that underpin today’s benchmarking and yield analysis systems in standardizing data and terminology. Innovations in juice clarification, such as fractional liming, pH-controlled flocculation, and double-heating processes, improved raw-sugar purity and Noel Deerr’s derivation of the “SJM” sucrose-split formula remain a daily calculation in factories worldwide. Early adoption of electrical pH probes, conductivity meters and detailed process-flow diagrams fostered the move toward automated control systems, reducing variability in boiling and evaporation stages. Symposia on boiling schemes, molasses exhaustion and filter technologies encouraged cross-regional learning, solidifying a global community of sugar technologists whose practices still reflect these foundational studies.

Collectively, these contributions laid the scientific and operational groundwork for efficient, high-quality sugar manufacture that endures in contemporary mills.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Factory Processing 1950-1974

Ross Broadfoot

r.broadfoot@qut.edu.au

INTRODUCTION

During the nine Congresses that were held between 1950 to 1974, major advances were made in factory processing technologies. There was a strong focus on developing systems to provide uniformity in reporting factory performance, in increasing sugar recovery, improving processing efficiencies and equipment designs, reducing environmental impact and in improving factory processing operations to produce sugar of higher quality. During the period most aspects of factory processing, from processing the juice extracted at the milling train through to the storage of raw sugar, received attention. The latter part of this period was the era when digital computers started being used for mathematical modelling, for assisting equipment design and for developing a more fundamental knowledge of factory processes. Factory automation took large steps forward.

Importantly, great advances were made across most areas of factory processing and this is testament to the contributions of the ISSCT Congresses in recording and disseminating the works from the many eminent sugar technologists of the period.

RESEARCH ADVANCES

1950 Congress, Australia

At the 1950 Congress Bosworth and Duloy discussed the use of two methods to measure the rate of circulation of massecuite in vacuum pans viz., a previously used method utilising the cross-correlation response of two conductivity probes placed 1 m vertically apart and a superior method of hot-wire thermocouple anemometry. Webre discussed the use of mechanical circulators to improve the operation and control of batch vacuum pans. The Congress also included noteworthy papers by Honig on the composition of scales formed in evaporators, Powell on the procedures to maximise the exhaustion of low grade massecuites, and Selman on the importance of controlling the juice level in evaporators to maintain strong heat transfer performance.

A major topic for discussion at the Congress was the report from the Special Committee on the Uniformity in Reporting Factory Data, as presented by Zerban. This report was the culmination of work for which the initial report was discussed at the Congress in 1935 and amended at the Congress in 1938. However, due to disruptions by World War II, the Congress in 1950 was the first opportunity at ISSCT to review progress and attempt to gain consensus. This report promoted Deerr's formula for calculating Reduced Boiling House Recovery. A paper by Gundu Rao was presented at the Congress describing an alternative formula for Reduced Boiling House Recovery. Subsequently it was decided at the Congress to give more time for consideration of the two formulae.

1953 Congress, Jamaica

Discussion continued at the 1953 Congress on calculating Boiling House Recovery. Zerban provided a report from the Special Committee on Uniformity in Reporting Factory Data. The main focus of this discussion was to report on the survey of responses to the use of the Gundu Rao method compared with the Deerr method for calculating Boiling House Recovery. The results were fairly evenly split between the two methodologies and the main conclusion was that both methodologies would be improved if the effect of the composition of the non-sugars in molasses was incorporated into the methodology to determine molasses exhaustability. Douwes-Dekker proposed that a target purity for final molasses which would account for the effect of the composition of the non-sucrose should be incorporated into the calculation of boiling house performance. His analysis examined the recovery formulae of Carp and Winter.

This Congress also heard interesting presentations on procedures to use inhibitor chemicals to reduce the incidence of scale formation and also chemical cleaning of heating surfaces. Keller discussed evaporator cleaning using caustic soda firstly, followed by acid (HCl). The possible use of sulphamic acid was also discussed. Interestingly these methods are still widely used today.

Yearwood presented a comprehensive review of control methods across all process stations from mixed juice through to final sugar production. The review was a collation of principles used by technologists at several factories in the British West Indies Sugar Association.

1956 Congress, India

The Factory Processing Section of the 1956 Congress is notable in terms of the prestigious line-up of famous technologists including Pieter Honig, K Douwes Decker, MC Bennett, FHC Kelly, HG Kulkarni, SN Gundu Rao, JH Payne and GE Sloane. This Congress was characterised by presentations on several groundbreaking topics.

Bennet *et al.* described the use of the chelating agent EDTA as being highly suitable for dissolving inorganic scales on evaporator tubes. The paper also described the procedure to regenerate EDTA, thus avoiding the need to purchase fresh chemical for each chemical clean. Crawford and Shann investigated the heat transfer coefficients in juice heaters of the shell and tube type, and established relationships for the dependence on juice velocity.

Davies determined that the juice velocity (and absence of convective currents) and the size of the flocculated particles were the key process requirements for an effective use of continuous defecation clarifiers. Hence, it was recommended that the clarifiers should incorporate flocculating chambers to ensure the particles were of sufficient size to provide settling against the upflowing juice stream. Douwes-Dekker chaired a symposium on juice clarification. Storrar provided details for a continuous flow clarifier (as distinct from the previously used intermittent clarifiers) based on the multiple sloping tray design.

Pieter Honig continued the discussion on boiling house recovery in a paper which explored the effects of reducing sugar and ash on the limiting purity value of exhausted final molasses. This paper makes mention of the ideal viscosities of mother molasses in C massecuites in feeding batch centrifugals. Gundu Rao and Kulkarni presented further refinement on the boiling house formulae discussed at previous congresses.

Kelly investigated the melassegenic effects of various non-sucrose components on sucrose solubility and crystallisation behaviour. The ratio of reducing sugars/ash was proposed as a measure of the non-sucrose effects on the exhaustion of final molasses.

Marches provided details for the preparation of lime saccharate to suit pH control of juice prior to defecation. On a similar topic, Honig discussed the chemical reactions taking place in limed juice.

Perk provided a detailed examination of the operation of condensers.

Wise and Nicholson reported results of studying the solubility of pure sucrose solutions across the temperature range 20 to 80 °C. A solubility cell was constructed to determine the effect of KCl on the solubility of sucrose. At low concentrations of KCl the solubility of sucrose is decreased but, at higher concentrations, the sucrose solubility is increased. Interestingly, this pattern of influence of non-sugars is now widely accepted to describe the solubility coefficient of both beet and cane sugar solutions.

1959 Congress, Hawaii

The 1959 Congress contained many papers focussing on the growth rate of sugar crystals (Foster; Smythe; Albon and Dunning; Golovin and Gerasimenko; Napper and Alexander; Powers), measurement of the supersaturation level (Rush and Meredyth), inclusions of impurities (non-sucrose) in the crystal lattice (Tu and Onna; Tu *et al.*), the factors affecting the shape of crystals (Sheftal and Gavrilova), the formation of fine grain and its effects (Raha) and pan circulation (Hugot and Jenkins). Fundora and Mascaro discussed aspects related to the boiling scheme. This Congress was obviously an important step forward in increasing the knowledge of crystallisation of sugar and provided a strong basis for subsequent research, as presented in the following Congresses.

1962 Congress, Mauritius

The 1962 Congress covered a wide range of topics including investigations into qualities in raw sugar including colour and filtrability (Douwes-Dekker; Tu *et al.*). Three papers (Davis and Clarke; Foster; Proskowetz and Chen) described investigations into the removal of sludge from A and B molasses. Foster and Wright continued the investigations of the previous Congress on crystal growth rates.

Burgess *et al.* described the use of a laboratory method to assess the settling rate of mud particles. The procedure allowed the various parameters that affect the settling rate in limed juice to be evaluated and settling rates improved.

1965 Congress, Puerto Rico

The 1965 Congress was characterised by papers across a wide range of topics and no theme emerged where several papers dealt with a similar area of technology. The papers covered sludge removal from molasses (Chen and Proskowetz), procedures for ‘safe’ storage of juice at weekend stops (Saint Antoine and Vignes), factors affecting the quality of crystal sugar (Moritsugu and Payne), precipitation of non-sugars during juice concentration (Honig), gas formation in final molasses (Honig), colour formation in evaporator syrup (Tu and Payne), use of resistance heating of C massecuites prior to centrifugalling (Wright), use of magnesia as an alternative to lime to increase juice pH prior to clarification (Hamilton and Payne) and the incorporation of insoluble particles within raw sugar crystals (Tu).

A meeting of the Committee on Uniformity of Reporting Factory Data (Clayton) discussed the relative merits of the Gundu Rao and Deerr formulae for calculating the boiling house recovery. Support existed within the committee for each formula with the Gundu Rao formula being adopted.

1968 Congress, Taiwan

A strong theme in the 1968 Congress was the application of computers for problem solving and also for process control. There were many papers on the topic, with many focussing on improvements in batch pan control. The technologists from Taiwan and Japan were particularly progressive in this application.

At the Taiwan Congress several authors (Hu, Hughes, Lu, Ruy, Sloane) presented papers on the automation of factories. Automation based on feedback control (proportional, integral and derivative) had become established in processing industries in the preceding decade and the sugar industry was embracing the change and opportunity, including the use of digital computers in process control. Interestingly the discussion included comments on the suitability of centralised control – something cane factories around the world are discussing earnestly at present for overall factory control, particularly by embracing AI and machine learning to provide supervisory assistance to factory operations. Other topics that were discussed in the context of factory automation were the requirements for more knowledgeable operators/supervisors and the training of operator/supervisor staff. Ultimately, the focus turned to the need for measurement systems in key sections of the process.

Mori and Umetani described the development of dynamic modelling of a batch pan and its application for pan control in the newly constructed Nagoya Sugar Refinery Company. It is noteworthy that the system employed an in-pan microscope to allow monitoring of the crystals from the control room. The refinery required one pan stage operator to manage seven batch pans. This was certainly ground-breaking work at the time.

Wright and White presented a mathematical model to describe the operation of a batch vacuum pan to allow predictions of performance under changed processing conditions and to determine improved control procedures. The model was solved on a digital computer.

Ziegler described the use of consistency (mobility) and boiling point elevation in pan control.

As is usual for most Congresses there were papers related to the quality of sugar product. These papers included topics on the inclusion of impurities into the crystals (Delavier and Hirschmuller; Yamane, Suzuki, Kaga and Takamizawa), raw sugar colour (Munday, Burgess, Aimes and Davis) and filtrability of sugar (Lee, Tu).

1971 Congress, Louisiana

At the 1971 Congress there was a strong focus on the origin of colour in sugar, methods for colour analyses and identification of the types of colour and processing options to remove colour. Farber and Carpenter identified colour pigments present in the cane supply that persist through to raw sugar and even in the first-strike boiling in refineries. Smith and Gregory developed analytical procedures to identify colour compounds. Chen observed the colour development during processing was often associated with a reduction in invert concentration and attributed to the browning reaction (the Maillard reaction). A detailed study of the development and optimisation of the Talofloc process was provided by Bennett, Gardiner, Abram and Rundell for colour removal in syrup flotation using cationic surfactants at optimised dosing rates.

The other major topic of the 1971 Congress was the generation of liquid effluent and treatment procedures to reduce the impact of factory discharges on the environment. Frew described a double layer louvre system that would coalesce droplets of juice entrained in the vapour upflow stream of evaporators, thus producing a less contaminated vapour (and condensate). This de-entrainment system, and several variations of the design, are commonplace today in evaporators and pans in many cane and beet factories. Miller investigated the use of mechanically aerated ponds and Bevan investigated the use of activated sludge plants using surface aerators to reduce the BOD loading prior to discharge.

Two other papers at the 1971 Congress were major forerunners for sugarcane processing. Tilbury described the use of dextranase to substantially eliminate dextran present in juice extracted from deteriorated cane, and so substantially reduced the harmful effects of dextran on processing operations. Hale and Whayman described the results of a trayless defecation clarifier which provided 4-6 times the juice processing throughput per unit volume than the conventional multitray type clarifiers. The design incorporated multipoint feed and takeoff systems using concentric launders and an annular feedwell.

This design was the forerunner of the SRI (Sugar Research Institute) clarifier and variants, often termed SRT (Short Residence Time) clarifiers.

1974 Congress, South Africa

The 1974 Congress was characterised by a wide range of factory processing topics, without any common theme. The presenters certainly introduced some very important technologies, operating principles and foundations for further advances in factory processing. Kelly presented a list of 13 raw sugar quality parameters that impact on the costs of refining. This list has been adapted, and to some extent simplified by many cane industries to define the specifications for raw sugar sales (for export and for direct sales to customers). Tu *et al.* investigated how high and low molecular weight colorant levels change as cane juice is processed into sugar and which colorants end up in the washed raw sugar crystal. Samaniego and Solaiman studied the development of colour during the long-term storage of sugar and concluded caramelisation was the predominant mechanism.

The strong interest in improving the productivity of pan stages was again addressed; this time by Batterham *et al.* who investigated the optimal control of vacuum pans and Wright and White presented the results from a mathematical model of vacuum pan crystallisation.

Whayman and Crees studied the effects of the molecular weight and degree of hydrolysis of partially hydrolysed polyacrylamide flocculants on the settling rate of mud particles. This information proved to be highly important for effective defecation clarification performance.

Following the disastrous failure of a pan stage cut-over pipe during a steam-out operation, Foster studied the mechanism for failure and determined that the exothermic Maillard reaction could generate very high (disruptive) pressures when massecuites are heated and contained in closed or blocked pipework. The severity and speed of the reaction was greatest in C massecuites because of the high concentration of non-sugars. This study provides critical information that should be adopted by all process technologists. As a result of this study, Australian factories adopted the practice to flush cut-over lines with clarified juice, as the use of steam to remove blockages was prohibited.

PROMINENT CONTRIBUTORS

During the period 1950 to 1974 the Processing Section was blessed with many highly-distinguished technologists whose contributions are the foundations of many technologies and procedures in use today. Three highly-influential technologists and their enduring contributions are listed below:-

K. Douwes-Dekker for his work in defining methodologies for boiling house recovery assessment and his pioneering work in establishing a target purity for final molasses to help define pan stage exhaustion performance.

P. Honig further developed the procedures to define boiling house recovery and investigated the effects of reducing sugars and ash on the limiting purity of final molasses. Honig also investigated the chemical reactions occurring during the liming of cane juice and so provided foundations for improvements in juice clarification.

M.C. Bennett for his use of EDTA for dissolving inorganic scales on evaporator tubes and importantly, in defining procedures to regenerate EDTA and so reduce the disposal of spent chemicals.

IMPACT OF THE RESEARCH

The Proceedings of the ISSCT Congresses 1950 to 1974 provide an excellent source of technical information for factory processing technologists. The articles plot the path of technical developments in factory processing as laid out by many eminent technologists. During the period there was a strong

focus on developing systems to provide uniformity in reporting factory performance, in increasing sugar recovery, improving processing efficiencies and equipment designs, reducing environmental impact, and in improving factory processing operations to produce sugar of higher quality.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Factory Processing 1975-1999

Gillian Eggleston

geggleston@agcenter.lsu.edu

INTRODUCTION

The period 1975 to 1999 represents an innovative period of research and development advances in processing for the global sugarcane industry that continue to have tremendous impact today. New analytical techniques including high-performance liquid chromatography revolutionized our understanding and measurement of sugar and impurity components of cane products, and this knowledge has underpinned further processing developments. Such developments include reducing expensive sucrose losses in the factory and how to separate and remove specific impurities at the factory and refinery. Near-infrared spectroscopy (NIRS) was introduced in this time period and more and more sugarcane producing countries are using this fast and accurate technique, particularly in cane payment systems. Continuous-pan technologies were developed and started to be adopted at factories, and factors affecting crystal growth, size, and shape were elucidated. Improvements in cane milling at factories also occurred, such as the increased use of heavy-duty shredders to improve cane preparation, larger heavy-duty mills, Lotus rolls, Donelly chutes, underfeed rolls, L scrapers, flangeless rolls and welding on rolls to increase drainage, throughput and extraction. Improvements in steam economy occurred in global sugarcane factories by using more evaporators in evaporator stations as well as bleeding more vapor from later evaporators. Improved and expanded use of automation throughout factories continued to occur, to improve operations and reduce labour requirements.

Between 1975 and 1999 women were finally being noticed for their research and development success as well as leadership in the sugar industry.

RESEARCH ADVANCES

Overall, 26 major subjects were covered during this period and varied from cane quality and payment systems to the formation of beverage floc from refined sugars. Only one processing subject was covered in each of the eight congresses held between 1975 and 1999, namely crystallization systems (boiling schemes, etc). The close subject of crystal size and morphology was covered in all but one congress. Similarly, color incorporation in and on the surface of sugar crystals was covered in four congresses. The latter two subjects reflect the new knowledge gained on the effect of impurities on crystal growth, habit shape, and size presented particularly by Cuban, Italian, and South African technologists (Ravelo *et al.* 1995; Vaccari *et al.* 1999; Morel du Boil 1995).

At the beginning of the period at the 1977 ISSCT congress (São Paulo, Brazil) there were 16 papers on raw sugar refining which represented approximately one-third of the total papers in the Factory Commission. The number of refinery papers, however, tapered off quite considerably after 1977, with only five refinery papers in the 1999 congress (New Delhi, India). The main reason for this decline in refinery papers was the introduction of high fructose corn syrup (HFCS) in the 1970s, which forced many cane refineries around the world to close along with their associated research facilities, causing much less research to be generated. Unfortunately, even with the later decline in HFCS in the late 1990s (HFCS production peaked in 1999 and declined thereafter, with the decline being consumer

rather than price driven), sugar refining research facilities have not been replaced. This is a pity because the quality of raw sugar has a great impact on refinery unit processes. The quality of raw sugars is expected to have more impact in the future due to current climate changes around the world affecting the quality of sugarcane as well as changes in the genetics (from breeding) and physiological growth of sugarcane.

Continuous pan technology at sugarcane factories was the subject of much research and development work, particularly in Australia and South Africa, during this period and started to be adopted at some factories. Most of the focus was on C-crystallizers because there the crystal size distribution was less critical than for shipment sugar and more steady flow gains could be achieved. Additionally, there was increased use of large vertical crystallizers and operation of smaller, horizontal crystallizers in series.

Another subject introduced between 1975 and 1999 was the new analytical technique of high-performance liquid chromatography (HPLC), which is easier and less difficult to use than gas chromatography (GC) and thin layer chromatography (TLC). At this stage it was mostly used by researchers to (i) more accurately measure sugars, and (ii) better separate and identify impurities in cane products (Curtin and Paton 1980). Other analytical techniques for use at the factory or refinery sites were also introduced at multiple ISSCT congresses between 1975-1999 and included but were not limited to: a titratable acidity method to measure cane deterioration, column chromatography to determine oligosaccharides in cane products, and new instrumental methods to determine moisture in white and brown sugars as a replacement of time-consuming oven methods. Another analytical technique first presented to ISSCT in 1992 was near infra-red (NIR) spectroscopy for use in sugarcane factories to gain rapid results for cane payment systems. The continued introduction of new analytical techniques remains important for the development and sustainability of the global sugar industry.

Between 1996 and 1999 many more cane milling papers were presented at the ISSCT congresses (Table 1) and this most likely reflects that (i) tandem milling is still the major choice of juice extraction in many parts of the world, especially the Americas, and (ii) the ISSCT congress proceedings prior to 2001 did not appear to rigorously separate the engineering and processing papers.

Cogeneration using surplus bagasse to produce electricity was first presented in the processing section of the Factory Commission at the 1999 ISSCT congress in New Delhi and, thereafter, became a major topic for the global sugar industry.

Significant advances

It was during the period of 1975 to 1999 that investigative studies on the use of near infra-red spectroscopy (NIRS) in the sugarcane factory were introduced, and the first ISSCT paper was presented at the 1992 ISSCT Congress in Bangkok, Thailand by Clarke *et al.* (1995). NIRS was already finding increasing application in the quality control of chemicals, pharmaceuticals, and food products as well as for sugarcane breeding programs and sugar beet analyses (Vaccari *et al.* 1987). By using a scanning NIR spectrophotometer, results from the very rapid analysis of unfiltered juice samples at different periods during the crop and from varying geographical locations, were compared favorably with conventional pol, Brix, and apparent purity values (Clarke *et al.* 1995). NIRS has gone on to have impact in the global sugar industry.

The analytical chromatography technique of high-performance liquid chromatography (HPLC) was introduced to the sugar industry between 1975 and 1999, which began to replace the more time consuming and cumbersome gas chromatography (GC) and thin-layer chromatography (TLC) techniques. At this stage, analytical chromatography was mostly used by researchers to directly and more accurately measure the concentrations of sucrose, glucose, or fructose in cane products as well as other cane constituents and impurities (Curtin and Paton 1980). GC was also being used by the South African sugar industry to determine sucrose, glucose and fructose for cane payment systems (Tsang *et al.* 1989). HPLC and GC gave new and valuable insights into true sucrose purity values as compared with apparent pol purities ubiquitously measured with polarimeters in the sugar industry.

Because pol values are the arithmetic sum of all optically active components in the cane product, rather than just sucrose, they are less accurate than true purities calculated with either HPLC or GC sucrose and often underestimate sucrose. The new use of HPLC in the sugar industry during this period also provided many new insights into the extent and location of sucrose losses at the factory and refinery. Moreover, glucose and fructose changes and ratios have provided valuable insights into which sucrose loss reactions are occurring at different stages of the raw manufacture and refinery processes, e.g., acid or alkaline degradation, microbial reactions, caramelization and Maillard colour forming reactions, among others, as well as processing parameters which affect them. Ion chromatography with integrated pulsed amperometric detection (IC-IPAD), a specialized HPLC technique based on anion exchange chromatography and electrochemical detection, was introduced to the sugar industry in the late 1980s by scientists from the Sugar Processing Research Institute in Louisiana, USA and was so sensitive it could readily detect minor oligosaccharides that affect crystal formation (Tsang *et al.* 1989).

Early in the period, Nancy Paton, Peter Smith and associates from Australia continued to present their innovative research on cane-derived phenolic colorants and their analysis by thin layer chromatography (1977 congress in Sâo Paulo, Brazil) and then high-performance liquid chromatography (1980 congress in Manila, Philippines). This research expanded the identification of the major classes of phenolic colorants (phenolic acids and flavonoids) and explained their roles in raw sugar manufacture and refining (Curtin and Paton 1980). The latter advances underpinned further research and development work on how to separate and remove them at the refinery. The group from Australia additionally found that approximately two thirds of the color of raw sugar came from phenolic acids and flavonoid groups. They also showed that sugarcane flavonoids, specifically flavones, can be used as chemotaxonomic markers.

Throughout the period, much attention from sugar research organizations was given to continuous sugar boiling (crystallization) as an alternative to batch boiling. The first advances in this area had already occurred in refineries in Europe (Broadfoot and Allen 1977). Sugar technologists at the Sugar Research Institute (SRI) in Australia and from Huletts Sugar Ltd. in South Africa conducted experiments on the C-crystallizer, i.e., the continuous boiling of low grade massecuites (Broadfoot and Allen 1977; Rein 1980) to underpin the development of new designs. Continuous boiling of low grade massecuites was investigated because the crystal size distribution was less critical than for shipment sugar. Additionally, adoption of continuous low-grade boiling together with continuous cooling crystallizers and continuous low grade centrifugals results in much more controllable steady flow in the recovery station and, therefore, better factory performance. Mathematical modelling of continuous crystallization was applied by the research groups to provide (i) a better understanding of the process, (ii) the influence of the operating and design variables on performance, and (iii) optimized operation and performance at the factory.

Automatic process control throughout the factory continued to receive attention and improvement. There was a paper presented at the 1980 ISSCT Congress in Manila, Philippines, on automatic process control in sugar and factories (Withers and Jobling 1980) where the authors stated that, up until 1980, the constraints to automation were mostly limited by economic and social factors and not by the existing control technology.

Research on the origin of oligosaccharides and polysaccharides in sugarcane products and their effects on crystal size and shape were studied by multiple groups between 1975 and 1999, including Cuban (Ravelo *et al.* 1995), Italian (Vaccari *et al.* 1999), and South African (Morel du Boil 1995) sugar technologists. Both oligo- and polysaccharides were shown to form during cane deterioration and the method of cane harvesting had a marked effect. A general rule of thumb is that the rate of cane deterioration caused by the cane harvesting method occurs in the following sequence: burnt billets > green billets > burnt whole-stalks > green whole-stalks.

Oligosaccharides are considerably lower in molecular weight than polysaccharides and, therefore, get absorbed on certain crystal faces and hinder growth along a specific axis which causes deformation of the crystal shape and can reduce the rate of crystal formation. Oligosaccharides were reported to be the principal cause of crystal elongation in raw sugar manufacture, although no one molecule is usually

entirely responsible (Morel du Boil 1995; Ravelo *et al.* 1995; Vaccari *et al.* 1999). Ravelo *et al.* (1995) observed that the formation of total oligosaccharides was greater than the formation of dextran and ethanol in sugarcane subjected to cut-to-crush delays and, therefore, were a more sensitive indicator or deterioration. Kestoses are a group of fructo-oligosaccharide isomers of 3 or 4 degrees of polymerization, that were unequivocally shown to have a c-axis elongating effect on raw sugar crystals (Morel du Boil 1995). The resulting deformed crystals have triangular to rhombic habits (Vaccari *et al.* 1999). Although it was reported during this period that oligosaccharides form during cane deterioration, the specific origin, e.g., microorganism or physiological source, was still not known.

Research on new separation techniques such as membrane filtration were also introduced in this period, particularly by Dr. Michael Saska of the Audubon Sugar Institute in Louisiana, USA. Although the uses of such membranes are innovative and are used in many industries, the impact has been relatively low for the sugarcane industry mostly because of the complexity of impurities in sugarcane when compared to, for example, those of sugar beets, and such impurities easily foul membranes.

PROMINENT CONTRIBUTORS

Margaret Clarke was an exceptional contributor to the ISSCT, presenting 13 papers in the Processing section at nearly every congress between 1977 and 1999—more than any other participant in that period. Her groundbreaking work introduced High-Performance Liquid Chromatography (HPLC), Ion Chromatography, and Near Infrared Spectroscopy (NIRS) to the sugar industry. A strong advocate of technical innovation, she elevated the quality and scope of ISSCT research, particularly in analytical methods and sugar chemistry. Her presentations, leadership, and mentorship significantly influenced ISSCT's scientific agenda and inspired increased female participation in what was once a male-dominated field.

Giuseppe Vaccari actively contributed to the ISSCT Processing section by presenting six papers at congresses from 1986 to 1999, often in collaboration with Mantovani. His work advanced the understanding of sucrose crystallization, colorant inclusion, kestoses, and NIRS analysis in beet processing. As a respected scientist, he helped bridge research between sugarcane and beet processing, enhancing ISSCT's multidisciplinary relevance. His innovative research complemented his leadership in international sugar bodies and added considerable depth to ISSCT's technical proceedings. Vaccari's contributions helped modernize ISSCT's scientific output during a period of increasing complexity in sugar processing.

Ross Broadfoot's impact on the ISSCT was marked by four influential papers presented between 1977 and 1999, beginning with his landmark work on continuous vacuum pans, a technology that reshaped factory crystallization processes. A pragmatic researcher, he shared practical innovations in massecuite handling, heat transfer, evaporators, and crystallizers. His contributions were notable for their immediate applicability and collaboration with factory personnel, demonstrating how science could directly improve industrial practice. Broadfoot's work exemplified ISSCT's mission to advance sugarcane technology through both innovation and application, making him a key figure in process engineering discussions at the society's congresses.

IMPACT OF THE RESEARCH

Most sugar researchers and sugar technologists now have access to high performance liquid chromatography instruments or services which continue to generate accurate and sensitive data to underpin processing research and development work. In the last 20 years, more and more sugarcane factories, distilleries, and refineries have started to use HPLC techniques in their processing and quality control laboratories and papers are now available on how to interpret HPLC factory data (Eggleston *et al.* 2018). Major research insights from the use of this direct technique to generate new research advances in processing or the sugar industry are too great to mention here.

The use of HPLC by Nancy Paton and associates to separate and identify cane-derived phenolic colorants was a key measurement in the development of modern decolorization processes at the refinery. The old technology of bone char was shown not to remove the colorants very well, whereas granular or powdered activated carbon have been unequivocally shown to remove these small molecular weight colorants much better, and even better than ion exchange resins. This research on cane phenolic colorants has also underpinned later research on the antioxidant capacities of cane products, including brown and non-centrifuged sugars, because such compounds exhibit high antioxidant behavior.

By 1999, continuous pan boiling already had widespread adoption in many countries, including the Southern African countries (South Africa, Swaziland, Zimbabwe, Zambia, and Malawi) as reported by Rein and Msimanga (1999). These authors attributed the routine incorporation of continuous pans as a reason why in 1999, this region of the world incorporated most of the lowest cost producers of sugars in the world. Nowadays, continuous crystallizer pans are common in most, but not all, parts of the world. Furthermore, vertical continuous crystallizers have been introduced as an alternative to the traditional horizontal continuous crystallizers which have larger footprints.

Improvements in cane milling at factories included the increased use of heavy-duty shredders to improve cane preparation, larger heavy-duty mills, Lotus rolls, Donelly chutes, underfeed rolls, L scrapers, flangeless rolls and welding on rolls to increase drainage, throughput and extraction. There was also increased use of chokeless pumps to replace drag conveyers and rubber intermediate carriers between mills to reduce maintenance at the factory.

From 1975 to 1999, improvements in steam economy were seen at global sugarcane factories by using more evaporators in the evaporator stations as well as bleeding more vapor from the later evaporators. Additionally, during this time, there was also increased use of plate evaporators and plate heaters.

Improved and expanded use of automation throughout factories occurred from 1975 to 1999 to improve operations and reduce labour requirements. Since then, automation has expanded greatly with new computer and software technologies which has also allowed modelling of unit process operations.



The First 100 Years of the International Society of Sugar Cane Technologist - 1924-2024 Research Advances and Impact

Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Factory Processing 2000-2023

Roderick J Steindl

steindlr@bigpond.com

INTRODUCTION

Congresses between 2001 and 2023 show significant developments in the way mixed juice is clarified. There has been an increased focus on the production of white sugar without the use of sulphitation. All other aspects of factory processing received some attention, particularly analytical techniques, the increasing use of NIRS and the impact of cane quality on processing standards.

A total of 166 full papers and 83 poster papers were presented at the eight congresses during the period in the Processing Section of the Factory Commission. Two important decisions made prior to the 1999 Congress have influenced the number of accepted papers since: the Co-products Commission was introduced for the 1999 Congress which would have removed a number of papers from the Processing Section; and poster papers were introduced as an important second opportunity for technologists to present their work to the ISSCT community. The creation of the Co-products Commission has not reduced the number of full papers accepted for the Processing Section. What is not obvious is the increasing trend towards confidentiality of R&D outputs to retain ownership of intellectual property arising from research projects.

A Processing Section Workshop was held in conjunction with the 2001 Congress in Brisbane. This reduced the available time for oral presentations at Congress to just two days. At the end of the Congress, the consensus was that workshops should not be held during Congress in the future.

RESEARCH ADVANCES

Cane supply

The quality of the cane supply and its effects on downstream processing still remain an issue for some factories (Sens and Decagny 2001). Most reported R&D has focused on sucrose losses and the measurement of deterioration products and their impacts on processing standards and the final sugar quality.

Juice clarification

This subject which covers all aspects of juice processing from the mixed juice tank through to clarified juice is the first of the two important stages within the factory that have significant effects on the quality of the sugar being produced. The 28 contributions to the Society included papers on clarifier design, colour changes, removal of fibre and mud thickening through to the use of diffusers to produce clear juice, using natural extracts as flocculants to clarify juice for organic sugar production, and the treatment of clarified juice by ion-exchange and membrane filtration for quality improvements and increased productivity and recovery of sucrose.

Steindl (2001) was the first to apply computational fluid dynamics (CFD) to the design of the cane juice clarifier. Similar approaches were used by Chetty (2001) when analysing the flow in a Rapidorr 444 clarifier and Gaudet and Kochergin (2013) with the development of their Low Turbulence clarifier. Gil *et al.* (2013) used CFD to analyse the flow in an existing clarifier and successfully modified it to reduce the residence time. Rein *et al.* (2016) applied CFD to develop new clarifier designs incorporating lamella plates for juice and syrup clarification.

Steindl (2007) was also the first to study the behaviour of the settled mud, factors affecting the density of the underflow and options to remove the mud efficiently. The paper identified inefficiencies of the existing designs of mud scrapers.

The feasibility of using the final cells of a diffuser to act as a filtration step to produce clear juice directly without the need for a clarifier was proposed by Jensen (2013). Subsequent experiences with this application were presented by Jensen and Davis (2016) and Narendranath and Pillay (2019).

Mud treatments

There remains some interest in solid bowl decanters for the treatment of the mud from the clarifier. A few Indian factories have adopted two or three stage treatment systems that include decanters as suggested by Steindl *et al.* (2010) but results suggest that there may be better options. One alternative technology is the belt press filter as reported by Petit (2013).

Evaporation

Seven papers discussed aspects of scale formation in evaporator tubes and cleaning options. Another four papers discussed sucrose degradation losses in evaporators which were of particular interest to factories implementing steam economy measures at the evaporator stage with extensive vapour bleeding from large vessels and the use of higher steam pressures (Peacock 2007; Rackemann and Broadfoot 2016; Rackemann and Marasinghege 2023). Other papers looked at the design of evaporators, in particular, the length of tubes and its effect on heat transfer coefficient (Cobo *et al.* 2016; Thaval *et al.* 2019).

A useful practical paper on the use of plate heaters for both heating and evaporation duties was provided by Rostagno and Olivero (2019).

Crystallisation systems

This section received by far the most papers at 43. Most of these papers (14) considered the design and operation of continuous vacuum pans and crystallisers. A few of the more useful papers include those from Broadfoot (2005), Moor *et al.*. (2019), and Awasthi *et al.* (2019) that provide information that factory staff should review when considering the installation of new vacuum pans into their factory.

Rackemann and Broadfoot (2007) described a new jigger system that injects and distributes numerous small bubbles of steam and incondensible gases into the base of the pan. Circulation is improved through a combination of the rising bubbles and the increased heat transfer that results from the increased velocity of massecuite through the tubes.

One common problem that most boiling houses experience is poor crystal size distributions (CSD) resulting from factors like poor circulation, limited control of the supersaturation level in the pan and the absence of a good microscope on the pan floor. There have been several papers to congresses that discuss the advantages of pan microscopes and at-line measurement of CSD for better control of the pan strike and improved quality, productivity and recovery. Ramirez (2005) described systems that have been implemented into several factories in Central America to monitor all pan drop massecuites for crystal populations, quality and exhaustion. A more recent paper from Singh *et al.* (2023) describes the

use of pan microscopes for crystal monitoring as part of pan automation projects. Broadfoot and Petersen (2005) also addressed this issue with their experiences with a specially designed cooling crystalliser to improve the quality of the C magma prior to its use as seed crystal material in the high-grade pans.

Improved recovery from low grade crystallisation was the subject of two papers (Steindl *et al.* 2001; Broadfoot 2019).

Sugar drying and storage

This subject has received limited interest in recent years but the problems of caking and storage at high temperatures still exist in many countries. Tait *et al.* (2010) demonstrated the use of a short residence time conditioning system to eliminate caking of sugar in 50 kg bags of sugar. Schuermann *et al.* (2016) discussed the benefits of using silos to store white cane sugar rather than storing the sugar in 50 kg bags. Steindl (2007b) used a computer-based model to control the operation of a rotary drum dryer to produce raw sugar with suitable temperature and moisture properties to avoid degradation or caking during bulk storage.

Kochergin (2010) reported results of a survey that showed how stored sugar can maintain an equilibrium relative humidity and temperature with the surrounding air well into the sugar pile and not confined to the surface layer.

Low colour sugar

The steady swing away from the use of sulphitation is still evident in those countries where the principal crystalline sugar product is plantation white sugar. Several factories have chosen to produce a low colour raw sugar which is then remelted, clarified by either carbonatation or phosphatation, filtered and recrystallised.

Several papers proposed processes to reduce the colour of the juice or syrup to allow plantation white sugar to be produced without sulphitation. These include Steindl (2001), Davis (2001), Steindl and Doherty (2005), Madsen and Day (2010), Serpa *et al.* (2013) and Ngasan *et al.* (2016).

There have been several contributions to congresses that outline systems to produce white sugar directly to replace sulphitation or the double crystallisation method which is expensive. One such plan was proposed by Tongaat Hulett (Fechter *et al*. 2001; Jensen and Kitching 2007). The White Sugar Mill (WSM) process involving membrane filtration followed by ion exchange technologies was installed in a factory in South Africa. Unfortunately, the plant was shut down after a short time for economic reasons.

Dedini (Olivério *et al.* 2007, 2010) proposed their DRD process which comprised a set of process solutions, among them syrup decolourisation by ion-exchange resins, allowing direct syrup to refined sugar production. However it is uncertain if a full-scale plant was ever installed into a factory.

Others have also proposed systems involving a combination of membrane filtration with either ion exchange or chromatography to produce directly either low colour or refined quality sugar. These include Kochergin *et al.* (2001), Phaeon *et al.* (2016), Kesarwani and Moharana (2016), Brichant (2019) and Liu *et al.* (2023).

Effluent systems

Eight papers discussed a range of options to achieve or approach zero effluent output to comply with local environmental laws.

Energy

Most factories receive cane trash and other biomass as fuel for the boilers to maximise their export power potential. In some cases, the cane trash comes to the factory with the cane supply and is processed through the factory. The trash creates additional problems at most processing steps that can impact on the sugar quality. These issues are best summarised by Corcodel and Roussel (2010) and Kent (2013).

NIR Spectroscopy

Near-infrared spectroscopy technology first appeared as an oral presentation at the Congress in 1992. Since then, there has been a steady stream of papers relating experiences with calibrations and a variety of applications at many factories. Probably the most notable amongst the 14 papers in this review period are some from SMRI; Simpson and Naidoo (2010), Naidoo and Walford (2013), Walford (2019) and Madho and Barker (2019).

Analytical techniques

Several papers on a variety of analytical methods and techniques were presented during the review period. These papers covered a range of target constituents including the measurement of extraneous matter in the cane supply, polysaccharides and deterioration products in the cane supply through to acid beverage floc and its precursors and the detection of heavy metals and pesticide residues in the product sugar.

PROMINENT CONTRIBUTORS

There are five members who should be acknowledged for their contributions to ISSCT and the sugar industry.

Roderick Steindl for the investigations into juice and syrup clarification resulting in a significant improvement in the standard of clarification in factories, mud treatments and sugar drying and storage and for his role with the Technical Program Committee extending from 2005 to 2023.

Ross Broadfoot for his continued involvement with ISSCT through 13 papers dealing with a range of technologies associated with evaporation, crystallisation and centrifugation.

Darryn Rackemann for his 13 papers covering such topics as membrane filtration, evaporator design and degradation of sucrose in the evaporators.

IMPACT OF THE RESEARCH

The following comments are based on my observations and experience during visits to most cane sugar producing countries over the period of review using the previous period as a baseline.

The ISSCT proceedings database provides an excellent resource for factory staff but it is difficult to gauge how widely knowledge of this resource exists. The usual response from most senior staff is that they were unaware of its existence.

It has to be acknowledged that technologies that can make a step change in factory performance are only made available through ISSCT with the permission of all stakeholders and many developing technologies that are potentially good for the industry are never presented at Congress because of IP issues.

The single technology that has had the biggest impact on factory processing has been the development of the SRI NG clarifier by Rod Steindl. Currently, there are about 1000 units installed in factories in probably all cane growing regions around the world. The manager of a Brazilian factory best summed up the comparison with his statement ‘Half the size, half the price but twice as good’.

Continuous vacuum pans (CVP) for A, B and C massecuite boilings are becoming more common in factories in both the horizontal and vertical configurations. Bosch projects (Bruce Moor) and SRI (Ross Broadfoot) have been responsible for many of the original horizontal CVPs while the VKT from BMA is the most recognised vertical CVP.

Several papers from eminent technologists including R. Broadfoot, D. Rackemann, S. Davis, G. Kent, B. Moor and M. Saska provide important reference information for both researchers and practitioners.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Co-products 1924-1938

Oscar Almazan

oscar.almanzan@icidca.azcuba.cu

INTRODUCTION

The task of going from the birth of ISSCT in 1924 up to 1938, or from Hawaii, to Havana, to Indonesia, to Puerto Rico, to Australia and in 1938, to Baton Rouge, was a privilege for me and also a challenge; but most of all, an exceptional and passionate experience to review the contributions made by Co-products to ISSCT.

As a starting consideration, it was a challenge to find out how and when the demarcation of Co-products became significant and, of course, to explain it as the result of a professional and pertinent appearance, because it is clear, then and now, and always, that first comes first.

RESEARCH ADVANCES

1924 and 1927 Congresses

At the beginning when ISSCT became an independent professional society in 1924 in Honolulu, Hawaii, at the time when (I quote) “An International Conference of Sugar Cane Men; meeting as the sugar sector of the First Pan Pacific Food Conservation Conference…”. At the first two congresses, that of 1924 and at the second one in Havana in 1927, all the interest was devoted to sugarcane, this marvelous crop, its seeding, cropping, crossing, new and better varieties, etc. and of course to a similar analysis of milling, purification, energy, efficiency, yields, in sum sugarcane processing.

1929 Congress

We find the first appearance of co-products in the study of “Bagasse as Fuel” by Esnouf (Mauritius) in the third congress in Surabaya Indonesia in 1929, at the Factory Commission meeting. The paper gives an exhaustive study, with a complete description of bagasse constituents, required oxygen for combustion, composition of flue gases, among others and a careful notation – for the first time - “the different types of bagasse”. This was a solid contribution of knowledge and real and early evidence of the significance of energy generation in sugar manufacturing process, jointly stressing the fact that sugarcane provides the fuel for its processing.

1932 Congress

For the period 1924-1938, co-products were located in the Congress´s Organization at the Factory Engineering and Factory Operation and Control. There was no significant presence until the IV congress in Puerto Rico, when co-products had a significant representation by three papers.

One dealing with “Molasses as a Fertilizer” by Kerr from Australia which was concerned mainly about “The problem of the economic disposal of molasses”, and starts with a very curious statement, “Molasses has been a serious one for many years past, throughout Queensland sugar factories”. The paper has a detailed description of the many large problems, about the pollution of rivers, destruction of fish and furthermore, being a menace to public comfort and health; giving at the end a recommendation “The study of the chemical, physical and biologic influences of molasses applied to the soil opens up field for extensive research; and a more complete and detailed study of the whole question would probably show that molasses possesses a much high value as a fertilizer than as a fuel or as a source of carbohydrate for industrial alcohol production”. These of course respond to the peculiar situation of molasses in Queensland at the beginning of the Twentieth Century.

The second paper by Cruz Monclova of Puerto Rico, with an effort, quite successful for that time, demonstrates the possibilities of blackstrap molasses as a main bacterial media component for biosynthesis of organic acids. It gives 11 products: acetic, lactic, propionic, butyric, oxalic, citric, fumaric and gluconic acids and also glycerin, butyl alcohol and acetone. The paper includes detailed data about yield, technology, all at a high level of knowledge for that time.

A third paper by Davies from the Department of Sugar Technology of the Imperial College of Tropical Agriculture, in Trinidad, reports a careful study of what was “The State of the Art”, in “A suggested practical method for measuring molasses exhaustion”, stating that a reliable and ideal method for measuring “molasses exhaustion” has not been developed. The paper provides an ample review of the available literature, finalizing with a summary of nine points of facts and proposals, that some years later became a useful base for studies giving solution to a satisfactory method to determine molasses exhaustion.

1935 Congress

In 1935 at Brisbane, Australia the V Congress, it was an unexplained “dry” co-Products contribution, with only one paper “The Keeping Quality of Sugar Cane Molasses” by Browne, from the Bureau of Chemistry and Soils, of the U.S. Department of Agriculture. Spencer called attention to a peculiar type of deterioration of a molasses tank, and comments are made that it was chemical and not a biological decomposition. Such deterioration is something we in our professional life testify more than once, becoming in some cases a final dangerous explosion. The paper made a well-oriented explanation of the causes.

Up until 1935, co-products referred almost only to blackstrap molasses, with the noted exception of two studies of bagasse as fuel. Indeed, the word co-product has become the preferred term in the last 30 years to describe any product other than sugar produced from sugarcane. Prior to this, the term by-product was widely applied.

Up until 1935, co-products referred almost only to blackstrap molasses, with noted exception of two studies of bagasse as fuel.

1938 Congress

The VI Congress in Baton Rouge was “the jump of co-products”, with an ample collection of papers (6) for the first time, coming from four different countries and dealing not only with blackstrap molasses and bagasse, but including very appealing works. This includes one from Yamafuji of Taiwan about “The Value of Cane Juice as a Yeast Nutrient” and another from Avice about “The Byproducts of the Mauritius Sugar Industry”, both deserving comments in this review.

There were contributions from Neuville of the “Sucreries d’Egypt”, and Geerligs from Java. They both reported on the keeping quality of cane sugar molasses. The latter noted the brixing-up of final molasses

in a pan to decant to form solid bricks for export was “temping the gods” because of the potential for spontaneous decomposition.

Two papers deserved special attention, the one about “The value of cane juice as a yeast nutrient medium” by Yamafuji and Ohtsu, from Taiwan. The authors state that sugarcane is common in the tropics and for a great many years has been the source of cane sugar. No experiments have been brought to their attention regarding the value of cane juice as a yeast nutrient medium for the commercial production by yeast fermentation. They report comparative trials with nutrient media of common use, describing the use of three species of yeast which were employed commonly in the fermentation industry.

It´s evident that this paper gives, for the first time, a solid and well tested demonstration of the potential and possibilities of sugarcane co-products to become an attractive technological and economic option as substrate for the biotechnological industry. The paper provides very important background for the development of sugarcane industry diversification.

The other paper “The By-Products of the Mauritius Sugar Industry” from Avice, starts with a statement that still holds true today, but many people don´t know and I think this Centennial Review will help to remind. Mauritius was the first country to use molasses as manure some 75 years ago. Its value in the fields, as first discussed, was definitely recognized and its application to cane fields then became a general practice.

In Mauritius, the challenge of isolation was successfully faced by talent, and Avice showed the success in his paper. In 1876, the manufacture of rum reached a record figure when 1,423,000 L were produced for local consumption and 4,591,000 L were exported. The export trade is now small owing to lack of demand.

The methods of production have been greatly improved during recent years, but at that time some excellent products were undergoing development, and the ethanol was used in the manufacture of liquors, perfumes, and pharmaceutical products with some market restrictions. Vinegar was also produced on a small scale.

Early trials reported several attempts have been made to utilize alcohol as fuel in internal combustion engines on a large scale. A mixture known as Cernite (a very Mauritian name) composed of 95 G.L. ethanol 64%; ether 30%; and kerosene 6%; met with a certain success in 1932-1934 when the price of motor spirit was relatively high.

Avice reported 95 G.L. ethanol mixed with gasoline, had been used as fuel to a certain extent for the past six years, but the water contained in the alcohol does not permit the mixing of the two fuels in the proportion giving best results, arriving at a true fact. The manufacture even today of “absolute alcohol” would no doubt give a new scope to the alcohol industry, but at that time in Mauritius for various reasons, no plant has been installed.

The total amount of filter press cakes produced was employed in the fields as manure, almost exclusively applied to virgin canes either at planting or when the canes are 5 to 6 months old.

The ashes left after the combustion of bagasse, except for a certain amount which fuses to form a hard clinker, are utilized in the fields. Ashes are usually applied, mixed with filter press cakes, molasses, and even bagasse. The compost known as Saccharogene was applied at the rate of 5 to 12.6 t/ha.

Bagasse is the only fuel used to produce steam in sugar factories. The manufacture of raw sugar leaves a certain amount of surplus bagasse. The amount is not important enough, however, to make possible the baling of bagasse or the production of paper. Bagasse was used in the fields mixed with other substances, but it remains in an unchanged state for a considerable time.

In sum, after reading this paper, it is obvious that the small island of Mauritius had the talent and potential for many years concerning sugarcane co-products, with an amazing educational capacity and R&D-I for Africa and the rest of the world. That is surprising and admirable for me.

PROMINENT CONTRIBUTORS

A few highly distinguished technologists have been identified for their contribution to the field of co-products in the formative years of the Society.

Auguste Esnouf, a noted engineer and author, for his paper “Bagasse as a Fuel”, arguably the first co-products paper presented at a congress. Esnouf was a director of Forges Tardieu in Mauritius and noted French writer who wrote under the nom-de-plume Savinien Mérédac. He authored “Nomographs in a Nutshell” and was a laureate of the French Academy and Knight of the French Legion of Honor.

Charles Albert Browne Jr., a distinguished sugar chemist and former head of the US Department of Agriculture Bureau of Chemistry, which later became the US Food and Drug Administration. Browne was involved in the formation of the American Chemical Society and published on the degradation of molasses, a noted problem in the development of this co-product.

Henry William (Bill) Kerr for his contribution to research in the Australian and international sugar industries, in particular for the problem of the economic disposal of molasses. Kerr together with Norman Bennett and William Seymour-Howe co-founded the Queensland Society of Sugar Cane Technologists (later to become the Australian Society of Sugar Cane Technologists). He was a director of the Australian BSES and the first director of the SRI.

IMPACT OF THE RESEARCH

This paper reviews co-product papers presented at six ISSCT congresses held from 1924 to 1938. Research on co-products was reported in the factory commission in this period since the Co-product Commission had not been formed. Early co-product research focused mainly on backstrap molasses including its storage and degradation, and other research investigated bagasse as fuel. There was a jump in the number of co-product papers delivered in 1938, to include discussion on the biosynthesis of organic acids, yeast nutrients, rum manufacture, alcohol as fuel in internal combustion engines, industrial ethanol, glycerin, butyl alcohol and acetone production, filer cake and ash as fertilizers, indicating that research into co-products had come of age. For many years, the island of Mauritius has been a leader in the development and production sugarcane co-products.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Co-products 1950-1974

Pedro Avram-Waganoff and Gunshiam Umrit

pedro.avram@web.de

INTRODUCTION

Here, we review of 59 papers on co-products presented during the nine ISSCT Congresses held from 1950 to1974, highlighting their research and development contributions. The Co-Products Commission was not formally established and papers dealing with "co-products"– referred to any products other than sugar arising in parallel or downstream from the processing of sugar cane in the sugar factory - were usually presented under the Manufacturing Commission. The economically most important co-products during the period 1950 -1974 were the production of particle boards and paper pulp from bagasse and the production of drinking grade alcohol (rum) from molasses. By 1972 a total of 50 bagasse pulp mills in the most important cane-growing areas produced nearly 1 Mt of bagasse pulp for paper and cardboard production. Other co-products that aroused interest included industrial chemicals based on sucrose and molasses, wax from filter press mud and feed additives.

RESEARCH ADVANCES

1950 Congress

The potential use of hydrous ethanol as an automotive fuel was described by Dunster (Australia) who tested its direct injection into the carburettor of internal combustion engines to increase the octane rating and decrease knocking. Testing showed the fuel injector operated satisfactorily on a wide range of road vehicles. Symes (Brazil) described methods of treating molasses distillery wastes (slops) before discharge. These included ammonifying bacteria to more elaborate schemes involving yeast centrifuging and recovery. For larger distilleries anaerobic digestion was recommended, wherein methane is recovered and the residue treated in aerobic filters.

De la Roza (USA) described bagasse treatment for producing cellulose or fibreboard including the digesting and washing equipment that could yield uniform, high-quality cellulose at a more competitive price than wood pulp. Vazquez (Cuba) described the production of fibre and pulp from bagasse either by chemical means (low yields) or mechanical means (grinding, diffusion, filtering, forming and trimming). Fibreboard produced by mechanical means was very competitive and over 10,000 t were produced in 8 years of experimentation.

1953 Congress

Wiggins (Trinidad) identified five products which included (i) sucrose for the manufacture of glucose, fructose, mannitol, sorbitol, plastics, oxalic and lactic acids, (ii) cane tops and leaves for cattle fodder and maintaining soil organic matter, (iii) bagasse for paper or cellulose stock, fibreboard, hard board, furfural, pyrolysis, (iv) filter mud for soft fatty matter for cattle feed and hard wax for multiple uses and (v) molasses for potable alcohol, cattle fodder, citric and lactic acids, yeast, etc.

Chadwick *et al*. (Trinidad) described laboratory-scale experiments to establish achievable yields of lactic acid when treating molasses and sucrose, with calcium hydroxide at different temperatures and reaction times. The levels of acetic, formic and lactic acids formed were determined by chromatographic methods. Lactic acid yields of nearly 60% were obtained for molasses heated to 250°C. The method seemed very promising to replace lactic acid fermentation procedures.

Davison *et al* (Trinidad) discussed wax yields from filter mud in Jamaica, Trinidad and Guyana. Wax content varied with cane variety, pre-harvest burning and storage conditions of the filter press mud. The best wax yields (17.6% crude wax on dry filter mud) were obtained in the north-eastern Caribbean islands which have a drier climate and where cane was not burnt.

Payne presented the paper of Baver (USA) for the Hawaiian Sugar Planters' Association between 1951 and 1953, which included (i) the separation of pith and fibre fractions of bagasse; (ii) utilization of A and B molasses with pith for animal feed; (iii) bagasse for the production of pulp for corrugated board and mulching paper, (iv) determining the wax content of filter cake, which averaged of 6.8% crude wax. Diversification through co-products is expected to make significant contributions to the economy of Hawaii.

1956 Congress

Bhatla and Mukherji (India) reported on the development of cationic exchange resins by the condensation of sucrose with phenol-sulfonic acid to yield a product with improved exchange capacity and physico-chemical properties. Murkherjee also presented on the extraction, purification and decolorisation of sugarcane wax in India. The analyses of press mud from sulfitation factories and of hard and soft waxes were presented. Results showed that filter press mud had significantly more wax than rotary filter mud and that cane varieties and month of the season also had an influence.

Samuels and Landrau reported on the chemical and physical properties of filter press cake from all mills in Puerto Rico. The main advantages and disadvantages of filter press cake as well as practical recommendations for its use as a source of nutrients were given.

Podder *et al*. (India) reported on a high-quality bagasse pulp mill employing the Celdicor process and on the prerequisites for an economical and successful operation. These are: (i) proper storage of bagasse, (ii) removal of pith and (iii) maximum utilization of the pith removed. Bagasse is baled and stored for at least 3 months to enable the moisture content to fall to 10 to 15%, disintegrated to remove 20 to 22% of the pith from the fibre. The depithed bagasse is digested in a continuous process and serves as stock for paper production.

Molasses is deficient in nitrogen for cattle feeds. Wiggins (Trinidad) reported on the ammoniation of molasses as a means of fixation of nitrogen for use in animal feeds. Preliminary reports of feeding ammoniated molasses were encouraging but on a large scale, a few animals developed hysteria and restlessness. Some heterocyclic compounds believed to be the cause were removed and extended trials with sheep were successful.

Shukla and Kapoor (India) presented on growth promoting factors in the fermentation of molasses and these are adsorbed by precipitates from pre-treatment by either ferrocyanide or superphosphate. Shukla and Tewari reviewed the instrumentation and process control systems in Indian distilleries. The paper highlighted the need for Indian plants to equip themselves with modern instruments and control devices.

Joshi and Gopinathan recounted the production and challenges of gur from date and palmyra palm trees in India since the 17th Century. Palm juices have pol contents between 10 and 16% with purities between 84 and 89%. The juice however is easily fermented by contact with air and must be preserved by adding lime.

Parthasarathy described the production of gur from sugarcane in India. Because of inefficient milling without imbibition, a considerable quantity of sugar in cane is lost in bagasse which is burnt in open furnaces. The overall recovery for gur is about 68.3% compared to 83.0% in sugar manufacture. The clarification of juice in open pans is inefficient and gur has poor keeping qualities because of its high moisture content between 4 and 8%. The presence of minerals in gur, which are believed to be more nutritious than refined sugar, therefore gur will continue to be an important cottage industry product.

1959 Congress

Hass (USA) reported on a survey that revealed the importance of sucrochemistry at the time was considerable and rapidly growing. Sugar and its co-products were being used to produce solvents, plastics, plasticizers, fibres, building materials, surfactants, humectants, papers, waxes, feeds and feed additives, condiments, anti-biotics, vitamin C, oil-well drilling additives, surfactants and high explosives. Promising projects not yet in commercial operation included other surfactants, plastics, and drying oils.

1962 Congress

In his address as Section Chair, Keller (USA) summarized the papers presented and remarked that some schemes are unreported as these are regarded as secret (e.g. alcohol, yeast and other fermentation production).

Lengel (Canada-Venezuela) reported on optimum methods of bagasse-fibre preparation and storage for a dry-process board plant, including the production of softboard, particleboard, and hardboard in Venezuela. From these investigations a pilot plant was designed, erected, and operated at Central El Palmar to determine final process operations and economics.

Hsi-Sheng Wu (Taiwan) described the preparation of bagasse, its digestion, refining, and pressing for the manufacture of hardboard of superior quality. The fibre thickness in the pulp was found to be an important factor determining the board strength. For good quality board, the 0.05-0.15 mm faction must be over 66%.

Atchison (USA) gave a comprehensive review on the manufacture of pulp and paper from bagasse. Improved collection, storage, preservation, depithing and pulping of bagasse had expanded greatly during the late 1950s and by the end of 1961 25 bagasse pulp mills were in operation.

Villavicencio (Mexico) described a continuous process to obtain high-quality cellulose pulp and white papers. The process is suitable for areas with small local demand for paper materials where large plants would not be profitable.

Pathak (India) reported on the isolation, fractionation and determination of the sugars in bagasse hemicelluloses. Chromatographic examination revealed the occurrence of xylose and arabinose in all fractions.

Brown (USA) determined the most desirable level of bagasse-blackstrap molasses to feed cattle in a wintering ration. The bagasse-molasses portion made up 70% of the total ration. The remaining 30% was made up of feeds which were used to supply protein, additional energy, vitamins, and minerals. The rations were consumed without any kind of digestive disturbances.

1965 Congress

Atchison (USA) presented on experiences gained in the development, construction and operation of five pulp and paper projects. Information is presented regarding the time to develop a project up to the time financing is arranged and the extent of the preliminary work required for financial institutions to consider a project favourably.

Vincenty and collaborators (Puerto Rico) reported on the cold soda process (normally applied to hardwoods to produce paper pulp) applied to bagasse briquettes. Bagasse does not require the use of pressure or vacuum systems for impregnation nor the expenditure of large amounts of energy for mechanical treatment of the resulting pulp.

In India, the increasing need for bagasse as a source of raw material for pulp and paper manufacture has prompted studies. Gupta and collaborators analysed the steam economy in seven representative sugar mills and showed practical steps to reduce the steam demand from 64.4% to 46.3% on cane to provide surplus bagasse to the paper and pulp industries. Pathak and Srinivasan continued previous work and reported assays of the hemicellulose fractions of bagasse fibre.

Bose and collaborators (India) reported the laboratory experiments to establish procedures for obtaining a purified cane wax to compete with established wax products. A mixture of ethylene diamide and glycerol ester sugarcane wax derivatives in 1:4 ratio behaves as a true hard wax and may substitute carnauba wax in paste polish preparations.

Keo (Taiwan) presented on molasses fermentation to increase the sugar concentration from about 12% to about 20% sugar for commercial fermentation. The higher concentration boosts existing plant capacity by 40% and enables a saving in fuel of 20%.

Garcia and collaborators (Puerto Rico) reported on replacing conventional chemical methods of analysis by a gas chromatographic procedure. The chromatographic method provides greater information on rums with a significant reduction in both analytical time and sample size.

Parish (Mauritius) investigated the supplementing the feed rations of cattle, pigs, chicken and sheep with dried filter scums. Results showed that digestible crude protein of oven-dried scums (mud) is low and about the same nutritive value as dried green cane-tops despite a considerably higher content of crude protein. Cane-juice coagulate was fed as a supplementary protein source to chickens since it has one half the value of fish meal. Amino-acid analyses of the coagulate show methionine is low and supplementation is needed. Staub and Darné (Mauritius) proved that a blend of scum/molasses/fish meal is as good for milk production as the standard concentrate blended from imported foodstuffs.

1968 Congress

Clayton (USA) gave a short account of the pulping of bagasse and construction of the world's first commercial bagasse paper mill in 1939 in Peru as well as the development of facilities for manufacture of cardboard boxes, alcohol, alcoholic beverages, and polyvinyl chloride.

Atchison (USA) reported that by 1967 about 500 000 t of bagasse pulp were produced in 36 paper mills. Growth was most pronounced in areas where traditional pulpwood supplies are scarce. Bagasse pulp can compete favourably with hardwood and even some softwood pulp for most types of paper. Wu reported that the Hsinying Pulp Mill, in southern Taiwan was producing 130 t/day of high-grade bleached bagasse pulp in 1968. The mill employed the sulfate process coupled with chlorination, alkali extraction, and two hypochlorite stages which will soon include with chlorine dioxide oxidation in its final stage.

Gloria (Philippines) reported a lack of interest in pulping bagasse because of inadequate bagasse supply for an economic-size mill, factory-sugar planter relations, problems in marketing, economic/financing deterrents, lack of supporting basic chemical industries, and technical considerations regarding the process.

Langreney and Hugot (Réunion) described the Bagapan plant for the manufacture of 40 t/d particleboards. A short account of the control of the process, labour and other costs, and ideas for future expansion are given. Particleboards made from partially depithed bagasse treated with urea-formaldehyde glue have better properties than European wood particleboards.

Use of sugarcane bagasse as a potential raw material for production of industrial chemicals such as furfural has attracted significant research interest. Ramos and collaborators (Puerto Rico) reported that the production of furfural from bagasse industrially yields 9-10% which is a low degree of conversion. When a concomitant production of furfural and levulinic acid was attempted, a total yield of 25% for these two chemicals, based upon the dry weight of bagasse, was obtained. As the potential yield of furfural and levulinic acid is 45.50%, the conversion efficiency is 55.9% for these two chemicals. Nee and Hsieh (Taiwan) presented on the feasibility of producing furfural in conjunction with fibreboard from bagasse. Design data are given for a 3.5 t/day furfural plant in conjunction with a fibre-board plant which cooks 20 to 30 t/d of bagasse. Duffey (USA) reported furfural is a specialty chemical with limited markets almost entirely confined to the highly industrialized countries. Only the most economic raw materials, in the best location from the viewpoint of marketing costs, processed in efficient plants can offer a satisfactory return on the high plant investment required. An efficient bagasse furfural plant required about US$ 10 million investment in 1968. Its operation must be coordinated with a very large sugar mill grinding cane most of the year. Most sugar mills do not meet the conditions required for profitable production of furfural.

Gupta and Shukla (India) described an industrial anaerobic fermentation process, whereby cellulosic and other industrial agricultural wastes are rapidly converted to bio-gas, for use as fuel, and bio-manure, for use as fertilizer. Data presented show the bio-gas/bio-manure process has potentially far-reaching possibilities to produce more food per acre, in a sustained manner compared with chemical fertilizers.

Zachariassen (Sweden) presented on producing dried yeast from the excess yeast normally going to waste in a conventional alcohol plant. Procedures for molasses clarification and fast fermentation were described which allow two-thirds of the separated yeast cream to be converted into dried yeast as a valuable co-product.

Liu (Taiwan) discussed the effect of oxygen absorption velocity on the growth of *Torulopsis utilis* in shaking culture and Su and collaborators (Taiwan) presented results from their study on the amino acid composition of 16 different strains of yeast prepared from standard molasses.

1971 Congress

Atchison (USA) reviewed modern depithing methods and described depithers that were in commercial operation. The preferred depithing technique involves a 2-stage process. The first stage moist-depithing (50% moisture) removes 25-35% of the weight of the bagasse at the sugar mill. The second wet-depithing stage removes an additional 10-12% of the dry weight at the pulp mill, resulting in a clean, high-quality fibre going to the digester. In a second paper, Atchison reviewed the progress made toward establishing a sound basis for the purchase price of bagasse, progress made in handling bagasse at the sugar mill, various methods developed for storing bagasse at the sugar mill or the pulp mill, the economics of storage methods including losses involved in storage, and factors to be considered in choosing the best methods of handling, storage, preservation, and recovery from storage for any given location. Villavicencio (USA) reported on the development of a centrifugal wet-depithing system for bagasse. The system removes pith, dirt, sand and solubles from the potential papermaking fibres, considerably reducing the chemicals demanded and improving pulp and paper products.

1974 Congress

Atchison (USA) presented a review paper, on a world-wide basis, for bagasse and other non-wood plant fibres as fibrous raw materials for the pulp and paper industry. There were 30 large bagasse pulp and paper mills of 100 to 150 t/d capacity and approximately 50 in the 10 to 25 t/day size range worldwide during 1972. Total bagasse pulp production reached 915,000 t and bagasse pulp mill capacity was expected to exceed 1.2 Mt by the end of 1973. Percentagewise, the use of bagasse as a raw material for pulp and paper increased faster since 1950 than the use of any other fibrous raw material. Its use doubled in the past five years and increased tenfold since 1950. The two remaining products, which are

not yet being produced commercially from bagasse; namely newsprint and dissolving pulp for textiles, were under intensive study, especially by ICIDCA in Cuba. Advanced technology was being developed which promises a break-through in both areas and large bagasse newsprint projects were being considered in Peru, Mexico, Cuba and Egypt.

Villavicencio (USA) presented a review of bagasse fibre's anatomic and chemical composition to comprehend some of its similarities and differences with hardwood fibres. A comparative evaluation of bagasse fibre digestion with caustic soda, kraft and alkaline sulfite processes was made with results in both technical and economic areas favouring the alkaline sulfite pulping process. Characteristics of the market grade bleached bagasse pulp were compared against commercial hardwood pulps. The bleached bagasse pulp has excellent paper making characteristics which enable it to compete with hardwood bleached pulps in the market.

Huang (Taiwan) presented the findings from investigations on changes in the quality of bagasse during storage and the effect of the changes on the particle board quality. Changes in physical properties and chemical composition of bagasse were noted. Fresh bagasse produced boards with better strength and lighter colour, but with lower water resistance than the aged ones. Moisture content of bagasse before shredding had remarkable effects on the quality of boards, and moisture contents between 22 to 32% are preferred.

Morgan and collaborators (South Africa) presented the findings of a study for wet bulk storage methods for bagasse. Test piles of between 1,000 and 1,500 bone-dry t each with Ritter solution, backwater and an organic acid solution as storage media. Storage losses, the effect of storage on the physical and chemical properties of bagasse as well of microbiological processes were determined. The Ritter treatment was found to be superior to both backwater and organic acid treatments regarding physical strength, wetness and chemical consumption of the resultant pulp.

Samaniego and collaborators (Philippines) reported on a comprehensive study on the effects of the methods of pulping, bleaching and blending on the properties of bagasse for newsprint. Depithing of bagasse was carried out in two stages, dry depithing followed by wet depithing and the depithed bagasse was subjected to 30 minutes steaming prior to mechanical pulping. Based on its strength properties, the experimental newsprint produced out of a mixture of 50% mechanical bagasse pulp, 25% bleached cold-soda bagasse pulp and 25% Puget bleached kraft sulfate pulp met satisfactorily the FAO specifications for standard quality bagasse newsprint and was as good as 11 commercial newsprints imported from Canada and the USA. Cheong and collaborators (Mauritius) presented results on the effect of steam treatment on bagasse in relation to digestibility and furfural production. The digestibility of cane bagasse was increased by steam treatment. Total acids and furfural production increased with steam pressure and duration of treatment.

Imrie and Parker (UK) examined the main problems inhibiting the development of non-food applications of sucrose. Chemical degradative reactions are unlikely ever to be economically competitive with those using other carbohydrate sources. However, fermentation is more likely to offer industrially viable processes, particularly in the hydrophilic polymer field. Future profitable applications were discussed speculatively, with special reference to detergents, emulsifiers, resins and agricultural products.

Chen and Tsou (Taiwan) reported on a laboratory fermentation process for production of microbial gum from sucrose. *Xanthomonas manihotis,* a strain isolated from the wild cassava tree, is able to produce microbial gum in a sucrose medium. The most interesting property of this new gum is the response to temperature. At a higher temperature, its viscosity increases suggesting it could be very valuable as an agent in drilling oil wells.

Preston (Mexico) presented work on the use of molasses, de-rinded sugarcane and bagasse for cattle feed. When molasses is used, roughage, supplementary nitrogen and protein are necessary to maximise animal performance. Limited data suggest that similar constraints apply to de-rinded sugarcane when used as the major component in a fattening programme. Steam treated bagasse, supplemented with urea and a small amount of molasses provides the requirements for cattle feed.

PROMINENT CONTRIBUTORS

Three personalities distinguished themselves through R&D in the Co-Products Sector in the period 1950-1974.

J.E. Atchison (USA) for his indefatigable pertinacity in furthering the advancement of technology concerning the usage of bagasse fibre for pulp and paper manufacture. He contributed major papers during the 1962, 1965, 1968, 1971 and 1974 congresses.

L.J. Keo (Taiwan) for his lengthy and effective research for improving the capability of yeasts employed in fermentation to withstand sugar concentrations of up to 20% in molasses mash on a commercial scale and also for improving the removal of aldehydes in distillation in industrial alcohol.

F.K.E. Imrie (UK) for the comprehensive paper on the main problems inhibiting the development of non-food applications of sucrose. Chemical degradative reactions will not be competitive with other carbohydrate sources but fermentation in the hydrophilic polymer field should offer industrially viable processes.

IMPACT OF THE RESEARCH

The most significant advancement during the 1950-1974 period was the technological development of pulp-and-paper production from bagasse which brought this technology to the same level as wood pulping so that by 1974, more than 80 bagasse pulp mills were operational in 22 countries producing close to 1 Mt annually. Another advancement was the development of low-cost, efficient feeding systems for the tropics based on molasses and whole bagasse or pith. R&D in this field contributed significantly to sustainable livestock production and resource utilization in developing countries. Although the huge potentialities for industrial utilization of products derived from sucrose, bagasse, filter press mud, molasses were recognized since the early 1950s, their development was limited by insufficient knowledge of sucrochemistry, the abundance of cheap petrochemical feedstocks and absence of policies. Nonetheless, the knowledge base established during the period 1950-1974 laid the foundation for advancements seen in later decades.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Co-products 1975-1999

Darryn Rackemann and Giovanna Aita

d.rackemann@qut.edu.au

INTRODUCTION

During the eight Congresses that were held between 1975 to 1999, major advances were made in integrating co-products of significant value into cane sugar production. There was a strong focus on developing high quality and cost-effective pulping and fibre product technologies, developing new fermentation products and sugar derivatives, optimizing bioethanol production and addressing the vinasse disposal issues associated with distilleries, and managing energy consumption and maximising co-generation potential.

The interest in co-products and especially energy increased significantly during this period following the world energy crisis in 1972 as the sugar industry became more aware of the need for more efficient use of cane bagasse due to its inherent potential for energy and other products. Several other political and market influences on sugar prices also intensified the interest in co-products. For example, the Brazilian government made mandatory the blend of ethanol fuel with gasoline at levels between 10% and 22% during the 1970-1990s which led to >4 million vehicles running on pure ethanol by the late 1980s. Brazilian authors contributed about 8% of the papers in the Co-Products theme during this period with a large focus on autonomous distilleries, stillage disposal options and integration of energy.

1977 Congress

At the 1977 congress Andrews provided a review of the socio-economic conditions and markets driving the decline of co-product industries in South Africa but also outlining the potential for development, while Paturau provided an overview of the commercial value of co-products with the key conclusion to improve the economic potential of sugar factories requires implementing energy efficiency measures to enable saving of bagasse for pulping and chemical production (furfural) and greater molasses utilization in fermentation industries and animal feeds. Deville detailed how silages of good quality (similar to that reported in silages made from grass, maize, sunflower) could be made from sugarcane tops alone or with the addition of molasses.

Atchison discussed the concept of how moisture affects the fuel value of bagasse and other fibre sources and comparisons to fossil fuels enabled a means of valuing bagasse for pulp, paper, board, and other industrial products. Depithing was considered necessary to improve the quality for diverting significant quantities of bagasse to co-product industries with the pith able to be utilized in boilers with supplementary fuels to supply the factory's energy requirements. Other pretreatment strategies to remove pentosans that could be utilized for furfural production were reported for producing good yields of quality pulp from depithed bagasse. Based on commercial experiences in Venezuela, Smith and Cordovez reported the factors and operating parameters used to produce a successful fibreboard plant, as a guide to those interested in using bagasse as a raw material for this product.

Chenu examined where to obtain non-molasses feedstocks from the sugar production process for enhancing overall alcohol production. He concluded mixed juice as the ideal feedstock to minimise

impact on overall steam balance. Additional papers studied production of enzymes (Hsie), microbial gums (Chen *et al*.) and melamine-formaldehyde copolymers that could be derived from molasses or sucrose (Lin and Kuo).

1980 Congress

At the 1980 Congress several authors reported on microbiology aspects of bagasse storage and impacts of baling, drying and chemical control agents, while pulping studies on chemical consumption, paper quality and ageing properties were well covered (Atchison; Fernandez *et al*.; Lacey; Lois *et al*.; Luna and Torres; Walter). Wang *et al*. detailed procedures developed to produce fungal mycelial protein from bagasse pith.

Paturau provided an economic assessment of ethanol produced from molasses or juice as a fuel replacement to petroleum, while Filgueira detailed a novel concept for a sugar factory distillery able to produce 75 L of ethanol, 220 kg biofertilizer and 110 kW export electricity from 1 t cane. Isidro described a process design and techno- economic factors for integrating a liquid CO_2 plant into a sugar mill and distillery. The Brazil experience with utilizing stillage as an alternative to fertilizers, and how application rates were dependent on soil type and nutrient content and opportunities from stillage concentration were detailed by Castello Branco *et al.* Soil conditioner produced from filter cake and ash was discussed by Donato *et al*.

Beverage floc polysaccharides were investigated by Miki *et al*. and methods for isolating polysaccharides from molasses were reported by Cremata and Orozco. Richards *et al*. detailed the development of a synthesis method for fructosides and polysaccharides based on alkaline and thermal degradation of sucrose. Liquid ozonolysis was reported by Cepero to improve quality and colour properties of sugar cane wax and Manohar Rao detailed the extraction of sugarcane wax from mud and required R&D to grow wax markets. Almazan *et al.* detailed a high yielding process for microbial production of fat and protein from molasses and showed how selectivity was based on operating parameters, feed composition and yeast strains.

The Tilby separation process to produce rind, pith and high purity juice and its potential for new fibre products of higher value was reported by Laurie and Moeltner. The process is based on separation of the hard outer rind of the cane stalk from the soft pithy tissue containing the sucrose. This process yields wax and a pith-free fibre fraction, which has optimal morphological and chemical characteristics for producing paper and board products.

1983 Congress

The 1983 Congress had a stronger focus on energy efficiency compared to previous congresses. Gonzales *et al.* detailed the development of mathematical models for simulating evaporation performance (and scaling) to determine heating surface area required' Friedman *et al.* described computer-aided design to examine modifications of evaporator stations to improve efficiency with industry examples provided. Wittwer and Mauch modelled retention time distribution and operating parameters (temperature, pH) on sucrose losses and on bagasse savings for evaporator station modifications. Keenlislide discussed improving efficiency with air pre-heaters and bagasse dryers to produce surplus bagasse and pellets for cogeneration out of season. At the time, these strategies were not considered economical due to the low cost of natural gas and electricity.

Lois and Suarez investigated baling and depithing of bagasse for improved storage, while Cullen provided a cost comparison and details of equipment required for loose storage, pelletizing and baling for a typical factory, and quantified the impact of bagasse drying on boiler efficiency. Gutierrez *et al.* examined white fungus (*Sporotrichum pulverulentum*) to degrade lignin and cellulose in bagasse as a pretreatment method for pulp production. Atchison and Molina *et al.* reviewed experimental bagasse paper machines and the commercial development of bagasse newsprint.

Rao reported on Indian commercial plant for treating stillage to produce biogas, fertilizer and water to ameliorate disposal issues. Nunez and Silva found fresh mud, lime and pith improved the production and quality of biogas. Garcia *et al.* reviewed the economics of biogas production from wastewater streams based on experimental work.

Other novel co-products were reported, including production of CMC from bagasse cellulose (Ashkienasi and Triana), and methods to ferment and recover acetic acid from mud and green tops because of their high free amino acids and nutrients content (Mellowes). Gomez *et al*. described microbial protein production from molasses and detailed a process concept for scale up. Liu and Sang reported on pilot plant testing of L-lysine production from molasses. Roberts *et al.* reported a more selective analytical method to reliably determine dextran in raw sugar.

1986 Congress

Bagasse co-products and energy efficient production were a major focus in the Congress. Developments in depithing and bagasse storage, chemi-mechanical pulping to produce fine paper, and white rot fungus (*Phanerochaete chrysosporium K-3*) delignification to reduce pulp refining energy requirements were reported (Aguero and Hernandez; Correa, Gutierrez *et al.,* Mita, Villamil *et al.*). Bagasse was used in wood-cement boards and bagasse ash was tested for incorporation into ceramics due to its high silica content (Alrnagro, Santillanes and Rodriguez; Elkader, Mostafa and El-Kholi). Bagasse drying efficiency, costs and corrosion were reported by several authors. Keenlislide examined high fibre canes to economically assess the production of sugar, ethanol and power to extend the crop period for greater asset utilisation. Ramaiah and Chikhalikar reported on the energy generation from distillery wastes by examining concentration and incineration and anaerobic digestion to produce methane. Both produced sufficient steam and power for distilleries to operate at low or high brix fermentation.

Mohamed reported operating parameters in Egypt for commercial production of acetone and butanol from molasses, noting the higher cost compared to petrochemicals. Kurniawan and Mochtar investigated electrodialysis, ion exchange and membranes as a lower cost method to desalt molasses for use as feedstock co-products. Hutasoit examined the effects of minerals, temperature and pH to optimize enzymatic conversion of glucose to fructose. Cheng and Wang studied viscosity, shear rate, temperature, and pH effects of microbial gums produced from sugar to compare with commercial xantham gums.

1989 Congress

At the 1989 Congress, diverse research advances related to fuel production, energy efficiency at the factories, bagasse pulp, and valorization of sugarcane by-products.

Alves da Cunha discussed ion exchange resins for the purification of hydrated ethanol to reduce corrosiveness. Hernandez introduced an economic method for the treatment of distillery effluent by mixing with sugarcane pith and drying to 50% using flue gases to feed the boilers. Lorenz *et al*. described a new trend for improving energy efficiency in factories in Brazil, which was attributed to the development of new outlets for surplus bagasse (fuel, cattle feed) and the increasing prices for electricity. A cost-effective solution for improving alcohol production from molasses involving recycling of hot vinasse for molasses dilution and gravity sedimentation of precipitated calcium sulphate was discussed by Gray *et al.* It successfully extended mash column cycle times and provided significant steam and chemical savings. Oliverio and de Miranda discussed the production of methane from the anaerobic digestion of stillage, and the successful incorporation of methane as a substitute for traditional fuels in cane transport trucks at a Brazilian distillery. The pros and cons of a mechanical vapor recompression evaporator for distillery slops were discussed by Hazos and Cordovez. Ogden *et al*. discussed the benefits of a high-pressure condensing-extraction steam turbine generator for boosting export electricity by up to 15% through steam economy. This same research group assessed

the benefits of biomass-gasifier steam-injected gas-turbine co-generation systems for a Jamaican sugarcane factory, using cane residues as fuel. Deepchand described an integrated system to produce electricity, protein and ethanol from fresh cane tops and leaves, and Elkader and Yassin presented results on the economic use of filter mud cake mixed with bagasse for steam generation. Reid and Wienese reviewed the interest in energy conservation in South Africa, due to the growing energy value of bagasse as a source for fibre, pith, steam, or electricity, while similar discussions on energy optimization and electrical power generation d by Oliverio *et al*. De Armas and Diaz shared experiences in the optimal design of an evaporator-heater station, considering both economic production and thermal efficiency. Saechu and Bahri discussed the performance of combination-type boilers installed in three Indonesian sugar factories.

Several authors (Aguero *et al*.; Diez and Lois, Lee and Wang; Saveedra *et al*.; Valdes *et al*.) discussed advances in pulping technologies including depithing of bagasse for different kinds of paper, high-quality board materials, and absorbent disposable products.

Chuang *et al*. described a low-cost biological treatment including activated sludge, lignin-adsorbing, and flocculant-producing bacteria to improve the quality of wastewater from pulping bagasse. The techno-economic aspects of a process to dry and bale sugarcane tops for animal feed was described by Friedman and Ponce. Lois and Ginterova introduced a new use for tops, leaves, and bagasse as substrate for the cultivation of oyster mushrooms (a high protein source). The use of glucose isomerase for the continuous production of liquid sugar with a high fructose content from molasses was reported by Hutasoit. The production costs for high fructose content syrup and glucose from sucrose as well as sorbitol from glucose were discussed by Lodos and Herve. A detailed study on the structure and composition of hemicellulose in sugarcane was conducted by Saavedra *et al*.

1992 Congress

Research presented at the 1992 Congress focused largely on bagasse pulping technologies and pulp products, and on the diversification of sugarcane by-products.

Atchison discussed the success in producing quality bagasse newsprint acceptable to publishers. The technology was operational in India, Indonesia, and Mexico at the time. The technological success was attributed to mechanical bagasse pulping, wet depithing systems, appropriate bagasse storage conditions and bleaching system to maximize brightness. The limitations of conventional chemical pulping technology were reported by Garcia and an alternative technology requiring mechanical action with reduced amounts of chemicals added to decrease energy consumption and enhance strength properties were presented. Mansito and Aguero evaluated the potential of bagasse pulps in three-ply linerboard to decrease the amount of imported long-fibre and achieve the strength quality requirements. Torres and Krkoska concluded it was possible to describe the strength of the chemi-mechanical pulp from bagasse from mathematical equations relating the strength properties of paper with geometrical and physicochemical parameters of fibres and pulps. Production of bagasse particleboards with calcinated magnesite as a binder was successfully demonstrated by Valdes *et al*. Yee *et al*. developed overlay paper from cellulose obtained from mild acid hydrolysis treated bagasse. The chemical and morphological characteristics of sugarcane fibres were reported by Fernandez *et al*. who concluded rind fibres were longer, more lignified, and had a higher cell wall thickness than other sugarcane fibres, with a flexibility ratio greater than those of bagasse and hardwood fibres thus posing a higher papermaking potential.

Bernhardt and Proudfoot described a process to produce animal feed proteins from the yeast *Candida blankie* fed with fermentable sugars (glucose, xylose) extracted from bagasse using sulfuric acid. An economic assessment on the use of sugarcane and its by-products for animal feeding purposes under different agro-industrial conditions was provided by Cabello and Galvez who concluded that the production of animal feed from sugarcane co-products alone was insufficient considering ecological, nutritional, and economical reasons, and the proper combined use of sugar and animal feed technologies was suggested to maximize the economic value of sugarcane. Cheng *et al*. reported the

successful production of biodegradable padding materials from bagasse fibres. Lysine production from molasses at laboratory and pilot plant scales were reported by Kurniawan, Liu *et al*. and Wang *et al*.

1995 Congress

At the 1995 Congress most presentations were on energy efficiency and valorization, with a few also on bagasse pulp and ethanol fermentation.

Hablein and Langhans presented an overview on energy savings in sugar factories. Noel shared views on technical solutions for both new and existing sugar factories in Mauritius that achieved acceptable levels of efficiency for co-generation. Aguilar *et al*. presented a comparative analysis between the energy features of cane agricultural waste and those of several different solid fuels conventionally used in the industry (bagasse, peat, lignite, anthracite).

Overviews on the potential of bagasse to produce animal feed, cellulose, paper, composite board, industrial filtering media, and products for biotechnology and pharmaceutical industries were presented by Fernandez and Garcia and Cruz *et al*. A process to produce cattle feed (PREDICAL) from predigested bagasse treated with lime and steam was described by Bambanaste *et al.* Liquid and solid organic fertilizers produced from concentrated ethanol distillery slops (rich in yeast metabolites, yeast cells, nucleic acids, proteins, vitamins, and minerals) showed a synergistic effect when used in combination with a chemical fertilizer, greatly increasing plant growth, productivity, and quality of short-term crops (tomatoes and lettuce) (Liu *et al*.). The production of nucleotide-5'-monophosphates (reagents used in biological research) extracted from yeast cream (a co-product of ethanol fermentation) was reported by Yang and Wang. Cruz *et al*. discussed the economics for lignin recovery from black liquor acidulation using sulfuric acid. Lysine synthesis by *Brevibacterium lactofermentum* from molasses was reported by Chang *et al*. The use of sucrose for the synthesis of mono fatty acids esters (Martoyo *et al*.) and the production (via fructosyl transferase) of fructo-oligosaccharides and their chromatographic separation (Yang *et al*.) were also discussed. Keskar and Kolekar reported that high performance liquid chromatography was a superior technique than the traditional polarimetric and chemical methods used for the analysis of sugars in molasses.

Fernandez and Perez reported processes that enable separation of the stalk fibre fraction by nonconventional milling resulted in a superior fibrous material for papermaking when compared to traditional bagasse. Aguero and Leal investigated the effects of refining on the strength properties of bagasse soda chemical pulp.

Mutton *et al*. evaluated ethanol fermentation yields in liquid and semisolid phase with and without topping, and Stupiello *et al*. reported on the effectiveness of quaternary ammonium compounds and virginiamycin against eight Gram-positive bacteria (isolated from ethanol fermentations in Brazil.

1999 Congress

The 1999 Congress was heavily focused on co-products. An overview of Indian co-products industries was presented by Manohar Rao and included ethanol and fermentation products from molasses, yeast and animal feeds, and biogas and compost from distillery effluents and filter cake. Chang reported on flocculating yeast for recycling in continuous ethanol production. A process for producing extra neutral alcohol from molasses was described by Paul. The development of a wide range of biodegradable plastics by incorporating sucrose stearate into a cassava starch/polycaprolactone blend was introduced by Sriroth *et al*. Yang and Wang demonstrated the synthesis of various fructo-oligosaccharides from sucrose with the aid of the enzyme *p*-fructofuranosidase, produced by *Aspergillus* spp. Michelena *et al*. described a process to increase the yields of dextransucrase from *Leuconostoc mesenteroides* at a semi-commercial scale. Studies on cellulase production by a mutant strain of *Trichoderma reesei* from bagasse were reported by Wang.

Valdes *et al.* discussed alternative solutions for the treatment of wastewaters to reduce their ecological impact, including the use of stabilization lagoons and disposal via irrigation, the direct use as fertilizers, the installation of biogas plants for contaminated wastewaters from distilleries and yeast industries. Concerns of methane emissions from bagasse burning at sugar factories in India were presented by Narang *et al*.

PROMINENT CONTRIBUTORS

Three highly distinguished technologists in the field of co-products were identified based on the prolificity of research presented in the 1977-1999 period.

Joseph Maurice Paturau who was considered the world authority on sugarcane co-products and his book entitled *By-products of the cane sugar industry: An introduction to their industrial utilization* published in 1969 has been revised many times. He was the General Secretary of the 1962 Congress held in Mauritius and the Co-products Commissioner in 1989-1992 and continuing his association with ISSCT until he passed away in 1996, is celebrated by ISSCT through the 'Award for best paper in the Co-products' category presented at ISSCT congresses since 2005 and is the only sugar technologist in the world who has a bank note bearing his effigy.

Joseph E. Atchison of Atchinson Consultants was inducted into the Paper Industry International Hall of Fame in 1998. He contributed papers on pith and bagasse use for energy, pulp paper and board products in 10 ISSCT congresses from 1974 to 1999. Atchison is an internationally recognized and widely published authority on the utilization of non-wood plant fibres for papermaking, playing a key role in the development and implementation of 40 mills in 25 countries. His contributions have played a key role in the dramatic worldwide expansion of the non-wood pulping capacity for papermaking from 9 Mt in 1975 to more than 24 Mt in 1998.

P.J. Manohar Rao from the Ministry of Agriculture & Irrigation (Government of India) published many papers in ISSCT, several books including *Industrial Utilization of Sugar Cane and Its Co-Products* in 1997 and *Other Co-product Options from Cane Resources* in 2012. He is celebrated through the 'P.J. Manohar Rao Gold Medal for Excellence in Co-products' award at the annual Sugar Technologists Association of India conference.

IMPACT OF THE RESEARCH

With factories implementing new energy efficiency measures, additional surplus bagasse is now available for co-generation and other products. Bagasse-based processes account for an estimated 2-5% of global production of pulp and paper products. A review of the Indian co-product industries exemplifies the value represented by the development of industries based on the three main cane sugar byproducts of bagasse, molasses and mud cake (Manohar Rao 1999). By 1999 India had begun operations of the following bagasse-based plants: 4 large-scale and 55 small scale paper plants; 4 particle board plants; 10 co-generation plants exporting power to the national grid; and 1 furfural plant. Additionally, 285 molasses distilleries were in operation as well as 7 plants producing citric, lactic acid and ephedrine using molasses as the feedstock. A further 150 biogas and 30 compost plants were operating on mud cake and vinasse.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Co-products 2000-2023

Bryan Lavarack

b.lavarack@mkysugar.com.au

INTRODUCTION

Over 150 papers were presented at eight ISSCT congresses held during 2000-2023. In previous congresses, the term by-product was applied to any product other than sugar produced from sugarcane. These products were manufactured from, but are not limited to bagasse, molasses, mill mud and boiler ash. The old term is found in the title of both the paper and textbook by Paturau (1986 and 1989) and infers these products are of secondary or lesser value than sugar and have limited potential for adding value to the sugarcane industry. This of course is incorrect, particularly with developments in the latter part of the 20th century of significant co-product industries such as the Proalcool program for fuel ethanol production in Brazil, the widespread development of cogeneration, and pulp and paper manufacture from bagasse in India and other countries. ISSCT has moved away from the perception of lesser value for products other than sugar, calling them co-products to project the view that there is value in all parts of the cane plant. This view is applied for example to the title of the textbook by Manohar Rao (1997). This paper reflects the better perception of co-products in the new Millennium.

RESEARCH ADVANCES

2001 Congress

Eleven papers were presented at the Brisbane congress. Interesting new products and processes were described including, fructo-oligosaccharides (FOS), biodegradable plastics, natural glucans, mannitol, selenium yeast, DEAE-bagasse, the development of power generation and environmental issues.

Huang *et al.* presented the technicalities in producing fructo-oligosaccharides (FOS). These are considered health foods because of their special properties including sweet taste, and ability to lower lipid serum levels, increase intestinal calcium absorption and indigestibility (calorie-free and safe for diabetics). FOS is produced from sucrose and is composed of 1-kestose, nystose and fructo-furanosyl nystose. The process was commercialized in Taiwan. On a similar theme, Day *et al*. reported on the use of oligosaccharides as functional foods. Yields of glucans and mannitol were given.

Kong Win Chang *et al.* reported on the evolution of the sugar industry in Mauritius with a focus on power generation noting (i) reductions in greenhouse gas emissions (displacement of 215,000 t coal and reduced fuel oil dependency) and (ii) increases in power production from 31 GWh up to 360 GWh per year. The program rehabilitated and modernised cane processing into centralised operations. It provided a model to others planning to progress to reduced greenhouse gas emissions, factory modernisation and reduced fossil fuel consumption.

Selenium has been reported as a key component of some antioxidants that can prolong life expectancy of animals. The organic sources of selenium are superior to inorganic; Liou *et al.* examined the production of selenium yeasts from sucrose feed.

The production of ethanol in a continuous tower reactor with a flocculating yeast was described by Viegas *et al*. The process examined a fluidised bed type reactor for ethanol fermentation and showed two yeasts out of an initial six dominated at the end of a 15-day cycle.

When examining co-product options, environmental aspects are often not discussed, although can terminate projects if not addressed successfully. Sapkal *et al.* reviewed reducing environmental emissions in Indian sugar factories. On the theme of environmental, Vandana and Prakash presented a study on the decolourisation of wastewater from anaerobic digesters. They determined 80% colour removal by a fungal strain, which when supplemented with chemical methods, can lead to 100% colour removal. Mane *et al.* (2001b) chemically modified bagasse with diethylaminoethyl chloride (DEAE chloride) to produce a material that decolourises sugarcane juice by adsorption and ion exchange mechanisms.

2005 Congress

At the Guatemalan congress, there was a resurgence in the number of papers from the previous congress, with 22 published, with noted focus on 1st (1G) and 2nd (2G) generation ethanol.

In the plenary session, an integrated sugar, ethanol and cogeneration plant based on modelling work was benchmarked for sustainable production (Avram-Waganoff *et al.*). The models maximise overall efficiency for a range of co-products, proportioning 50% of its sugar to ethanol production and 50% to plantation white sugar manufacture. The process house has low-pressure steam consumption of 21.9% on cane for a 20,000 t/day factory. High-pressure boilers of 65 bar are assumed; either two boilers rated at 250 t/h or three at 176 t/h. One steam condensing turbine has extraction points at 11 and 2.5 bar for all steam consumers. The factory consumes all vapours from the evaporation station. Vapour 3 is fed to both juice heaters and pan stage. Clarified juice enters at the 3rd effect to cope with the sugar factory steam demand. There is virtually no condenser loss and condensers are required mainly for start-up. Condensate is flashed in condensate cigars for steam efficiency. The extraction steam turbine produces 42.5 MWe and condensing turbine produces 60.5 MWe, with 79 MWe exported. Additional power can be exported if bagasse drying to 10% moisture bagasse is achieved. The fuel ethanol plant is fed with B molasses and is rated at 800 kL/d. It has multi-pressure distillation to reduce steam consumption from 3-5 kg/L to 1.4-1.9 kg/L. All vinasse is concentrated and burned in a vinasse boiler / turbo-generator. The vinasse boiler is rated at 38 bar and 82 t/h and generates another 10.5 MWe but requires an auxiliary feed for combustion.

The theme of ethanol R&D from the co-product workshop (Leal) continued at congress. Finguerut described the advantages of simultaneous production of sugar and ethanol in Brazilian factories with the aim to convince other sugar-producing countries to manufacture ethanol as a feasible and profitable activity. Brazil implemented the national program (Proalcool) in the 1970s and benefits lie in replacing imported petroleum and adding value to the industry. Advantages of simultaneous processing include no requirement for sugar recovery in the factory back-end, low pressure vapour can be applied to ethanol production, reduced problems in sugar production, co-location benefits of shared facilities, reduced water consumption in the distillery (dilute molasses with juice), better quality products, higher profitability, and less reliance on sugar pricing. In summary, ethanol is a viable co-product that adds value to a sugarcane factory. Nogueira evaluated gasohol production in six Central American countries exploring production from juice and molasses and for 10% and 25% gasoline blends. The conditions were favourable for Guatemala, Costa Rica and El Salvador for the introduction of gasohol in the short to medium term. Davis *et al.* followed the theme and reviews the potential for fuel ethanol production in Guyana.

Olivério and Hilst reported on a semi-industrial plant producing 5 kL/d 2G ethanol from bagasse. It used a continuous one-stage process to hydrolyse bagasse into component sugars with an organosolv and dilute acid process. Only C6 sugars are fermented to yield 109 L/t ‘in natura’ bagasse. There is potential to improve the yield to 150 L/t through C5 sugar fermentation and to 180 L/t from increased extraction of both C5 and C6 sugars. If ethanol is produced from the sugar available in sugarcane only, 1 ha yields

80 t cane to produce 6.4 kL ethanol. If cane leaves and tops are recovered from 1 ha (16 t) and surplus bagasse from the factory are processed, ethanol production increases by 5.7 kL which almost doubles production to 12 t/ha. Rossell *et al.* provided more detail of the 2G ethanol process, noting the organosolv is ethanol-water and 0.10-0.25% sulphuric acid is applied. The lignin dissolved in the organosolv is precipitated after extraction. The conversion of sugars was about 59% to produce 80 g/L liquor after 10-12 minutes residence time. A yeast strain, tolerant to high concentrations of inhibitors, ferments the C6 sugars. The inhibitors for the fermentation include short chain organic acids, furfural and hydroxymethylfurfural.

Mane *et al*. reported that aconitic acid has a melassigenic effect since lower aconitic contents are found in low purity molasses and higher contents in higher purity molasses. Aconitic acid effectively blocks fermentable sugars and makes them unavailable for fermentation. Gomes Moura and Rocha D'Avila examined the dehydration of ethanol with cyclohexane azeotropic distillation, molecular sieve and extractive distillation with ethylene glycol. They determined the cyclohexane process is very suitable for small to middle sized fuel-alcohol plants and represents the minimum-investment. The extractive process based on ethylene glycol is a good option as a middle-investment for anhydrous alcohol production containing a trace of the agent present in the product. Finally, the molecular sieve process, whose anhydrous alcohol does not show any trace of the dehydrating agent and has the lowest steam consumption, was the higher-investment option.

Penatti *et al.* reported vinasse improves fertility and promotes sugarcane root system growth. It carries elements important for sugarcane nutrition like calcium, magnesium, sulphur and potassium. Vinasse plus mineral nitrogen increases the cane yield more than vinasse alone; so mineral complementation is needed but can be reduced as vinasse doses are increased.

Narendrath reported on a factory in India producing over 12 co-products in one location. Leimar and Finguerut reviewed alternatives for dried yeast and its products.

2007 Congress

The resurgence in co-product papers continued at the congress in Durban, with 23 papers, and followed a successful workshop in Maceio, Brazil .

Lavarack *et al.* examined the ability to capture carbon dioxide lost in ethanol fermentation through the Zeachem process which chemically converts it into ethanol product. Moura and Medeiros reviewed chains of processes to achieve a specific objective (e.g. steam efficiency or product quality). Dias *et al*. examined efficient cooling during fermentation. Kulkarni reviewed the deterioration of molasses and methods to prevent it. Olivério *et al.* reported on the integration of biodiesel production into a sugar and alcohol mill. The importance of evaluating greenhouse gas emissions was beginning to become noticeable with a paper on life cycle analysis (LCA) on vinasse disposal options (Rocha *et al.* 2007); for the Brazilian situation, the option of fertigation without evaporation and transport by channels had the lowest environmental impact.

Bagasse gasification studies were reported by Hobson, Hobson and Joyce, and Ueno. It was possible through the gasification of bagasse and application of the biomass integration combined cycle to increase power export potential at an Australian mill by a factor of four relative to an existing low-pressure boiler (17 barg) steam plant.

2010 Congress

Twenty-three papers were presented at Veracruz, leveraged off a fruitful workshop in Coimbatore, India.

Leal and Walter reviewed the Brazilian experience to help potential biofuel producers arrive at the best technical option for their local conditions. The reduction of greenhouse gas emissions, and natural

resources available are important factors. Castillo *et al.* reported on bioethanol developments and investments in Colombia. By 2006 bioethanol production had increased to 1050 kL/d in five factories.

Chotineeranat *et al*. demonstrated that high calcium content in molasses feeds decreases the productivity of ethanol fermentation particularly for sucrose but least for glucose.

Finguerut reviewed the progress made by the Brazilian industry, particularly the improvements in the production of ethanol. Olivério promoted ethanol technological advances achieved by an absorption chiller and through fertilizer production. Otero *et al*. reported on the removal of potassium from vinasse by *Candida utilis* propagation. The propagation of yeast on vinasse medium is an excellent pre-treatment for irrigation. Vinasse with COD less than 30 mg/mL and potassium content below 2.5 mg/mL offers no ecological impact when used for cane field irrigation. Arias Polo modelled the production of biogas from vinasse and its use to generate steam and power and Ribas *et al.* modelled the fermentation process to match commercial scale production. Rochas *et al.* updated previous work, reporting on alternative routes for the treatment and disposal of stillage, if fertigation becomes non-viable. They applied life cycle analysis and determined that bio-digestion was the best alternative. Schopf and Erbino examined the use of vinasse as a supplementary fuel in a proprietary burner for biogenic fuels. About 20% support fuel is required in the burner.

Obando *et al.* examined the production of second-generation ethanol and determined it is not cost-competitive to conventional ethanol processes. The high costs of the enzyme (USD0.32/L) accounted for two-third of the cost and would require production at site to reduce production costs (USD0.05/L) to make the process competitive. Walford determined that ethanol production from enzymic hydrolysed bagasse is not economic, the production of single cell protein is possible and ethanol from hemicellulose hydrolysate is marginal.

Kim and Day investigated the production of butanol from sugar juice as an alternative to ethanol production. Otero and Almazán determined that oil-yeast production could be an attractive alternative to oil seeds for the production of biodiesel. Jais demonstrated that a small factory with 6500 ha of cane can supply all the energy to fuel a small community of 100,000 people with all their sugar, electricity and automotive fuel requirements. Thangamuthu discussed the production of biogas from mill mud which is a cheap fuel.

2013 Congress

The Congress in Sao Paulo, Brazil followed a successful workshop in Thailand. The maturity and size of the ethanol industry, particularly in Brazil, was reflected in the increased number of co-product papers to 29, with focus on ethanol technology including value-adding to vinasse.

Olivério and Boscariol reviewed the expansion of the Brazilian industry from 320 to 620 Mt of cane, highlighting learnings from the expansion. After 2003, 75% of factories were dedicated to ethanol production and remainder to combined sugar and ethanol production. The factory size increased to about 15,000 t/d with improved factory efficiencies, including mill extractions (97-98%), reduced steam consumption (down to 32% steam on cane), efficient boilers (400 t/h and 120 bar), better overall ethanol yields (87 L/t cane) and fermentation and distillation yields (92 and 99.5% respectively), decreased fermentation time and increased beer content (6-8 h and up to 16 °GL), reduced water consumption (0-3.7 L water/L ethanol) and low stillage production (0.8-5.0 L vinasse/L ethanol). Biomethane production started (0.1 Nm^3/L) and factories had better integration of bagasse to increase electricity production (e.g. 50.7 MW for 12,000 t/d factory). Other co-product developments included an edible oil plant, polyethylene manufacture, sodium bicarbonate plant, farnesene manufacture, biodegradable plastic, and second-generation ethanol.

Developments in ethanol technology included an on-line fermentation monitor (Yamakawa *et al.*), distillation simulation (Batista and Meireilles), establishment of vapour-liquid equilibrium data (Fonseca *et al.*), compliance to zero effluent norms in India (Patil), reduction of water consumption in an integrated

first- and second-generation ethanol plant (Mosqueira-Salazar *et al.*), biogas production from vinasse (González), optional routes for biorefineries (Viera *et al*.). Schopf and Erbino report on recent developments for liquid burners. Ohara *et al.* reported a novel yeast to remove reducing sugar before sucrose extraction and improve factory yields.

Day *et al.* described recent work on continuous butanol fermentation and Chen *et al.* on vinegar production by submerged fermentation. Faife *et al.* reviewed processing wastes into animal feeds and microbial oils and Otero *et al.* discusses converting ethanol wastes to protein feedstock. Shintaku and Meireles investigated applying supercritical CO_2 to extract from sugar and ethanol industry wastes.

Several papers focussed on adding value to bagasse; Bourzutschky described conversion of bagasse into charcoal; Almeida *et al.* described a pneumatic method to reduce the cost of enzymic hydrolysis of bagasse; Roussel *et al.* reviewed harvesting to promote multi-cane production; Seabra *et al.* examined biorefineries based on gasification; Cobo *et al*. assessed harvesting residues in thermochemical processes; Walter *et al.* reviewed the potential for marketing of bagasse and pellets.

2016 Congress

The congress in Thailand followed a successful Workshop in Mauritius and saw 24 papers.

Ethanol continued to be a major focus with about half of the papers focussing on ethanol research and development. Leal and Leite reviewed ethanol as a major co-product and discussed its rise to prominence over last 40 years and noted its growing importance under different low carbon scenarios in the transport sector. Two papers on the removal of reducing sugars prior to sugar extraction continued work from the previous congress (O'Hara *et al.* and Ohara *et al.*). Both Yamakawa *et al.* and Nolasco Junior *et al*. presented the assessment and implementation of a very high gravity fermentation process undertaken in Brazil. Milintawisamai *et al*. isolated a strain of yeast from sugarcane juice and tested this this commercially and found it had higher yields, required less acid in the process and tended to overcome high microbial contamination and volatile acids than a commercial strain. Phaengthai *et al.* investigated the effects of inorganic salts on fermentation with Saccharomyces cerevisiae.

Both Kumar *et al.* and Sundaram *et al*. foreshadowed the rapid development of fuel ethanol production in the next decade in India through changes to include alternative feedstocks.

The disposal of vinasse through concentration and burning in boilers continued to receive attention in papers by Strünkmann and Morgenroth and Subramanian and Singla (2016). The boilers described by the latter are all co-fired with bagasse or coal or wood chip.

Lavarack reviewed the development of co-products in Australia, with development of cogeneration throughout the industry and limited uptake of ethanol production and other co-products.

Sugarcane agricultural residues (SAR), trash or straw, received attention, with Bernhardt examining a prototype burner to convert it into charcoal, and Umrit *et al.* investigating SAR conversion to bioplastics polyhydroxyalkenoates (PHAs). Value adding through the use SAR is becoming a major topic for investigation.

2019 Congress

The workshop in Brazil preceding the Argentinian congress in Tucumán, focussed on the full use of sugarcane and residues. The 27 papers presented at the congress continue this theme and included three3 plenary papers with strong co-product themes. Autrey *et al.* reported on the competitiveness of sugarcane industries in an era of low sugar prices and noted diversification is a must and requires supportive government regulation and policy.

Leal *et al.* reported that SAR can lead to energy recovery efficiencies above 40% or higher if associated with future increase in cane yields and the use of second-generation (2G) ethanol technology. This is provided SAR is recovered sustainably; meaning leaving enough SAR in the field to accrue the agricultural benefits. The interest in increasing surplus electricity generation, including in the offseason, incentivizes mills to collect a portion of the SAR to increase the power generation by supplementing the bagasse in the mill boilers. However, several barriers have been preventing the expansion of SAR use to meaningful levels. Motivated by that, the SUCRE (Sugar Cane Renewable Electricity) project was conceived to identify and overcome the barriers that are preventing a broader use of SAR to supplement bagasse.

The SUCRE project (Soares *et al.*) concluded that the industrial processing of SAR should be designed with aim of removing mineral impurities, decreasing the concentration of critical chemical elements, and reducing trash size to make the particle size distribution as close as possible to that of bagasse. The project determined areas of future work including (i) provide a good practice guide for SAR removal, (ii) improve the washing system to remove, K, S and Cl, (iii) improve SAR downstream washing operations, (iv) work with boiler manufacturers to minimise impacts of SAR in boiler fuel, (v) develop designs for SAR collection, (vi) develop a business model for power generation and (vii) disseminate project results.

Leal *et al.* reported several countries undertake SAR collection. Mauritius was trialling SAR collection to displace coal in power generation to reduce GHG emissions and potentially to use in plastics production. Colombres and Paz reported the Ledesma Mill in Argentina was collecting and burning SAR in the boilers to produce electricity and steam at several pressure levels to supply the industrial units at the mill site (sugar factory, ethanol distillery, ethanol dehydration plant and a paper factory). They determined the potential for generating power through gasification cycle is 588 GWH for 1 million t of dry SAR. Fonte-Pérez et al. reviewed gasification for increased power production in Cuba. Mohan and Swain reviewed the production of power in Indian factories from several sources including SAR, bagasse and vinasse.

Although there were fewer papers on ethanol R&D, significant developments were reported. Mohan *et al.* reviewed the production of ethanol from alternative feedstocks in India which predicts a sizeable increase in fuel ethanol production in the next decade. Olivério *et al.* reported that in 2017, Brazilian legislation (RenovaBio) recognizes the environmental qualities of bioethanol and defined criteria to transform reductions of Greenhouse Gases (GHG) emissions into a financial asset called CBio. These represent a new income stream that can be earned by the sugarcane mill.

Ortiz and Erazzú reported on a study for power production from vinasse in Argentina and determined power generation is economic for ethanol plants larger than 70 ML/y and biogas production is recommended for smaller ones. Zamora-Rueda *et al.* determined the physical and energy characteristics of vinasse at various concentrations providing a benchmark for comparison purposes. Russo *et al.* reported on the optimisation of a process for simultaneous sugar and ethanol production including vinasse concentration in Argentina.

Leal and Teodore reviewed bioproducts from the perspective of the sugarcane industry. Almazán *et al.* reported on the integration of a process to obtain biobutanol. Patil *et al.* reported on the production of lactic acid from bagasse with *Bacillus coagulans*.

Rearte *et al*. examined bagasse pellet production in Argentina. Bermúdez *et al.* showed that although a 10 t/d production of Torula yeast from vinasse has high power costs, production can be undertaken with good return by integrating a concentration-incineration system to generate power. Lencina *et al.* investigated the production protein while reducing contamination in vinasse which can reduce the contamination load in vinasse (effluent).

2023 Congress

The planned co-product workshop was substituted with a webinar (COVID-19). There were 17 papers at the congress in Hyderabad, India.

The webinar had an excellent presentation by Coral (2022) on the development of co-products at Raízen's Bioenergy Parks in Brazil. Unfortunately, the webinar presentation was not upgraded to a paper for presentation at congress but is reported by Lavarack. Raízen's portfolio of co-products includes: (i) 1G ethanol, (ii) 2G ethanol (with potential 50% increase over 1G ethanol production from the same planted area with SAR), (iii) power generation (from steam optimization), (iv) biogas production (from sugarcane residues), (v) pellets (from sugarcane residues to replace non-renewable fuels). As well, five co-products are noted as addressable markets: (a) sweeteners, (b) sustainable aviation fuel, (c) hydrogen, (d) biobunker fuels, and (e) bioplastics. Some learnings from 2015 to 2022 for the 2G ethanol at the Costa Pinto Bioenergy Park were presented. The 2G plant is integrated with the existing 1G ethanol plant to save on capital costs and to improve operational efficiencies. Both productivity and reliability have steadily improved for 2G operations following close collaborations with both equipment and enzyme suppliers. Three full scale 2G plants were under design/construction with a plan to have 10 completed by 2030/31. The design ethanol yields were given as 261 L/dry t (and includes C5 sugar fermentation), operational uptime 86.7% and 2G ethanol production larger than the 30 ML/y achieved at Costa Pinto. Although 2G ethanol production is more costly than from sugar feedstocks, it has a low carbon footprint which will become more valuable as the world progresses to zero emissions in 2050. The carbon intensity of the fuel ethanol produced in the 2G ethanol plant is considerably reduced compared to 1G ethanol and other liquid fuels.

Mohan reported on the major swing to fuel ethanol production in India which has saved the Indian sugar industry. The target of E10 fuel production has been achieved and the mandate increased to E20 to be accomplished by 2025. Dani and Gopalakrishnan discussed the clarification of B molasses to assist in storage and to reduce scaling in ethanol plants. The use of alternative feedstocks has assisted in achieving the targeted fuel ethanol production.

Vinasse R&D was discussed. Awasthi *et al.* reviewed the development of boilers to incinerate vinasse by co-firing with bagasse. The latest design was reported to have improved reliability and reduced times between boiler cleans. It had a pre-dust cleaner and a mechanical dust cleaner (and no electrostatic precipitator). The optimal temperature for vinasse combustion is 700-725°C to minimise scaling and is below the ash deformation temperature. Seven design considerations were given for the latest generation of vinasse-bagasse co-fired boilers. The boiler can switch between vinasse produced from syrup, B molasses and C molasses. Lorenzo *et al.* investigated the effect of nutrients on vinasse. Wu-Tiu-Yen and Eve explored potassium extraction by ion-exchange from the methanization effluent of vinasse. Further work was required before the process can be commercialized.

Research into SAR continued. Yepez *et al.* investigated xylose production from SAR. They determined xylose yields of 89% at solid-to-liquid ratios of 1:6 and sulphuric acid concentration of 3% at mild temperatures. Hydroxymethyl furfural (HMF) and furfural at 0.04 g/L and 0.49 g/L were contaminates. Ketsub *et al.* showed the hydrothermal-anaerobic process (undertaken in that order) of SAR produces hydrochars having higher HHVs than the anaerobic-hydrothermal process (undertaken in that order). The latter process had the highest methane yield of 126.4 kg based on 1 dry tonne of sugarcane trash or 58% more methane than the hydrothermal-anaerobic process. Mohan *et al*. studied the implementation of a two-stage pretreatment process to convert sugarcane bagasse into chloromethylfurfural (CMF) and vanillin with the simultaneous fractionation of pentose sugars and lignin in a biorefinery. CMF is a practical alternative to HMF as platform chemical. The process can provide a new use for sugarcane biomass for renewable chemicals.

Cavailles *et al.* studied the moulding conditions for sugarcane bagasse in food packaging. The density of the product varied from 1210 to 1510 kg/m^3 and mechanical properties were improved by higher moulding pressure, temperature, and time. The best mechanical properties were obtained with sugarcane bagasse below 200 µm with 7.2 % humidity at 180°C, 102 MPa for 5 min.

Eggleston *et al.* reviewed the composition and health benefits of commercial vinegars. Overall, vinegars from cane juice had higher nutritional value than vinegars from syrups and white wine and were in the same range as red wine and cider vinegars.

Lavarack provided an overview of bagasse co-products including the accelerating development of 2G ethanol, the use of SAR in renewable energy and biochemicals, the development of both torrefied and bagasse/SAR pellets, and the application of fibre in new animal feeds. Muir reported on the development of co-products for the beet sugar industry and notes most chemicals are derived from fossil fuels. Although there have been ways to produce plant-based chemicals for over half a century, there has until now been no incentive to do so. With the European Green Deal program in action, some new technologies were seeing the light.

PROMINENT CONTRIBUTORS

Three researchers have been identified as contributing significantly to the ISSCT Co-products commission during the 2000s.

Manoel Regis L.V. Leal chaired the Co-products Commission over several terms and authored many papers at ISSCT. More recently, he co-chaired the SUCRE project investigation into Sugarcane Agricultural Residues.

Jose Luiz Olivério has been the technical lead at one of Brazil's largest suppliers of sugarcane machinery. That company has been a major innovator in the field of sugar co-products.

Oscar A. Almazán del Olmo is a distinguished Cuban researcher, life member of ISSCT and former General Secretary of ISSCT. He has been a prodigious author and promoter of co-products.

IMPACT OF THE RESEARCH

Bioethanol has consistently received the most attention in the period of the review. The technology for bioethanol production has developed considerably since the start of the Proalcool program in Brazil in the 1970s. The industry is starting to increase production of ethanol from 1G sugar feedstocks (juice, syrup and molasses) to 2G feedstocks (bagasse and sugarcane agricultural residues) in both Brazil and India. The lower life cycle emissions for bioethanol give ethanol a significant advantage over fossil fuels. Second generation ethanol has significant carbon abatement. The research and development into other fuels, such as butanol was recorded.

Power generation from bagasse has developed and is able to provide reliable base-load capacity. The potential of gasification to increase power generation from bagasse and sugarcane agricultural residues has yet to be commercialised. The technology has the potential to deliver a fourfold increase in power compared to the present boiler/steam turbine technology. The research into sugarcane agricultural residues left in the field is ongoing and can supplement bagasse production, however the high levels of impurities in the residues are impeding its commercialisation. Factory bagasse production can increase substantially if steam economy measures are introduced. However, these measures become progressively costlier as steam efficiencies improve.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Management 1924-1938

James M Shine, Jr

jmshinejr@gmail.com

INTRODUCTION

The Management and Extension Commission of ISSCT was not formally established in the early life of the Society. Many of the researchers and leaders in the industry were very much applied in their approach and the need to solve problems. Often the researcher was the manager and the extensionist. I have attempted to highlight the high-level themes of the congress(es) during this early period, making note of the contribution toward Management and Extension at the end of the summary of each congress.

1924 Congress

The inaugural congress of the International Society for Sugar Cane Technologists (ISSCT) took place in 1924 in Honolulu, Hawaii, which was small in today's terms with 47 delegates, representing 11 countries (29 of the participants were technologists and managers from the state of Hawaii). This meeting was a product of the Pan-Pacific Food Conservation Conference sanctioned by the Pacific Union (Science. 1924. 60(1549):216-217). The Pacific Union was organized principally by Hawaiian promoter of culture and tourism Alexander Hume Ford with the intention of stabilizing food security in the Pacific region in the wake of the First World War. At that time, the sugarcane industry was one of seven food conservation sections and the only one that was ultimately organized as a technical society (the ISSCT) with a plan to meet triennially. The initial core mission of the ISSCT was to promote mutual understanding and cooperation among those involved in the production of sugarcane. It subsequently expanded its focus beyond the pacific region to all sugarcane producing countries of the world. This was probably driven by the fact that Indonesia (Java) in the Pacific, and Cuba in the Americas, were the two largest producers of sugar for export at the time. Other countries produced cane sugar largely for domestic consumption or imported cane sugar from offshore.

The congress was conducted in more of a workshop format with 11 associated topical sessions, where presentations evoked discussion. The recurring theme was the need for more coordinated collaboration to develop technologies. There were no published papers as part of the proceedings because the overall conference publication decision was that papers on specific topics would be published in journals devoted to specific fields of science.

The themes discussed from the agricultural perspective were not much different than those discussed today. Of particular importance, however, was understanding the causal agents of diseases in specific countries and the need to develop resistant lines through plant breeding and the trading of resistant sugarcane varieties between countries. However, to prevent the inadvertent transfer of disease between countries, border controls, strong enforcement policies and strict quarantine procedures were also discussed. In-depth discussions on cultivation, trash management, crop nutrition in different regions of the world, and biological control strategies for pest management also took place. There was also a brief mention of the use of a 45-HP tractor on one plantation in Hawaii and the potential for mechanization to revolutionize cultivation in the future.

The noteworthy leaders that participated actively across the sessions included: E.W. Brandes, United States Department of Agriculture; Hunter Freeman, Australia, Colonial Sugar Refining Company; Mario Calvino, Cuba, Chaparra Sugar company; R.L. Pendleton, India & Philippines; and H. Atherton Lee, Philippines and Hawaii, HSPA Experiment Station. These sugarcane research pioneers had a very broad knowledge base and were mindful of their findings being implemented through management and extension practices.

1927 Congress

The six members of the charter committee had done significant recruiting to promote the new ISSCT organization in most of the sugarcane production regions of the world. Cuba had become the world's leading sugarcane producer with production approximating 5.25 Mt so it was apt that the second ISSCT Congress be hosted in Havana, Cuba in 1927. The program covered virtually all aspects of sugarcane production and processing. There were 61 foreign delegates representing 14 production regions around the globe. The four-day tour of the island and sugarcane production set a high bar for the future of ISSCT's pre- and post-congress tours.

The Cuban Secretary of State, Dr. Rafael Martinez Ortiz, made the opening address, emphasizing the importance of the ISSCT's free information exchange approach and how this would impact the economy of Cuba and the world. He used the example of the recent opening of telephone communications with England and then highlighted the need to improve both production practices and efficiencies, particularly irrigation systems. He also stressed the need for global market controls and encouraged other countries to follow Cuba's lead in setting production caps. It is important to note this was in the post-First World War recovery era and prior to the Great Depression.

The Congress recognized the important contribution of John Bovell, in collaboration with J.D. Harrison for the discovery of true sugarcane seed was recognized. Mr. Bovell went on to develop methods of making crosses and evaluating seedling progeny that had since become the foundation of most sugarcane experiment stations world-wide. The resolution also included recognition of his "contributions toward improving the standards of sugar cane husbandry"; a critical element of extension and management. The topic of plant breeding, extension and management was significant enough to attract the Commissioner of Agriculture and Labor of Puerto Rico, Charles E. Chardon, to lead the session. The Dutch botanist and director of the sugarcane experiment station in Java, Dr. Jakob Jeswiet gave several presentations on the current state of knowledge of breeding and selection, which included methodology for selection from bud sprouts from chimera stalks as well as true seed. This session provided the foundation for the modern-day ISSCT Breeding and Molecular Biology sections.

Related to breeding was the growing interest in sugarcane diseases, two of which were central to international motivation to introduce new germplasm into commercial sugarcane varieties. Sereh disease in Fiji, thought today to be caused by a phytoplasma, and sugarcane mosaic virus in Louisiana. These two diseases were bringing the respective industries to their knees, reducing production by over 60% overall in less than a decade in both industries. There were other diseases and insect pests significantly impacting respective production regions, but these two were dominant.

Since the first congress, in order to mitigate the introduction of foreign pests & diseases, the United States Department of Agriculture (USDA) had commenced construction of a quarantine facility in Arlington, Virginia, USA, distant from the sugarcane production region. The construction of the facility was described by Dr. Brandes in detail with photographs published in the proceedings. The elements of this first facility in the world are still seen in many of our existing sugarcane research facilities. The design features were and remain the basic principles we apply today in our current quarantine facilities and practices.

Consistent with the need to keep unwanted pests out was the need to import biological material into respective industries once a foreign pest was recognized. Dr. Harold Box, Puerto Rico, led a sectional discussion for a "Plan for a Cooperative International Organization for Parasite Introduction." The focus

of the discussion surrounded what was known about *Diatraea* and extended into a much broader discussion about the introduction of a given pest into a new region where its natural enemies did not occur.

Some sessions were directly related to management and extension. Dr. R.V. Allison, for instance, presented a paper on the classification of soils, a nascent field in which Dr. Allison was a pioneer. His statement “the judicious selection and treatment of the soil should be regarded as of foremost importance at all times.” His presentation shared the new (at the time) system of classifying soils in 15 families and other details. Dr. Oswald Scheriner presented the current understanding of humus, again a very new field of understanding we take as common knowledge today. An important theme in these presentations was the need for interaction of multiple disciplines including pathology, chemistry and soil surveying. They also pointed out the importance of standardized experimental design for the purpose of being able to robustly compare results obtained from different environments across the world.

The proceedings closed with new vigor for the six sectional committees and though there was no specific committee for Management and Extension, the mindset of all the scientists and leaders involved was interdisciplinary and focused on applying the technologies being studied and developed in the fields. It was also at this Congress that a resolution was passed “to alternate the conferences between the Eastern and Western hemispheres” for the benefit of all members of the Society.

1929 Congress

The 1929 Congress was convened in Soerabaia, Java chaired by Dr. Jakob Jeswiet. Part of his inaugural address included statistics on the ongoing impact of sereh disease on the Javan sugarcane industry, and mosaic virus in Louisiana, USA. Jeswiet recognized the discovery of the vector of SCMV by E.W. Brandes as one of nine resolutions presented to the delegates by the executive committee.

A number of topics presented in the past two congresses were meaningfully reported on and agreed to be progressed, including the need to study irrigation in a systematic way, to establish a uniform classification of soils, to identify and clarify the naming of duplicate varieties occurring in different countries, to quarantine and control international variety exchanges, and to form a standing committee to establish a uniform “Technique of Field Experiments.”

Jeswiet was recognized at the Congress for his effort and successful development of the Proefstation Oost-Java (POJ) varieties and the benefit the Louisiana cane industry was receiving in recovering from the SCMV epidemic. The POJ program was internationally impactful, laying the foundation for many of today’s breeding programs around the world. Its success lay in scientists and governments sharing material and knowledge, with extension and management as the value-adding vehicle.

With regards to management and extension, there was an interesting discussion in the Cultivation and Field Operations section following a presentation by David Sturrock of Cuba. He referred to the 1929 proceedings where it was stated that “the Cuban youth does not take to the mule, their dispositions do not work well together, the average Cuban youth is, however, mechanical minded, so it is important to move from ox/plow to tractor plowing.” His opening point was with regards to the ‘modern’ tractor: “It promises to put field work on par with millwork, and at present the average field work is a generation behind mill work.” He pointed out that without progress in technical research and development, Cuban sugarcane agriculture would be in trouble. He then discussed the introduction of the crawler, or track driven tractor, averaging 12-15 horsepower. This sharing of information at subsequent ISSCT Congresses has contributed to significant infield technological developments, where small crawler tractors have evolved into massive satellite-driven tractors using Global Information Systems (GIS) that have accelerated infield production efficiencies, all made possible through management and extension.

1932 Congress

The fourth congress was opened in San Juan, Puerto Rico. The international economic climate had dramatically changed with the Great Depression in full swing (1929-1939). The opening remarks by Mr. Ramon Aboy Benitez included comments about historically low prices, oversupply and concern about declining sugar demand. Reference was made to the US-led Chadbourne Plan to stabilize post-depression prices which had dropped from US$0.070 to US$0.015 per US pound. This plan called for significant reductions in exports from high-producing countries with specific mention of Cuba and Java. Mr. E.D. Colon, Commissioner of Agriculture, Puerto Rico, and past director of the Rio Piedras sugarcane experiment station, followed by introducing the idea of including "…social responsibilities in the context of sugar production. All our technical knowledge will be of no avail in the end unless a way is found to harmonize human relations".

The technical sessions had almost tripled since the 1929 congress, with continued interest in the exchange of germplasm and associated safety precautions. Dr. Brandes presented the report for the Committee on Protective Sugar Cane Quarantine outlines the challenges associated with poor telecommunications and slow travel means. The committee, mostly led by Dr. Brandes outlined the conditions for entry of sugar cane into 50 countries. The report also included restrictions considered with the exchange of non-living plant parts, i.e. bagasse.

A key highlight of the congress was the presentation of a film by Dr. Brandes covering the "American Sugar Cane Expedition to New Guinea in 1928." The expedition may have been initiated by the USA, but included the esteemed Dutch botanist, Dr. Jakob Jeswiet and the entomologist, Dr. C.E. Pemberton, from Hawaiian Sugar Planters' Association (HSPA). There is little doubt that the professional and collegial relationships between these three individuals, born and nurtured through ISSCT interactions, was what facilitated the financial support from the US Department of Agriculture, the HSPA and the Javan sugar industry to make the expedition a reality. The benefits of the trip were shared worldwide through the ISSCT and some of the germplasm collected on that trip is still being utilized today.

This Fourth Congress was the first one to include a trade exhibit, including manufacturers of milling equipment and supplies, tractors, fertilizers and road transport equipment. The Congress also continued the tradition of festive evening receptions, luncheons and tours of milling and agriculture activities on the island. It is also not surprising that the quality and breadth of presentations in the fields of pests and diseases, agronomic practices, crop and soil nutrition, field experimental design, breeding and variety selection and more was increasing within the ISSCT, which required continued efforts in the areas of management and extension.

1935 Congress

The fifth Congress convened in Brisbane, Australia, was addressed by Sir Leslie Wilson, Governor of Queensland. His opening remarks lauded the ISSCT, suggesting it was the only international technical organization to be thriving in a period of increased national isolation. The number of participating countries had not changed much over the past two congresses (12), but the number and depth of technical papers presented continued to increase, particularly from the milling and processing section.

The congress participants were treated to a tour of the Mackay and Burdekin Districts by train with visits to both factories and field experiment stations over a four-day period. G.S. Moore presented a report on behalf of the Committee on Increased Consumption of Sugar, established at the Puerto Rico Congress, that illustrated some of the ongoing depression era frustrations around the world at the time. Nevertheless, the impacts of economic policies on agriculture were falling into place. The US *Agriculture Adjustment Act of 1933* introduced subsidies and production controls on many US-produced commodities and the Jones-Costigan amendment that added support for storage facilities was passed in 1934. International agreements controlling imports/exports were. Unfortunately, constrained disposable incomes in most population groups around the world continued to hinder the increase of direct sugar consumption and subdued demand meant prices remained low.

Although there was no specific presentation or discussion on management and extension, this continued to be implied in the content of papers and the discussions that followed. The ISSCT organizers retained their focus on encouraging authors to present information to delegates in a way that would be useful.

1938 Congress

The 1938 Congress was convened in Baton Rouge, Louisiana, USA with 15 countries represented and 140 technical presentations. The General Secretary-Treasurer reported that paid-up membership in the Society had grown to 815. The Congress was held during the opening of the Louisiana “Sugar Bowl” harvest season and opened with a five-day tour of the Louisiana industry, including the usual receptions and fine meals for delegates and community members.

A welcome address was presented by the President of the American Sugar Cane League, Senator Edward Gay as part of the industry tour. He presented an interesting historical overview of the Louisiana industry in the context of overcoming the impact of the sugarcane mosaic virus. Disease parallels were experienced elsewhere like sereh in Java. His presentation walked the delegates through the process of growers with the extension arm of the agriculture university (Louisiana State University, LSU) working with the US government administration (USDA) to build a federal sugarcane research program in the interests of protecting the United States food supply during and following the First World War. The result of their efforts was the establishment of the US sugarcane quarantine program and the appointment of Dr. E.W. Brandes as the program leader. He explained that the American Sugar Cane League had partnered LSU and the USDA to expand the research effort in Louisiana and establish a quarantine station and variety crossing effort in Florida. These activities occurred between 1917 and 1924, prior to the Pan-Pacific conference resulting in the first ISSCT congress in Hawaii.

A central theme from the perspective of protecting and improving sugarcane production from the beginning of the first congress through to the sixth was the essential need to improve resistance to diseases and pests in the face of increased exchanges of cultivated sugarcane varieties from “indigenous” production areas to other production regions in the world. Technologists recognized the need to introduce new varieties and the risks associated with introduction of exotic pests and diseases along with such germplasm. However, research alone would never solve the challenges; extension and management must also play a key role.

PROMINENT CONTRIBUTORS

There were three notable ISSCT leaders who benefitted the sugarcane world through their efforts over their careers during the formative years of the ISSCT.

Elmer Walker Brandes (1891–1964), an American plant pathologist, played a foundational role in sugarcane research and international collaboration. As pathologist-in-chief at the USDA, he established key institutions including the Sugarcane Field Station at Canal Point and led the first U.S. sugarcane quarantine program. He chaired the inaugural ISSCT congress and helped initiate global sugarcane germplasm collections through the landmark 1928 expedition to Papua New Guinea, undertaken with Jeswiet and Pemberton. His contributions to breeding, disease resistance, and agronomic evaluation helped shape modern sugarcane science.

Cyril Eugene Pemberton (1886–1975), a Stanford-trained entomologist, was instrumental in protecting Hawaii’s sugarcane industry through biological control. Working for the Hawaiian Sugar Planters’ Association, he led expeditions across Asia and the Pacific to collect beneficial insects. Though controversially involved in introducing the cane toad to Hawaii, Pemberton consistently advocated for caution in releasing non-native species. He contributed actively to early ISSCT congresses and remained a respected figure in tropical entomology, earning a PhD from the University of Hawaii later in life.

Jacob Jeswiet (1879–1960), a Dutch botanist based in Java, pioneered sugarcane breeding for disease resistance. As director of the Pasoeroean experiment station, he developed the highly successful variety POJ 2878, which contributed significantly to global breeding programs. Jeswiet helped identify *Saccharum robustum* during the 1928 expedition and later served as a professor in Wageningen. A key figure in early ISSCT leadership, he chaired the 1929 congress in Java and left a lasting impact on cane genetics and taxonomy.

IMPACT OF THE RESEARCH

The founders of the ISSCT were sound scientists with broad backgrounds and were inter-disciplinary in their approach. Their collective effort established the foundation of how research programs are designed and managed for the benefit of the respective industries they serve, keeping a central focus on communicating knowledge to individual producers.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Management 1950-1974

David Calcino

dcalcino@hotmail.com

INTRODUCTION

Normal commissions for management and extension did not exist between 1950 and 1974. Because there are so few explicit mentions of management and extension, it is sometimes difficult to isolate papers that may have relevance in these areas. In attempting to identify papers that fit into management, extension or both, there will inevitably be some cross-over with other areas such as agronomy. I have separated management and extension.

RESEARCH ADVANCES

Extension, technology transfer and industry awareness

“Progress in the canegrowing sector depends as much on effective extension work to bring about early adoption of proven techniques as it does on research itself.” So stated Whitehead and Wilson (1971). The statement underpins the sometimes under-recognised contribution of extension to the overall effectiveness of agricultural research.

Only a small number of papers in this quarter-century period mention extension. While extension has existed for many decades, it was not until the 1960s that extension gained wider acceptance in many countries as a discipline in its own right.

Bawden (1962) suggested that information from the Rothamsted Experimental Station indicated that agriculture had been profligate in its demands on land and the practice of simply increasing production by increasing the area under cropping could not continue. He added that the prime role of research must be to increase agricultural efficiency, including raising yields and investigating the parts of sugarcane crops that were currently deemed to be waste products that might have alternative applications and uses. Research can benefit an industry only when the industry is willing and able to apply research results. Because so much research knowledge was not applied, there was an urgent need to determine how to have the knowledge adopted, a field that itself needed research and would likely be highly rewarding. Further research outcomes without adoption were pointless. The practical benefits of research must be demonstrated. Bawden’s insights were sone of the earliest recognitions of the importance of extension and adoption.

Papers that overviewed the sugar industries in several countries identified key management and extension areas where productivity improvements could be made locally and internationally. For example, when the US Government realised that many research outputs were not reaching farmers including canegrowers, the Agricultural Extension Service was established in 1914 to disseminate information and encourage adoption. In the following years, the Extension Service was claimed to be effective in keeping growers better informed and contributing to a higher standard of living for those growers, although no supporting data were provided.

In Hawaii, varieties, climate and fertiliser were identified as the key factors affecting sugarcane production, issues that are relevant around the world today. A strong plant-breeding program, a focus on climatic impacts, and excessive rates of nitrogen and potassium all needed attention. A 1962 paper stressed the necessity of research if the Mauritius industry was to remain competitive, saying the creation in 1953 of the Mauritius Sugar Industry Research Institute was a milestone in achieving that end.

Graugnard (1971) covered regulations operating in the Louisiana industry. Increasing wages for factory and field workers were welcomed and there were plans to train sugarcane workers to improve individual productivity. Interestingly, Graugnard understood the need for a social licence if the industry was to prosper, an issue that is critical in most countries today. Aligned with that insight, he also noted the sugar industry was becoming increasingly environmentally conscious.

Reviews of agricultural practices employed in sugarcane production in Colombia and South Africa, the steps that were taken to improve and standardise the quality of raw sugars in South Africa, the problems confronting the Taiwanese and Javanese sugar industries, and the establishment of sugar mills in Sudan supplied by tenant farmers were covered in congresses. A review of sugar production in Hawaii from the 1920 to the 1950s concluded the greatest impact on yields was a result of varieties produced by Hawaii's cane breeding program. The influence of climate was also extremely important in Hawaii, but the practice of applying excessive rates of nitrogen and potassium provided no improvement in cane yields but did result in a sizeable decrease in fertilise efficiency.

At the 1971 congress, several papers were devoted to extension activities in three sugar-producing countries. Pesson (1971) described the importance of an extension service to Louisiana agriculture including sugarcane. Embedded within the College of Agriculture of Louisiana State University, the extension service worked closely with research and teaching divisions. Extension units determined the focus and objectives of their programs, which were then incorporated into the long-range extension program. The program's aim was to assist Louisiana to progress economically and socially. Pesson said extension workers must expose intended audiences to new ideas and assist them to correctly use new practices. The final stage of the extension process was the evaluation of the success of the extension programs. While often not easy and requiring considerable time and effort, evaluation was important so that, when the program had been successfully implemented and adopted, new objectives could then be undertaken.

Essentially, extension workers are teachers, said Pesson. To encourage growers to move to adoption, they must be convinced of the value and relevance of the product or practice to their farming operation. The three major components of extension included individual contact, group interaction, and mass media pillars. Individual methods encompassed both visits by the extension officer to a farm, and grower visitations to the extension operative's office or research station. However, while very effective, one-on-one interaction is time-consuming and expensive. Group extension of two or more growers was more cost-effective than individual contact and could promote discussion and exchange of ideas. Field days and farm tours were popular forms of group activity. Many people could be informed very quickly through mass media. It was the most economical form of extension and was effective in creating awareness and developing interest. However, it was impersonal, did not allow for two-way discussion or exchange of ideas, and was not effective in achieving high levels of adoption.

Advisory and extension services commenced in South Africa in 1954. By 1968, the service has developed into a complete extension organisation. All of the accepted media for extension were employed in an effort to convey the latest information on all aspects of cane production and management to the growers.

In highlighting the critical importance of extension, Whitehead and Wilson (1971) observed blanket or recipe-style advice was not possible for the South African industry. The vast differences in factors impacting sugarcane production such as climate, soils, topography, management practices, farm size and available working capital meant that advice and assistance had to be tailored for individual situations. This situation would apply to most national sugar industries. All canegrowers in South Africa

had, as a minimum, access to free professional advice from experienced, regionally-based extension staff who were familiar with all aspects of farming in their respective areas.

Effective extension in the Indian sugar industry was problematic. Education and motivation of the vast Indian industry needed to be addressed. Mass education was in its early stages but more needed to be done. It was postulated that ISSCT could play a vital role in arranging extension education facilities and exchange programs in the different sugar-producing countries of the world.

Some of the earliest and most successful extension programs reported at congresses involved sugarcane nutrition. By 1968, the fertiliser advisory service in South Africa had produced “a revolution in fertiliser usage”. The service was highly influential in encouraging growers to use recommended rates of nutrients and had assisted the industry to increase productivity economically.

Apart from some comments about the importance of measuring the success of extension programs, little mention of the effectiveness of extension campaigns was presented at congresses in this period.

Management

Cane quality including deterioration after harvest

The deterioration of sugarcane after harvest has long been recognised as an industry problem. The loss of cane quality applied to both green and burnt cane but was exacerbated in burnt cane particularly if left unprocessed for more than 24 hours and if the cane was mechanically chopped into billets. Losses were unavoidable but could be managed, most notably and obviously, by transporting cane to, and processing at, the sugar factory as soon as possible after harvest.

Computerisation

As far back as 1961, the Experiment Station of the Hawaiian Sugar Planters' Association had been analysing yield trials using computer programs. One of the main advantages of computerisation was that data were always available and could be utilised efficiently for statistical analyses and reports. While primitive by today’s standards, this early computer use heralded the revolution that was to come.

Conventional procedures for increasing sugarcane productivity were providing only marginal increases in yield because of the complexity involved in the research. Computer modelling offered a means of integrating physiological knowledge to simulate plant growth and, from that, yield-limiting factors could be identified.

One of the first explicit congress references to the use of computers was in 1971. In Australia, process analysis, improvement and design by computer were being only slowly utilised, partly because not enough was known about the chemical and physical processes in sugar manufacture.

As a practical example of the benefits of early computerisation, the Tully sugar mill in Queensland has been producing reports for growers for the last half-century. This Comprehensive Area Productivity Analysis (CAPA) report provides individualised productivity assessments while the milling staff can use the system to assist in the monitoring of cane quality. A major benefit of the introduction of CAPA was a much stronger focus on mill-area productivity and a closer working relationship between the mill and the Bureau of Sugar Experiment Stations in attempting to raise productivity.

By 1974, the use of computers in South Africa was also streamlining and simplifying data analysis and assisting to overcome inadequacies of cane handling facilities. Similarly, early simulation modelling of a Philippines sugar-producing district was employed to assist with irrigation management and harvesting schedules. The exercise revealed the limitations of the model at that time but provided promise of the future benefits of modelling.

Diversification

Diversification refers to the development of sugarcane and its by-products for uses other than sucrose production, not to the use of sugarcane land for alternative crops.

At the 1968 congress, a raft of papers addressed diversification in the sugar industries in Australia, Hawaii, Philippines, South Africa and Taiwan. One paper summarised the situation with the words “diversification within the sugar industry has not progressed to any significant degree in any part of the world and, where it has taken place, has usually been in areas of protected markets”. Apart from excess power generated from burning bagasse in mills being fed into public electricity grids, very few products found markets.

While some products did find a market in the wartime economy in Australia, post-war economics ended that demand. Apart from the sale of electric power, Hawaii also could not develop profitable commercial operations through diversification despite a major effort in the 1950s to do so. Pulp, paper, soft and hard boards, plastics, furfural, lactic acid, yeast, and cane wax were all considered. None of these products was able to be translated into commercial operations. South Africa found a market for molasses as cattle feed and in the fermentation industry but little else. Taiwan successfully produced insulating board and paper from bagasse and animal feed and fermentation products from molasses.

An issue that needed to be resolved was the question of the legal ownership of the materials that might be used for diversified products.

Mechanisation

Developments in farm mechanisation, with the emphasis on harvester development and efficiencies, gained momentum throughout the period. In the early 1960s in South Africa, there was little demand and incentive to move from manual to mechanical harvesting. Labour was plentiful and the relative price and wage structure favoured the status quo. However, it was evident that social and industrial advances would result in mechanisation in the near future. In Australia, tentative efforts to find mechanical alternatives to all field operations began as early as 1930. Efforts increased during the acute labour shortages in World War II and by 1965 mechanical harvesting was entrenched, allowing for increased efficiencies including closer attention by individual growers to crop husbandry. By 1975, the entire Australian sugarcane crop was mechanically harvested. A 1968 paper claimed when cut/load rates reached USD1.00-1.20 per ton, preparation for mechanical harvesting should commence.

The introduction of mechanical harvesting heralded big changes in those countries that adopted the new system. Mechanical harvesting had to be integrated into the total farming and milling system. Consideration had to be given to transport systems, farm cultural practices, ground conditions including field layout, slope of the land, drainage lines and headland width, crop growth, and the requirement at that early stage of mechanisation to burn the crop before harvest. Other issues included increased levels of extraneous matter and sucrose losses from stale cane that had been delayed for milling after harvest.

Payment systems

Cane payment systems are particularly important in non-plantation farming operations so that large numbers of independent growers are assured of an equitable distribution of proceeds. The systems have evolved to suit each sugar-producing country’s needs. While it is beyond the scope of this paper to delve into the intricacies of each system, some general observations are offered.

The overall objective of payment systems is to achieve equitable rewards for growers and millers, and to supply improved quality cane for processing. When the factory and the cane belonged to the same owner, a payment system was unnecessary. However, when private growers supplied cane to mills, a system of equitable distribution of proceeds from sugar production had to be devised.

Panje and Gopala Aiyar (1956) reviewed cane payment systems in Australia, Cuba, India, Indonesia, Louisiana, Mauritius, Puerto Rico and South Africa. The system was most basic in Cuba where “the raw material should be paid for by weight alone and no account should be taken of its juice quality” because the system there “acts as a direct stimulus to the production of cane with low-juice-quality.” In Australia, relative cane payment schemes account for the individual grower's cane quality compared to the average of the quality of the cane supply in each week of the season. This technique encourages a constant supply of cane during the crushing season and removes anomalies among growers. The cane price formula has incentives for growers to improve the quality and sucrose content of their cane, and for mills to improve their efficiency.

Quarantine

The international exchange of sugarcane varieties has been the backbone of many breeding programs around the world. Various papers addressed the importance of quarantine to minimise the opportunities for exotic pests and diseases to enter a country. Similar quarantine principles were followed in each sugar-producing country.

Personnel training and education

The sentiment of one paper described a problem facing various world sugar industries; that the industry did not have the glamour, the growth potential, or the opportunities present in many other industries. The author postulated that ISSCT could rectify the situation by publishing and extending information to undergraduates that more realistically portrayed the industry as one with great career opportunities.

Taiwan focused on better utilisation of manpower through personnel innovation. Mexico sought to improve the capability of technicians to take charge of the research work and enhance the industry. In 1928, South Africa established a training course for technical personnel to provide the industry with people who would eventually rise to more senior positions. In the late 1960s, none of the curricula of South African agricultural institutions included sugarcane. To counter that situation, the industry provided collaborative training in sugarcane agriculture and agricultural science in collaboration with a College of Agriculture. To address the difficulty of attracting competent staff, Louisiana conducted training courses for technicians to fill roles that were inadequately staffed.

PROMINENT CONTRIBUTORS

F.C. Bawden (1962) bemoaned the fact that in the world of science, much research failed to be adopted because of a lack of, or poorly executed, extension efforts. Consequently, that research was largely wasted. He recognised the rapidly expanding world population needed more research and for the outcomes to be adopted to feed that population. Yields needed to increase on existing cultivated areas, not more land continuously put under agricultural production.

C. Whitehead and J. Wilson (1971) provided one of the few papers devoted to extension. They stressed the importance of extension to the adoption of research findings, and, therefore, to the effectiveness of research itself. Their comprehensive analysis of the extension program in South Africa identified strengths and also areas that required attention for improvement.

The extension principles of L.L. Pesson (1971) in relation to the Louisiana sugar industry (as provided above) were applicable internationally.

IMPACT OF THE RESEARCH

The presidential address at the 1962 Congress in Mauritius covered the general areas in which ISSCT had “guided the cane grower” during the previous 38 years. The paper concluded that more effort

needed to be directed to making full use of the potential offered by sugarcane, particularly as a source of raw material for chemical industries. Additionally, the utilisation of sugar industry by-products needed a stronger focus. These sentiments are relevant six decades later. In meeting the various challenges facing the world's sugar industries, the address stated ISSCT had a major role because "the most harmonious feelings have always existed among members of our Society".

A notable point is very little detail was provided in congress papers on assessments of outcomes. In other words, the impacts of research and extension activities were rarely reported. In addition, during the 1950 to 1974 period, only minor mention of environmental issues that would feature heavily at later congresses was made.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Management 1975-1999

Carolyn M Baker

cal.baker1954@gmail.com

INTRODUCTION

In the decades leading up to the establishment of a Management Commission in 2006, overt reference to integrating various aspects of management into technological activities or even research, with the intention of enhancing overall efficiencies in sugar industries were scarce. However, the buzzwords of 'sustainability', 'extension' and 'adoption' that are often signifiers used in conjunction with investigations associated with management and productivity, slowly began to feature in the papers presented at congresses in the period between 1977 and 1999. The importance of enhancing efficiencies in sugar industries, however, was widely acknowledged and it was in this regard that allusion to management was regularly made.

RESEARCH ADVANCES

Efficiencies and advancements

In this period congress papers alluding to evaluation of efficiencies was evident in a range of farming and factory practices to enable improved cost-effective production. The presentations covered a wide range of topics that included fertiliser efficiency, harvester and harvesting efficiencies, energy efficiency and milling efficiencies and productivity. The fact that in many or even most cases active management of the various practices to enable efficiencies was either not mentioned or only marginally referenced, highlights that most of the investigations at this time were focussed on accumulating new data and uncovering novel practices that exposed improved efficiencies.

Sugarcane nutrition and the efficiencies associated with N, P and K applications in particular were something of an exception, as considerable emphasis was placed on this subject (Chui and Samuels 1977; Gotera *et al*. 1980; Wood 1989; Ng Kee Kwong 1992). Most of this work stressed the importance of establishing correct protocols and management of the timing of fertilizer applications to enable efficiencies. In 1980, the significance of using tissue and foliar diagnoses in nutrition was highlighted by Zambello and Orlando and this was followed in 1983 by Ng Kee Kwong on the value of diagnosis and recommendation integrated system in the foliar diagnosis of nutrient status of sugarcane in Mauritius, where he focussed on foliar diagnoses in particular. These two papers signalled the development of a more analytical approach to nutrition with the express intention of achieving improved efficiencies.

Closely linked to investigations into nutrition was the increasing interest in soil management. In 1995 Meyer investigated the role that soils play in enhancing fertilizer use efficiency and crop yields. At the following congress in 1999, Meyer presented the results of a long-term investigation into the impact of soil fertility on cane yields, demonstrating the marked increases in soil acidification over the past decade that were linked to existing soil fertility practices. He outlined an approach to counter this trend through implementing corrective measures that would be facilitated by active and informed management. It was in this paper that the value of accumulating data over a long period became clear and that with the aid of computerised analytics, it enabled insights for informed management actions.

Work associated with water management, although not abundant during the period under review, was presented by Shih *et al.* in 1977 in which implementation of effective water management practices was identified as a key action to address drainage and irrigation challenges in the Florida climate. Indeed, in that year several other papers focussed on irrigation practices signalling an awareness of the importance of water optimisation. In 1989, the significance of implementing irrigation practices that would both enhance cane yields and conserve water was highlighted by Batchelor *et al.* in their paper on the design and management of sugarcane drip irrigation systems, which showed the increasing awareness of the requirement to actively manage resources to sustain productivity. Towards the end of the review period, the paper by Soopramanien in 1999 provided a useful summary of the work conducted on this subject.

The focus on harvesting practices in the 1983 congress heralded the beginning of the emphasis into harvesting machinery and systems which laid the foundations for future research that would evaluate efficiencies. The papers by de Beer *et al.* and Abreu and Puig (were largely concerned with providing data on specific practices, while Scandaliaris *et al.* compared the effectiveness of several practices, but with no mention of managing the systems to enhance efficiencies. It was only in 1986 that Kincaid's paper on mechanical systems integrity management introduced the importance of not only understanding specific attributes of the harvesting protocols but indicated that optimization required integrating the management of maintenance programs to achieve efficiencies.

Additionally, efficiencies related to research methodologies associated with sugarcane selection and breeding programmes emerged and the introduction of computer technologies to enhance parent selection and progeny management signalled a new approach that enabled complex decision-making (Hogarth and Skinner 1986). The following congress in 1989 saw Nuss *et al.* presenting a paper on the use of a computer in a sugarcane breeding program in which he outlined the range of data that were captured to enable generation of lists of possible and recommended crosses ahead of the sugarcane flowering season. In that same year Hogarth and Mullins' paper went a step further and described the range of changes that had been implemented in the Australian breeding program, and that had been largely informed through enhanced information management technologies.

Throughout this review period factory papers concerned with fine tuning the mechanical aspects of sugar mills to enhance processing technologies were plentiful and Paturau's paper in 1986 on the cane sugar factory of the future recommended several changes to factory equipment that would enhance performance and optimise power consumption.

Sustainability and the Environment

One of the express intentions of the Management Commission that held its first workshop in 2006, was to encourage integration of management aspects into both research and technology development to enable improved efficiencies and sustainability, through the participation of senior industry managers in the ISSCT. There was clear recognition of the importance of managing environmental impacts of sugar industries to enhance long term sustainability, and the Commission was seen to be the ideal platform to address these objectives.

Nowadays, the notion of sustainability goes hand-in-hand with good management, and yet in the current review period, mention of this was made in only two congresses: the first in 1995 and the other in 1999.

In 1995, Runge presented a plenary paper that together with three other papers were designed to spark discussion on this very important theme. Runge provided a comprehensive overview of the range of agricultural practices that were currently in use and that were designed with sustainability in mind. What he also did was to highlight the fact that sugarcane farmers were faced with a series of complex environmental issues, that in his view were more onerous than those experienced by farmers of other crops. Research and development and the adoption of research outcomes related to better burning practices that minimised the negative aspects associated with pre-harvest burning represented one such example. This approach together with the efforts to reduce 'off-farm' purchased inputs such as

fossil fuels, fertilisers and pesticides, heralded engagement with alternative and regenerative agriculture practices and focused on integrated pest management for example. A paper in the agronomy session by Meyer made it clear that incorporation of sound ecological principles would become an essential component of all soils management systems in the future and provided an excellent complement to the plenary presentation.

It was in this 1995 plenary session that three other papers also focused on sustainability. Echavarria addressed the issue of cane burning, and Platford and Bond presented a paper on an environmental management plan for the South African sugar industry, that highlighted the impact of sugarcane farming practices on the environment and provided an approach that would reduce their impact in the longer term. Some of the foundations for this paper had been laid in the previous congress in Platford and Meyer's 1992 paper on land use planning in the South African sugarcane industry, in which they detailed the manner in which to design and prepare a management plan for sugarcane farms. They recognised that in view of the variability in the South African sugarcane growing areas, productivity improvement in that industry would be secured only if the correct farm layout and agronomic practices were applied to each specific land type. Finally, the session was wrapped up by Purchase, who reviewed the challenges associated with effluent disposal and highlighted the move in most countries towards the introduction of legislation that required sugar industries to address the need for developing ecologically acceptable treatment plants to prevent pollution of water resources.

At the end of this period under review the importance of sustainability was summarised in the 1999 Congress Environmental Symposium, where Autrey presented an overview on sustainable agricultural practices. In his paper he outlined all aspects of the value chain that addressed sustainability, thereby providing a broad platform for numerous future papers on this topic.

Extension and Employee Management

Interestingly, 'extension' was expressly mentioned only once in all these years, when Egan in 1977 wrote about disease control and the extension worker in Australia and indicated that only once a successful bridge had been created between farmer and the scientific officer (pathologist) through an extension worker, would any progress on disease control, be made. This paper represented an early forerunner of many other papers in the 2000s that now regularly comment on the importance of the extension process in facilitating adoption of research outcomes and technologies. It is well known that the value in research and development (R&D) lies in whether its outcomes are translated into viable technologies or processes that lead to improvements in industrial practices, and hence the value of a research-extension continuum. However, in the current period under review, the important role of extension officers and mill technical staff in partnering with researchers to facilitate knowledge exchange and adoption of new technologies was seldom mentioned in any congress presentations.

In that same 1977 congress, a single reference to the importance of employees was made, and then not again in the period under review. Paty's 1977 paper that reflected on improving employee attitudes and skills for profit in a cane sugar operation, reported on the value of enhancing employee education to reduce repairs and maintenance costs and sustain cost-effective productivity in Hawaii. This early recognition that efficiencies in production could be achieved through employee education reflected on the importance of the role of employees in improving efficiencies in production and provided an important basis for research in future years.

New technologies and approaches

During the period under review the importance of emerging technologies became a subject of discussion. In the 1995 Congress, apart from the plenary on the environment and sustainability, there were two other plenary sessions, both of which explored new technologies and illustrated the trend towards interrogating existing industry practices to enhance efficiencies. The one focussing on Biotechnology included four papers, three of which focussed on agricultural applications and research

prospects (Irvine, sugarcane biotechnology: development, progress and potentials; Carroll and Curtis, plant biotechnology research and prospects for sugarcane, including transformation; Autrey et al., application of biotechnology to sugarcane pathogens). Irvine documented the early progress made in the research geared towards improving sugarcane breeding through molecular genetics that culminated in the formation of the International Consortium for Sugarcane Biotechnology (ICSB). The consortium, comprising researchers from Argentina, Australia, Brazil, Colombia, France, Mauritius, the Philippines, South Africa and the USA (Florida, Hawaii, Louisiana and Texas), committed to building their own research programs and contributing towards contract research in laboratories of other members. This co-operative venture signalled a significant shift in the conception and management of research in all participating industries. The fourth paper in this plenary by Almazon del Olmo focussed on by-products and highlighted a range of product innovations and the biotechnological techniques being used to enhance processing effectiveness and enable valorisation of industry 'waste'.

The third plenary on Information Technology included three papers, two of which concerned the value of geographic information systems in enabling analysis and management of productivity using accurate multidimensional spatial frameworks (Jhoty *et al.*; Kent and Mason). With an overall objective of optimising land use and maximising production and profitability, this technology promised significant value for extension support. The third paper in this plenary focussed on the requirements and technologies associated with automating sugar factory operations (Love). Recognising some of the complexities of automation systems, Love cautioned that "…for automation to be effective, it should be driven by business requirements, not by the technical capabilities of the latest equipment". It was apparent that with the increase in automation, greater emphasis on project management would be required to maximise the value of the technologies and productivity.

Symposia and Plenaries

It is worth noting that the introduction of symposia in 1992 (and also themed plenary sessions thereafter) enabled delegates at congresses to vigorously interrogate various key practices and advancements in sugar industries in a manner that highlighted the importance of engaging more consciously with management practices to achieve efficiencies. It highlighted the increasing value of including senior industry managers into the process, and, hence, paved the way for setting up the Management Commission in 2006.

In the last congress in the period under review, the four 1999 Plenary Sessions focussed on 'big picture' aspects of sugar industries. Bullock presented compelling reasons for international co-operation amongst sugar industries in their research and development (R&D) efforts and provided suggestions on the manner in which such collaborative efforts could be realised. He also showed definitively why senior industry members should be included in such debates. The sustainability theme was well established and Ireton's paper on international trends in environmental policy, legislation and regulation and the impact on the sugar industry provided an overview of the drivers for introducing legislation into sugar enterprises. These included international conventions and protocols developed under the umbrella of the United Nations Environment Programme (UNEP), and international labour law. The paper went further and outlined the key activities in sugar industries impacted by the new protocols and the systems and how they were being managed to meet the new standards. An awareness of the increasing importance of achieving efficiencies in productivity served as the theme in a session on improving productivity in the sugar industry and addressed both field and factory performances.

PROMINENT CONTRIBUTORS

There were several key influencers during the two decades of this review, all of whom played a valuable part in raising awareness of management aspects within the various sugar industry practices.

Mac Hogarth's leading work in guiding new and modern approaches to improve plant breeding was notable.

On a field and farm scale, Gordon Platford's recognition that productivity and efficiencies would be enhanced by making use of spatially conceived farm maps and an associated land use planning enabled a simple transition into the use of Global Positioning Systems (GPS) technology in later years – technology that is highly valued by extension workers today.

On the factory side, with the focus largely on reporting on the performance of various processing and engineering technologies, several authors deserve mention, but Raoul Lionnet stands out.

IMPACT OF THE RESEARCH

The research presented in ISSCT Congress papers from 1977 to 1999 had a foundational impact on modernising sugarcane industry practices by highlighting the value of efficiency, sustainability, and emerging technologies. While explicit references to "management" were still nascent, the body of work laid the critical groundwork in areas such as fertiliser optimisation, irrigation, mechanised harvesting, computer-assisted breeding, and early environmental management. These studies fostered a data-driven, systems-based approach to sugarcane production and processing, ultimately catalyzing the integration of management principles into technological innovation. This evolving perspective directly impacted the establishment of the ISSCT Management Commission in 2006 and shaped future research towards more holistic, efficiency-oriented industry practices.

The First 100 Years of the International Society of Sugar Cane Technologists - 1924-2024 Research Advances and Impact
Edited by L. Jean Claude Autrey, A. Salem Saumtally, Raúl O. Castillo Torres and Peter G. Allsopp
International Society of Sugar Cane Technologists, Réduit, Mauritius, 2025

Management 2000-2023

Kerry A Redshaw

kredshaw@miwasugar.com

INTRODUCTION

The ISSCT Executive Council introduced a new Commission, the Management Commission, before the XXV Jubilee Congress was held in Guatemala in 2005. The intention was to increase the role of sugar industry leaders in the ISSCT and to encourage the incorporation of strategic and management aspects into research and technological innovation to improve efficiencies and industry sustainability. Before the establishment of this separate Commission, there were several management-type papers presented as plenaries or within other commissions that covered topics such as organisational management, improved efficiencies and productivity, industry sustainability, transfer and adoption of new technologies.

Although scarce before 2000, papers related to extension and adoption of research outcomes and new technologies were generally presented within the Agriculture Commission. Extension was first incorporated into the ISSCT Agricultural Engineering and Agronomy Workshop in 2015. Extension forms an essential component of knowledge management and dissemination, and it was decided that papers discussing knowledge management and transfer should also be included in the Management Commission. Consequently, subject to the review process as appropriate, papers relating to Extension might be duplicated across these two commissions.

The first Management workshop was held in Durban, South Africa, in July 2006 as a separate event from Congress in a similar manner to other ISSCT workshops. However, at successive workshops, attendance of senior research and development (R&D) managers started to decline, and it was agreed at the end of the 3rd Management Workshop that Management workshops would be held in conjunction with Congress where industry leaders and managers would more likely be present. Consequently, this workshop has been run as a parallel session during Congress since the XXIX Congress held in Chiang Mai, Thailand, in 2016. The Management sessions have continued to follow a workshop style where interactive discussion and participation are encouraged and papers are presented around a particular theme identified at the same time as the call for Congress papers.

Themes for the Management Workshops held during this reporting period were:

- 2006 – “Managing change in mature sugar cane industries” (Durban, South Africa)
- 2008 – “Advancing sugarcane: leading and managing change” (Townsville, Australia)
- 2011 – “Effective research analysis and technology transfer using a multidisciplinary approach” (Temple Bay, India)
- 2016 – “Boosting sugar industry R&D: Current constraints, future opportunities, and global trends” (Chiang Mai, Thailand)
- 2019 – “From agro-ecology to agro-economics: Frameworks for sustainable production” (Tucumán, Argentina)
- 2023 – “Regenerative Agriculture: Implications for R&D Management” (Hyderabad, India)

Papers and posters on management topics unrelated to the workshop theme were also accepted but presented as a separate session within the workshop. At the end of each workshop, strategically relevant topics to general management aspects of R&D within sugar industries are discussed and suggested as themes for future Management workshops.

Management papers and presentations during the period 2000 to 2023 could generally be categorised into the following themes: research and organisational management; employee development; industry sustainability; environment; knowledge management and information dissemination.

RESEARCH ADVANCES

Research and organisational management

The long-term sustainability of sugarcane industries requires sustained investment in research, development, and extension (RD&E). Such investment resources are limited and effective management of them is essential to ensure stakeholders receive an appropriate return on their investment.

Considering the significant financial investment in RD&E over the years, the constantly changing industry landscape, and the ever-increasing external pressures on sugar industry stakeholders, there have been numerous papers during this period covering these topics. Continual evaluation and re-alignment of RD&E strategies within organisations were emphasised, since they are essential for R&D organisations to remain relevant and provide value to stakeholders (Dewar and Davis 2007; Wallis *et al.* 2007; Chen and Zhaonian 2010; Davis *et al*. 2010; Gopinathan 2010, 2013; Wynne and Gilmour 2010; Solomon 2013; O'Shea and Clement 2016; Payandi Pillay *et al.* 2016; Watt *et al.* 2016, 2019).

Highlights from this period include papers focused on the value of collaborative research (Henderson 2001) and some outcomes from co-operative projects involving researchers from different sugar industries (Burnquist *et al.* 2010, Autrey *et al.* 2013; Autrey and Lionnet 2016). These papers provided key insights into the value of sharing knowledge and expertise to improve productivity and profitability for stakeholders. Differences among research strategies and rates of technology adoption internationally were also covered. Burnquist (2013) presented a paper that discussed the increasing competition between R&D institutions (private and public) in Brazil and the expectation that this competition would drive increasing yield gains within that region.

Since researchers and research organisations receive funding from different sources, Wisler (2010) and Gilbert and Sandhu (2013) presented papers outlining how these different funding models might present challenges for research management. There were also a few papers focused on the implementation of various management practices that reduced costs and improved overall efficiencies within R&D organisations (Mallalieu 2007; Yadav and Ohri 2016).

Employee development

During this period there was greater recognition by senior managers of the value that skilled employees bring to the overall success of the industry. It was noted that industries must be able to attract young talent, while also focusing on training and retention of highly skilled employees. Investing in employees through ongoing employee development and empowering employees was identified as a key to the success of any business. In 2005, Valencia acknowledged that organisational success requires a balance between the management of technology, people, and economics. In this regard, international co-operation between different research institutions was reported to have led to a significant improvement in the knowledge and skills of the technical and scientific staff involved as well as delivered significant value to their respective industries in terms of new research and technologies generated for improving productivity for farmers and factories (Autrey *et al.* 2013; Autrey and Lionnet 2016).

During the reporting period, papers focused on how critical it is to train and upskill agricultural and factory workers as industries move from being historically labour intensive to becoming more capital

intensive with significant technological innovations (Mamet 2007, 2010; Milanés-Ramos, *et al*. 2010). The importance of understanding the level of skills within an organisation to ensure that there is continual skills development through the retraining (i.e. learning new skills to do a different job) and upskilling (i.e. learning additional skills) of workers at all levels within the organisation was emphasised. Papers discussing a range of different management tools for improving overall organisational communication, decision-making and the working environment were also presented (Sustaita and Asanza 2019; Daruich *et al.* 2023; Sawhney and Kohli 2023).

Industry sustainability

Long-term financial sustainability of sugar industries has been common topics of discussion among ISSCT members over the years, which relates to competitiveness trade policies and fluctuating world sugar prices. Papers were presented on the economics associated with world sugar markets and their associated economic indicators (Jolly 2007; Milford and Males 2010; Gheewala, *et al.* 2016; Autrey *et al.* 2019; Perez *et al.* 2019). Benchmarking models and analytical tools used to better understand the complexity of the sugar industry and production systems were also presented (Hanlon and McMahon 2001; Muchow *et al.* 2001; Thorburn *et al.* 2007; Amu *et al.* 2013; Tarumoto 2013; Rao *et al.* 2016; Mugabira and Chivaka 2016; Auzoux *et al.* 2019; Tamak *et al.* 2023).

Improving industry efficiencies to maximise profits for small- and large-scale farmers and millers were identified in many papers as fundamental for sugarcane industry success and long-term sustainability (Moor and Wynne 2001; Lejars *et al.* 2005; Ramjuttun *et al.* 2005;Davis 2007; Wynne and Milford 2007; Athipanyakul 2016; Leite *et al.* 2016; Vivek, *et al.* 2016; Schroeder *et al.* 2019; Castillo *et al*. 2023; Solomon *et al.* 2023). Many factors affect miller and grower profitability and being able to measure and predict the economic impact of these factors on profitability was also seen as essential for the long-term sustainability of any industry. There were many papers focused on economic optimisation covering a range of topics such as value-chain management strategies, length of milling season, impact of introducing new taxes and how cane payment schemes can affect industry revenue (Moor and Wynne 2001; Wynne 2005, 2007; Fleming *et al.* 2007; Lejars and Auzoux 2010; Auzoux and Lejars 2013; Kadwa 2023; Nicholson and Kadwa 2023).

Papers also highlighted the numerous challenges impacting the sustainability of sugar industries world-wide that went on to propose possible re-engineering and turnaround strategies (Milford 2005; Wynne 2005*;* Nicholson and King 2016; Toharisman *et al.* 2013; He 2016; Prakash *et al*. 2016; Murray 2019). The profitability and sustainability of sugarcane industries is also impacted by diversification of sugarcane products and practices and there were numerous papers highlighting these areas (Avram *et al.* 2005; O'Hara *et al.* 2013; Aguilar-Rivera *et al.* 2013, 2016; Sall and Chopart 2019*)*.

Environment

Historically, sugarcane related RD&E has largely focused on developing new technologies and best management practices to increase sugar production and improve profitability but more recently the impact of sugar industry practices on the environment has also become critical long-term sustainability factor. Climate change, and the impacts thereof, was a major focus area at ISSCT congresses and workshops during this period and many papers were presented on this issue across all ISSCT sections. within the Management section focused on understanding, monitoring, and managing environmental impacts of management practices and climate change include:

- Predicting the impact of climate change (Cheeroo-Nayamuth and Nayamuth 2001; Jintrawet and Prammanee 2005; Nayamuth 2005; Rein 2010; Fisher, 2013; Singels *et al.* 2013; Christina *et al.* 2023).
- Monitoring climate change and management practices impacting the production environment (Hanlon *et al.* 2001; Nogueira and Nogueira 2005; Mahe 2010; Viart and Rein 2013; Viart *et al.* 2016; Thitithawonwong *et al.* 2019).

- Adoption, adaptation, and mitigation strategies to ameliorate the negative impacts of industry practices and predicted climate change (Rayment 2001; Reghenzani *et al.* 2001; Milford 2005; Nayamuth and Cheeroo-Nayamuth 2005; Quirk *et al.* 2005; Cartwright *et al.* 2007; Schulze 2007; Finguerut 2010; Kealley and Milford 2010; Kealley and Quirk 2016; Brown *et al.* 2019; Garolera de Nucci *et al.* 2019; Tonatto *et al.* 2019; van Antwerpen *et al.* 2023).

Knowledge management and dissemination

The true value of knowledge generated from R&D is only realised when it has been translated into practical information and/or tools that actually enhance stakeholder productivity, profitability and/or sustainability. The inclusion of knowledge transfer in the R&D process is often referred to as the research, development and extension (RD&E) continuum.

A highlight from this period was the increased focus on knowledge management and different methods of dissemination used by institutions to support sugarcane farmers. In 2013, Chudasama argued that one of the main reasons for the large differences in cane productivity observed within sugar industries was related to the under exploitation of knowledge by some farmers. Technology exchange through participatory on-farm initiatives with farmers workshops in the local farming areas were highlighted as being integral to successful technology adoption and enhanced productivity and profitability (Payandi Pillay *et al.* 2001; Willcox *et al.* 2010; Calcino *et al*. 2010; Vivek and Singh 2013; Adendorff *et al.* 2016; Jumman *et al.* 2016; Watt *et al.* 2016; van Antwerpen *et al.* 2023).

For research results to be effectively adopted it was found that stakeholder consultation, collaboration, and participation before and during the research process was essential. Several papers discussed this technology exchange process and how adoption would likely improve if the economic benefit and ease of implementation in the field were clearly communicated and understood by farmers (Henderson 2001; Khandagave *et al.* 2005; Payandi Pillay *et al.* 2010; Jumman *et al*. 2019). How new technologies are packaged and transferred was also shown to influence the extent of adoption by farmers (Payandi Pillay *et al.* 2001; Amaya 2010; Isaacs *et al.* 2010; Jumman *et al.* 2016; Ramos Pousa *et al.* 2016; Jumman and Bezuidenhout 2019; Tonatto *et al.* 2019).

Knowledge management was demonstrated to have a positive effect on overall business performance (Valieidy and Taha 2013). Radmehr and Banineme (2019) presented a paper explaining how knowledge captured by employees could be used to better manage RD&E outcomes that ultimately improve organisational performance.

PROMINENT CONTRIBUTORS

During 2000-2023, there were numerous contributors to strategic and management aspects of research and technological innovation for improving sugar industry efficiencies and long-term sustainability. There were, however, a few contributors that stood out as key influencers within their particular areas of expertise.

Adrian Wynne and Bernard Milford were key influencers in the field of optimisation and economic maximisation for growers and millers within their countries. Wynne authored/co-authored six separate papers while Milford authored/co-authored five. Wynne presented on the importance of facilitating discussion between millers and growers within local groups in different regions so that appropriate solutions (*e.g.* financial incentives) and strategies could be identified to maximise profits through improving efficiencies and reducing costs. Milford discussed re-engineering strategies for the sugar industry and developing effective, collaborative value chains in response to decreasing profit margins and fluctuating market prices. In 2010, Wynne together with Gilmour discussed the value in research institutes employing capital budgeting methods for determining the economic benefits of R&D outcomes and demonstrated how this tool could be used to attract research funding, enhance technology transfer, and improve adoption.

This period included numerous papers on the adoption of research findings and improved technologies, demonstrating how fundamental this has become to the RD&E process. Ashiel Jumman was a key influencer on the topic of knowledge dissemination and adoption dynamics. He focused on the importance of designing and packaging innovations for easier adoption through various knowledge exchange communication pathways.

IMPACT OF THE RESEARCH

The research from 2000 to 2023 under the ISSCT Management Commission significantly influenced the strategic evolution of the global sugar industry by embedding management thinking into research, development, and extension (RD&E) processes. With a stronger focus on knowledge transfer, organisational effectiveness, sustainability, and climate responsiveness, the period marked a decisive shift towards integrated approaches that linked innovation with practical application. Advances in research collaboration, employee development, economic optimisation, and environmental stewardship directly contributed to improved productivity, profitability, and long-term industry resilience. Crucially, the emphasis on participatory methods, extension strategies, and knowledge management transformed the adoption landscape, ensuring that scientific innovations translated into measurable on-the-ground improvements across diverse sugar-producing regions.


International Society of Sugar Cane Technologists
Hawaii - Colombia
1924 - 2024