OPPORTUNITIES AND CHALLENGES FOR SUGARCANE BREEDING: A SUMMARY OF THE 9th ISSCT BREEDING AND GERMPLASM WORKSHOP

By

RAUL O. CASTILLO [1], NILS BERDING[2], PHILIP JACKSON[3], THOMAS L. TEW[4] and ANTHONY KENNEDY[5]

[1]*Centro de Investigación de la Caña de Azúcar del Ecuador (CINCAE), Av. Joaquín Orrantia y Juan Tanca Marengo, Ed. Executive Center, Mezzanine. Guayaquil, Ecuador*
[2]*BSES Limited, P.O. Box 122, Gordonvale, 4865, Australia*
[3]*CSIRO Plant Industry, Private Mail Bag P.O. Aitkenvale, Queensland, 4814, Australia*
[4]*Sugarcane Research Unit, 5883 USDA Road, Houma, LA, 70360-5578, USA*
[5]*West Indies Central Sugarcane Breeding Station, Groves, St. George, Barbados, West Indies*
rcastillo@cincae.org

KEYWORDS: **Sugarcane Breeding, Biotechnology and Biomass, ISSCT Workshop.**

Abstract

THE 9th Sugarcane Breeding and Germplasm Workshop was held from 17 to 21 August 2009 at the Novotel Rockford Resort, Coral Coast Drive, Palm Cove, Cairns, Australia. The workshop was hosted by staff from the BSES Limited's Meringa Experiment Station. BSES Limited, ISSCT, and the Sugar Research and Development Corporation of the Australian Government were sponsors for the workshop. The Breeding Workshop was attended by 70 delegates from different countries, and was distinguished by its scientific content, its impeccable organisation, and a great spirit of friendliness. Australia was well represented with a contingent of 20 breeders and researchers. Delegates from Argentina, Barbados, Brazil, China, Colombia, Ecuador, Fiji Islands, France, India, Indonesia, Japan, Mauritius, Reunion, South Africa, Sri Lanka, Thailand, Uganda, and USA attended. The presentations covered topics not only on breeding for sugar content but also biomass. There was an interesting analysis from an investor point of view on the advances in traditional plant breeding compared to the use of sugarcane transformation with novel genes. New molecular markers for mapping and genetic diversity studies and novel techniques for sugarcane biotechnology and bioenergy use also were discussed. Finally, an analysis on genetically modified (GM) sugarcane and associated biosafety risk was included. The Workshop demonstrated that traditional plant breeding and the biotechnology tools should work together in order to obtain rapid developments and increase production not only for sugar but also for bioenergy.

Introduction

The 9th Sugarcane Breeding and Germplasm Workshop was held from 17 to 21 August 2009 at the Novotel Rockford Resort, Coral Coast Drive, Palm Cove, Cairns, Australia. The Breeding Workshop was attended by 70 delegates from 19 different countries (Table 1), and was characterised by its excellent scientific content, impeccable organisation, and a great spirit of friendliness. The workshop theme was 'Sugarcane Breeding: Opportunities and Challenges'. An important delegation of 20 breeders, pathologists, entomologists, biometricians and researchers in general from Australia was present. The Australian researchers showed a commitment for a cooperative research venture and its great achievements accomplished from several threats of devastating diseases to the applications of tools like the informatics and biotechnology to manage information and use of germplasm resources. There were 44 technical presentations during four

days of the workshop. The Wednesday visit to Meringa Station and the clear and practical demonstrations complemented the high scientific component of the Workshop.

Table 1—Country of origin and number of attendees of the 9th ISSCT Breeding and Germplasm Workshop.

Country	Number	Country	Number
Argentina	2	Indonesia	2
Australia	22	Japan	2
Barbados	1	Mauritius	1
Brazil	8	Reunion	2
China	8	South Africa	3
Colombia	1	Sri Lanka	1
Ecuador	2	Thailand	6
Fiji Islands	2	Uganda	1
France	1	USA	7
TOTAL			70

Keynote talks and workshop topics

The 9th workshop had four keynote speakers covering topics:

1. 'Future opportunities for sugarcane biomass use' by Dr Les A. Edye, Principal Research Fellow, Queensland University of Technology, Brisbane.
2. 'Sugarcane crop improvement—an R&D investors' viewpoint' by Dr Frikkie Botha, Executive Director, Sugar Research and Development Corporation, Brisbane.
3. 'Global trends in sugarcane improvement—Syngenta's view' by Dr Manuel B. Sainz, Group Leader, Sugarcane Research, Syngenta Centre for Sugarcane Biofuels Development, Centre for Tropical Crops and Biocommodities, Queensland University of Technology, Brisbane, and
4. 'Application of DArT technology and associated informatics to sugarcane crop improvement' by Dr Andrzej Kilian, Director, Diversity Arrays Technology Pty Ltd, Yarralumla, Canberra, Australia.

The presentations were excellent and covered topics not only on breeding for sugar content but also biomass. The program for presentation was arranged in related groups of topics: 1) Bioenergy, 2) Molecular Breeding, 3) Physiology, 4) Biometrics, 5) Introgression, and 6) Crop Improvement grouped in five sessions.

Breeding for bioenergy

Many countries have initiated projects to exploit the potential of sugarcane biomass. The program of FAPESP-Brazil on bioenergy called BIOEN includes research on sugarcane breeding, ethanol production, and its impacts. BIOEN integrates comprehensive research on sugarcane and other plants. The Caribbean research is focusing on developing new cultivars that combine high sugar with high fibre content as multi-purpose energy canes, which will help to produce sugar as well as sustain energy production.

While traditional sugarcane may constitute the ideal energy cane in some scenarios, Type I (sugar + fibre) and Type II (fibre only) energy canes could have a broad-based impact in the national drive for developing sustainable energy technology. Future breeding of sugarcane for sugar plus energy production would be based on three objectives: 1) Economic analysis of different traits and determining optimal selection indices, 2) Optimal parental germplasm to use, 3) Target environments and selection systems.

Molecular breeding

This topic relates mainly to the use of molecular markers to help breeders to speed up the release of cultivars. Experiences from Australia on the use of molecular markers analysing the progress, lessons, challenges, and prospects, concluded that the impact of the use of molecular markers should be based on three strategies: 1) Association mapping in a broadly-based population of genotypes representing the core breeding program, 2) QTL mapping in one or several related crosses, and 3) QTL mapping in populations derived from wild canes. Results from association mapping indicated that markers correlated with cane yield, commercial cane sugar, and disease resistance can be easily found. A marker-assisted breeding program based on a narrowly based population may be effective for increasing rates of genetic gain compared with existing breeding programs. Comparative mapping of a sugarcane genetic map to the sorghum genome provides an important tool for identifying candidate genes underlying QTL regions that can lead to an acceleration of the breeding process for introgressing genes.

A long and constant research activity in CIRAD, France allowed characterisation of the Bru1 (brown rust resistance) locus and its distribution in sugarcane cultivars. Two PCR markers developed in the course of this mapping project in perfect linkage disequilibrium with Bru1 can be used to identify the presence of Bru1 in sugarcane cultivars. Identification of microsatellite markers associated with brown rust resistance in a sugarcane bi-parental cross is used in breeding programs of Brazil.

Target region amplification polymorphism can be used for studies on genetic variability among sugarcane genotypes. SSR loci have helped to identify the DNA profiling and genetic diversity of sugarcane germplasm. Identification of genes has allowed work on the molecular cloning and characterisation of cytosolic malate dehydrogenase gene SC cyMDH from sugarcane (*Saccharum officinarum* L.).

Molecular and *in vitro* technologies as adjuncts to conventional breeding are routinely used in South Africa. DNA fingerprinting is used to verify the identity of genotypes selected for bulking, while an *in vitro* micro-propagation protocol, based on the use of temporary immersion bioreactors, assists in both pathogen elimination and the mass propagation of selected genotypes.

Physiology and cane breeding

Sugarcane physiology related to plant breeding mainly covers photoperiod and flower induction. However, there is an increasing interest in studying the genetic control of some traits controlling sugarcane development and nutrient uptake. Assessing genetic variation in water use efficiency and resistance to water stress in sugarcane cultivars can help breeders to identify cultivars tolerant to water stress, providing direction for more focused and effective breeding and selection of improved cultivars. Efficient use of water is a major determinant of both irrigated and non-irrigated sugarcane production. However, improvement of water use efficiency and/or resistance to water stress has never been specifically targeted within sugarcane breeding programs elsewhere in the past. Breeding for high phosphorus use efficiency in sugarcane is of interest as low availability and high fixation of phosphorus are events frequently occurring either in acid or alkaline soils, which cover more than 30% of the world's land area. Therefore, phosphorus deficiency is a primary constraint to sugarcane production in the tropics and subtropics. Comparing high and low phosphorus use efficiency (PUE) expression will be possible for screening of candidate genes associated with high PUE by molecular markers and comparative proteomics.

Management of flower initiation in tropical conditions has shown positive results. Modifications in the glasshouse on flowering and crossing efficiency need to be reviewed in a sub-tropical condition, where natural flowering is generally poor and inconsistent. No viable seed is produced under field conditions and breeders rely on artificial regimes of photoperiod and temperature to initiate and synchronise flowering for crossing and production of viable seed. Synchronisation of flowering between wild and hybrid cultivars is necessary for introgressing

genes. Phenology of sugarcane and *Erianthus arundinaceus* (Retz.) Jeswiet and development of a technique to control flowering time of *E. arundinaceus* is being studied in Ishigaki Island, Japan.

Biometrical tools

Biometrics has been and will be a major tool for crop improvement. There are several statistical methods to apply in sugarcane considering the different selection stages and applications of family or clonal selection systems. Methods of analysis for family and parent data have been developed for improving the efficiency of estimating breeding values of sugarcane parents to enable breeders to increase the rate of population improvement by better choice of parents and cross combinations. Optimal experimental design and analysis for sugarcane clonal trials with analytical methods have been developed that combine multi-site multi-harvest data in a single analysis. The advantage of such a single analysis is that genetic correlations of testing cultivars over sites and crops can be utilised and proper accounting for the residual correlations between crops at each site can made allowing more accurate selection decisions than the common practice of conducting separate analyses of individual trials and harvests.

An evaluation of new designs for the first clonal stage of selection at Mauritius Research Centre-MSIRI has been tested with an Augmented Latin Square (ALS) design superimposed on the conventional layout at the first clonal (2-m plot) stage in three sub-trials. The ALS design also accommodated a second control variety of wide adaptation with similar ripening pattern as the standard control.

Quantitative genetic analysis of progeny tests to improve selection and genetic gains in sugarcane breeding programs were introduced into the Canal Point sugarcane breeding program to evaluate the benefit of using a combination of between and within-family selection to improve genetic gains for sucrose content and cane tonnage and also as an aid to determine the sample size of the best families for advanced selection.

Introgression in sugarcane

Introgressing genes from wild species has been a common practice over the last 50 years of sugarcane germplasm enhancement program in Houma, Louisiana, USA, aiming to develop parental material with an expanded genetic base for the commercial breeding program. Clones with multiple genera and/or species in their background contain: *Erianthus brevibarbis* Michx. × *S. spontaneum* L.; *E. arundinaceus* × *Miscanthus* Anderss. spp.*; Miscanthus.* spp.*, E. brevibarbis,* × *S. spontaneum*; *S. officinarum* L. × *S. spontaneum; E. arundinaceus* × *S. spontaneum;* and *M. sinensis* Anderss × *Saccharum* spp. hybrids. These wide crosses are being evaluated for cold tolerance, insect resistance, disease resistance, agronomic type, and yield characteristics.

Studies on morphological and genetic characters of the Thai *Erianthus* collection will help to identify materials for introgressing in a wide-crosses program. In China, studies on chromosome genetic analysis for the hybrid progenies of *S. officinarum* L. and *Erianthus arundinaceus* will help to identify the laws of chromosome transmission by chromosome number counts and karyotypic analysis in the hybrids and backcross progenies, and to get some cytological evidence of the use of *E. arundinaceus* in sugarcane breeding. Genetic diversity of sugarcane cultivars in mainland China is very low, as the pedigree analysis indicated using the core parental material which was descended from remote ancestral parents of two to four species of *S. officinarum, S. spontaneum, S. barberi* Jeswiet, and *S. robustum* Brandes and Jeswiet ex Grassl, with coancestry coefficients varying from 0.012 to 0.387.

Sugarcane crop improvement

A BSES-CSIRO joint venture variety improvement program for research and development (R&D), shows important innovations starting from the development of a web-based integrated database and crossing system (SPIDNet), use of mobile weighing equipment; routine use of SpectraCane, a NIR-based system for quality analysis using fibrated cane; a DNA fingerprinting-

based variety audit program for advanced clones and a molecular markers approach for marker assisted breeding. For example, the use of a centralised information management system like SPIDNet has produced benefits including data security, standardised data collection operations, fewer data errors, increased data availability, and the possibility of data exchange between BSES, CSIRO, and other industry partners.

The breeding objectives and its concept, construction, and implementation are based on each major production area with various steps: 1) examining the production system in each production area; 2) collecting all economic data related to each step in the production system; 3) assessing the impact of changes in performance for sugarcane traits on the economic data and 4) deriving economic importance or weight of each trait.

The foreign cultivars in the Australian sugar industry play an important role as parents in the development of new cultivars: 21 of the last 50 'Q' cultivars have at least one foreign variety as a parent. Imported cultivars generally do not yield as well as locally-bred cultivars in selection trials. However, they are an important source of diversity and of new genes for resistance to diseases.

Up until the year 2000, orange rust was only a minor disease in Australia recognised by just a few disease specialists, but that changed when a new strain of the pathogen developed and rendered the widely grown cultivar Q124 susceptible. Fortunately, a high level of resistance was found in the germplasm making the selection of resistant cultivars easier. Disease control has been achieved using resistant cultivars and the disease no longer poses a threat to the Australian sugarcane industry.

A web-based variety management and information resource for the Australian sugar industry will help growers to better manage cultivars by providing specific recommendations and a broad range of information on cultivars, accessing the database in a grower-friendly format.

Parental selection for crosses is performed using the System of Information of Varieties – SIVAR in Colombia. The system designs crosses using trait values such as sucrose (cane %), stalk diameter, height, leaf shading (cover), flowering, tillering, lodging, stalk population, and resistance to smut, rust, and mosaic. The algorithm adds values for certain traits of both cultivars in comparison and if the sum is equal to or below a critical value, the process moves to the second trait and so on until all the comparisons are done for all traits.

If the sum of traits exceeds the critical level then the cross cannot be performed. Each descriptor is weighted according to its importance in the prototype of an ideal variety and this is multiplied by its descriptor to add the value of all weights to generate a value of merit of the variety.

There is a need to identify parental materials of high-sucrose for early harvesting in Ecuador; two groups (G1 and G2) were evaluated. These groups will be the basis to arrange crosses for high sucrose content.

In SASRI, research is being conducted collaboratively with the Sugar Milling Research Institute to determine whether near infra-red spectroscopy can satisfactorily predict colour and pith:fibre ratio of cultivars routinely processed in SASRI's Mt. Edgecombe millroom.

A method that compares commercial productivity of new and older sugarcane cultivars is being used in Mauritius.

Plant breeders often are concerned about the commercial performance of their newly released cultivars relative to the older ones being replaced. Such a comparison is often difficult unless reliable and comparable commercial data are available.

Results were presented for a new multi-site selection network implemented in Réunion Island, which is designed to serve the very contrasting agronomic zones of the island.

Progress from breeding and variety selection programs in Argentina from 1989 until 2008 has shown a TCH increase of 5.3 t, TRS advanced by 4 kg per tonne milled, and TSH increased 0.85 t.

In China, over 90% of sugar produced is from sugarcane. The sugarcane growing areas are distributed mainly in the developing area of south-west China, where the economy is based on the sugar industry. Recently, sugarcane is grown for use as an 'energy crop'.

As for all genetically modified crops, any GM sugarcane will have to undergo regulatory processes prior to commercial release, focused on safety to humans and the environment. Research provides baseline information for the decision making for the future deployment of GM sugarcane within the Australian regulatory context. Based on the Australian analysis, the information is applicable for sugarcane industries around the world.

Conclusions

Opportunities and challenges for sugarcane breeding remain intact as many new alternative breeding methods, molecular tools, and most importantly, the need for new cultivars of different usage are in demand. Traditional breeding still remains as the only practical system to release new cultivars, and the sugar industry needs trained crop improvement scientists to ensure future cane production. New genes from wild species are incorporated into the hybrid cultivars to ensure disease resistance and incorporate traits that are important in dry environments or heavy soils with low mineral contents. The 9th Breeding and Germplasm Workshop was a successful meeting in term of presenting a high level of knowledge to those delegates investing the time and money to attend. All the presentations were of scientific merit, with adequate time allowed for discussions.

Acknowledgement

We thank the BSES Limited's management and staff for supporting the Workshop economically and technically. They shared their knowledge and scientific experiences in a series of presentations and their friendship shown during the Workshop and the social events were greatly appreciated by all participants. The work of the local Organising Committee: Dr. Nils Berding (BSES Limited, Chair), Dr. Michael Cox (BSES Limited), Dr. Phillip Jackson (CSIRO, Plant Industry), Mr. Ross McIntyre (BSES Limited) and Ms. Rhylee Pendrigh (BSES Limited), is gratefully acknowledged, as are the staff of the Meringa Experiment Station who provided excellent support for the field excursion.

LES OPPORTUNITÉS ET DÉFIS DE LA SÉLECTION AMÉLIORANTE DE LA CANNE À SUCRE: UN RÉSUMÉ DU 9ÈME ATELIER DE L'AMÉLIORATION GÉNÉTIQUE ET DU GERMOPLASME DE L'ISSCT

Par

RAUL O. CASTILLO [1], NILS BERDING[2], PHILIP JACKSON[3],
THOMAS L. TEW[4] et ANTHONY KENNEDY[5]

[1]*Centro de Investigación de la Caña de Azúcar del Ecuador (CINCAE), Av. Joaquín Orrantia y Juan Tanca Marengo, Ed. Executive Center, Mezzanine. Guayaquil, Équateur*
[2]*BSES Limited, P.O. Box 122, Gordonvale, 4865, Australie*
[3]*CSIRO Plant Industry, Private Mail Bag P.O. Aitkenvale, Queensland, 4814, Australie*
[4]*Sugarcane Research Unit, 5883 USDA Road, Houma, LA, 70360-5578, États Unis*
[5]*West Indies Central Sugarcane Breeding Station, Groves, St. George, Barbados, Antilles*
rocastil@espol.edu.ec

MOTS CLÉS: Amélioration Génétique de la Canne à Sucre, Biotechnologie et Biomasse, Atelier de l'ISSCT.

Résumé

LE 9ÈME ATELIER d'amélioration génétique de la canne à sucre et du germoplasme de l'ISSCT a eu lieu du 17 au 21 août 2009 au Novotel Rockford Resort, Coral Coast Drive, Palm Cove, Cairns, Australie. L'atelier s'est déroulé à la Station Expérimentale de Meringa du BSES Limited et parrainé par BSES Limited, ISSCT, ainsi que le Sugar Research and Development Corporation du gouvernement australien. Soixante-dix délégués de différents pays ont participé à l'atelier qui s'est distingué par son contenu scientifique, son organisation impeccable et l'esprit de camaraderie qui a régné. L'Australie était bien représentée par un contingent de 20 généticiens-sélectionneurs et des chercheurs. Des délégués étaient venus de l'Argentine, la Barbade, le Brésil, la Chine, la Colombie, l'Équateur, les Îles Fidji, la France, l'Inde, l'Indonésie, le Japon, Maurice, Réunion, Afrique du Sud, le Sri Lanka, la Thaïlande, l'Ouganda et les États Unis. Les présentations ont non-seulement couvert les thèmes concernant l'hybridation de la canne pour la richesse, mais aussi la biomasse. Une analyse intéressante a été présentée du point de vue d'un investisseur sur les avancées en sélection traditionnelle comparé à l'utilisation de la transformation génétique de la canne, avec des gènes nouveaux. Les nouveaux marqueurs moléculaires pour la cartographie du génome, la diversité génétique et les nouvelles techniques de biotechnologie pour la canne et l'utilisation de la bioénergie ont aussi été discutés. La canne génétiquement modifiée (GM) et les risques à la biosécurité ont également été abordés. L'atelier a démontré que l'hybridation traditionnelle et les outils de la biotechnologie devraient marcher de pair afin d'obtenir des développements rapides et augmenter la production, non seulement pour le sucre, mais aussi pour la bioénergie.

OPORTUNIDAES Y RETOS PARA EL MEJORAMIENTO DE LA CAÑA DE AZÚCAR: UN RESUMEN DEL 9TH TALLER DE LA ISSCT EN MEJORAMIENTO Y GERMOPLASMA

Por

RAUL O. CASTILLO[1], NILS BERDING[2], PHILIP JACKSON[3], THOMAS L. TEW[4] y ANTHONY KENNEDY[5]

[1]*Centro de Investigación de la Caña de Azúcar del Ecuador (CINCAE), Av. Joaquín Orrantia y Juan Tanca Marengo, Ed. Executive Center, Mezzanine. Guayaquil, Ecuador*
[2]*BSES Limited, P.O. Box 122, Gordonvale, 4865, Australia*
[3]*CSIRO Plant Industry, Private Mail Bag P.O. Aitkenvale, Queensland, 4814, Australia*
[4]*Sugarcane Research Unit, 5883 USDA Road, Houma, LA, 70360-5578, USA*
[5]*West Indies Central Sugarcane Breeding Station, Groves, St. George, Barbados, West Indies*
rcastillo@cincae.org

PALABRAS CLAVE: **Mejoramiento de Caña de Azúcar, Biotecnología y Biomasa, Taller de la ISSCT.**

Resumen

El 9th Taller de mejoramiento y germoplasma de la ISSCT se realizó desde el 17 al 21 de agosto de 2009 en complejo hotelero Novotel Rockford Resort, Coral Coast Drive, Palm Cove, Cairns, Australia. El Taller fue organizado por los investigadores de la estación Experimental Meringa de BSES Limited. Los auspiciantes del evento fueron BSES Limited, ISSCT, y la Corporación de Desarrollo para la Investigación Azucarera (SRDC) del Gobierno Australiano. Participaron en el evento 70 delegados-investigadores de diferentes países, caracterizado por su alto nivel científico, impecable organización y un enorme espíritu de amistad. Australia estuvo muy bien representada con 20 mejoradores e investigadores. Hubieron delegados de Argentina, Barbados, Brasil, China, Colombia, Ecuador, Islas Fiji, Francia, Indonesia, Japón, Mauritius, Reunion, Sur África, Sri Lanka, Tailandia, Uganda, and USA. Las presentaciones orales cubrieron tópicos no solamente de mejoramiento para contenido de azúcar, sino también en biomasa. Hubo un importante análisis desde el punto de vista de los inversores en investigación sobre los avances en el mejoramiento tradicional comparado con los trabajos de transformación genética con genes novedosos. También se discutieron nuevos marcadores moleculares para mapeo y estudios de diversidad genética, así como nuevas técnicas en biotecnología de caña y el uso en bioenergía. Finalmente, se discutió sobre los organismos genéticamente modificados (GM) y los aspectos de bioseguridad. El Taller, mostró que el mejoramiento tradicional y las herramientas biotecnológicas deberían trabajar juntas para obtener desarrollos rápidos no solamente en azúcar sino también en biomasa.