The ACP Sugar Research Programme: a review of achievements and prospects

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Abstract

The African Caribbean Pacific (ACP) Sugar Research Programme (SRP), an innovative scientific research venture, addresses the technological challenges of the sugarcane sector in ACP countries. Thirteen projects were undertaken to: research new sugarcane varieties; develop co-products; create new sources of revenue; reduce environmental impacts; and increase productivity. The ACP-SRP develops networking among ACP sugarcane research centres namely the: Mauritius Sugarcane Industry Research Institute (Mauritius); Sugar Research Institute of Fiji (Fiji); Sugar Industry Research Institute (Jamaica); Technical Services of the Swaziland Sugar Association (Swaziland); and West Indies Central Sugarcane Breeding Station (Barbados). The ACP-SRP was conceived in the early 2000s, projects were approved in 2007, and implementation took place from 2010 to 2015. This paper describes the general objectives, the main technical activities and results therefrom, for each of the projects. Key performance indices (KPIs), based on stated technical objectives and times of completion, and the degree to which they were met, are presented. The KPIs of 11 of the 13 projects were met completely. For the other two projects only some of the KPIs need to be completed, mostly because of time constraints. It is concluded that the projects have been innovative, non-academic and demand driven. Stakeholders have always been involved. Co-products have been valorised; there has been potential for industrial application and a number of favourable environmental outcomes have emerged. With the current low price of sugar on the world market, it is imperative that industries within, and even outside the ACP states, become more efficient and diversify for niche as well as large-scale markets. The outcomes of the ACP-SRP will certainly increase the competitive edge of the sugarcane industries of the ACP states. A second programme is being prepared based on 53 submitted concept notes.

Key words
Varieties, ACP-SRP, biopesticides, bioenergy, bioplastics

INTRODUCTION

At a Workshop held in Barbados in July 1999, the Directors of the sugarcane research centres of the African, Caribbean and Pacific countries (ACP) and members of the Sugar Protocol of the Lomé Convention discussed research priorities and agreed on a collaborative programme. The Bridgetown Statement on Intra-ACP Cooperation on Sugar was adopted as:

‘To increase productivity, profitability and sustainability of the respective sugar industries of the ACP countries by surmounting common challenges through institutional collaboration in R&D and information exchange.’

The first contract for the implementation of the programme was signed in August 2010. The programme was due for completion in December 2014. The objectives for the ACP sugar industries were to:

- increase productivity, profitability and sustainability;
- enhance and exploit the transition to a more open, less protected sugar market;
- increase competitiveness.

Thirteen projects were approved involving: the development of new sugarcane varieties with improved characteristics for sucrose content, fibre and disease resistance; investigations into co-products to diversify the uses of sugarcane and create new sources of revenue, thus ensuring sustainability; reducing the industry's impact on the environment, and increasing productivity. The programme also provided for building up of new infrastructures, acquisition of state-of-the-art equipment, and capacity building. It entailed development of networking among ACP sugarcane research centres (Autrey et al. 2013).

In 2014 the completion date for the programme was extended to December 2015, due to uncontrollable factors such as the weather and delays in obtaining equipment. The programme was completed by this second date; it is now instructive to review its implementation, the difficulties encountered and the successes achieved.
RESEARCH CENTRES

The ACP sugarcane research centres undertaking the 13 projects were:

- The Mauritius Sugarcane Industry Research Institute (Mauritius).
- The Sugar Research Institute of Fiji (Fiji).
- The Sugar Industry Research Institute (Jamaica).
- The Technical Services of the Swaziland Sugar Association (Swaziland).
- The West Indies Central Sugarcane Breeding Station (Barbados).

They worked in collaboration with nine other research institutions in ACP countries especially in Africa.

PROJECT PORTFOLIO

Five projects (1.1-1.5) investigated the production of new cane varieties. They covered: the advantages of state-of-the-art equipment for the analyses required for cane breeding; the development of high sucrose/early ripening varieties; quarantine facilities; early variety selection criteria; and the use of Erianthus species to produce hybrids with new, beneficial characteristics.

Four projects (2.1 to 2.4) dealt with reduction of costs, and of negative impacts on the environment. Efficient use of water, optimization of fertilizer application, and biopesticides for specific sugarcane pests were investigated.

Four projects (3.1 to 3.4) focussed on reducing losses of sugar during processing, and on the addition of value through the production of co-products. They included: the determination of non-sucrose components in sugarcane that affected processing and sugar quality negatively; the disposal of vinasse, a particularly troublesome distillery effluent; the production of bioplastics from sugarcane biomass; and the efficient use of energy.

Details about the individual projects follow.

Project 1.1: Improving capacity and speed of sugarcane breeding in the Caribbean by investing in state-of-the-art laboratory equipment (WICSCBS – Barbados)

High-speed whole-cane analysers were investigated in Barbados, Belize, Guyana and Jamaica with the intention of increasing the number of samples processed in each country from 500-700 per year at inception (2010) to at least 3000 after the implementation of the project. This KPI was met: the number of samples being 3000 to 7000 annually, compared to 700 previously, illustrating how efficiency can be improved with the use of modern equipment. Spectracane, which is designed specifically for the analysis of sugarcane, has been thoroughly tested and found suitable for breeders. A presentation was made at the ISSCT Germplasm and Breeding/Molecular Biology Workshops by Kennedy (2015).

Project 1.2: Increasing sugar productivity through the development of high-sucrose and early-ripening varieties (MSIRI - Mauritius)

The objectives were to develop high-sucrose and early-ripening (HS/ER) varieties for breeding and selection, to classify varieties and to identify/develop molecular markers linked to HS/ER features. Partners were Barbados, Fiji, Côte d’Ivoire, Kenya, Madagascar, Mauritius, South Africa, Swaziland and Tanzania. The KPI was met with the development and availability of 30-35 HS/ER parents/genotypes.

This project has many potential advantages for sugar and co-products. It allows the crushing season to be extended, which increased productivity of the agricultural, processing and co-products activities. Publications by Parmessur et al. (2013, 2014, 2015) and Badaloo et al. (2015) reflect positively on the scientific value of this project.

Project 1.3: International quarantine facility for the exchange of sugarcane germplasm among ACP countries (MSIRI – Mauritius)

This project enhanced productivity and efficiency in the ACP sugarcane industries by promoting germplasm exchange and improving responses to challenges in the global economy. It provided sugarcane free from pathogens and pests, to all ACP countries, thus safeguarding them from these damaging biotic factors. The risks of potentially devastating diseases...
being introduced to other countries were reduced, the duplication of resources was avoided, and the speed at which varieties become available was improved. The three KPIs were met namely, that the quarantine facility with a capacity to screen 150 varieties per year, offered half of the capacity used by other ACP countries, and that plant health officials from ACP countries could be trained in safe sugarcane germplasm exchange. The facility is of Biosecurity level 3, namely all liquids and solids are contained into the glasshouse that has an incinerator.

A training workshop on sugarcane quarantine was organized from 7-12 December 2015, at the MSIRI, Mauritius with the objectives to create awareness of the international quarantine facility and to train plant health officials of ACP countries in sugarcane diseases, diagnosis and biosecurity. Apart from local participants, 12 participants from 12 ACP countries (Barbados, Burundi, Cote d’Ivoire, Fiji, Ghana, Kenya, Mozambique, Sudan, Tanzania, Uganda, Zambia and Zimbabwe) attended the workshop.

This project received an award in the field of Natural Science and Engineering (Mauritius Research Council Post Graduate Conference) in 2015. Four papers were presented by Joomun et al. (2012), Joomun and Saumtally (2013), and Joomun and Dookun-Saumtally (2014, 2015) and the research was part of an MSc thesis by Motee (2014) at the University of Mauritius. A training course was held for 13 plant health officials from 13 ACP countries in December 2015 and certification from the International Quarantine Station was obtained.

Project 1.4: A comparative study of family and individual mass-selection methods as early selection criteria (SRIF - Fiji)

The project increased the efficiency of selection, particularly in the area of multi-purpose cane varieties. It helped in demonstrating that family selection was superior to individual selection.

The KPI for improved varieties with higher sucrose and desired characteristics to reach selection stages faster was partially met, because weather conditions were unfavourable. Hence, the project will be continued to achieve its objectives that are beyond a 5 year time-frame.

Project 1.5: Nobilisation of Erianthus species (SRIF – Fiji)

The project objective was to develop a nobilisation programme involving three Erianthus species and selected S. officinarum clones. Germplasm was collected in selected countries and crosses made to develop an array of genotypes with Erianthus ancestry. Hybrids with attributes from Erianthus such as vigour, high fibre, resistance to pests and diseases, and tolerance of drought and waterlogging are expected; and the genetic base of the gene pool will be enhanced.

An international workshop on the nobilisation of Erianthus was held in Fiji from 23-27 May 2013 with attendance from a 14 scientists from nine countries and five local staff from Fiji. The general objective of the workshop was to share information with international experts who had successfully produced Erianthus hybrids and also biotechnologists who used several techniques to prove that the seedlings were indeed hybrids of Erianthus. It was considered that the outcome of this unique workshop was very successful.

The KPIs were to collect and characterise the varieties, and develop true Erianthus hybrids with high vigour and biomass. Only the first KPI was met. From the start it was known that the project would be long and difficult. Fiji now has the gene pool and the equipment to continue the project. Three publications Sattar et al. (2013) and Singh et al. (2012, 2013) were produced.

Project 2.1: Developing biopesticides to control white grubs in sugarcane fields (MSIRI – Mauritius, SASRI – South Africa)

The objective was to identify methods of reducing the impact of white grubs in sugarcane. South Africa, Malawi, Mozambique, Madagascar, Mauritius, Swaziland, Tanzania and Zimbabwe were the partners. The work involved the development of less costly and more environmentally friendly bio-insecticides by using indigenous entomopathogens. A useful outcome was that a user-friendly morphological key to the white grubs of Southern Africa and the Indian Ocean islands is now available.

Prototype bioinsecticides were developed and made available commercially, and the taxonomy of white grubs was completed resulting in a user-friendly morphological key to the white grubs of Southern Africa and the Indian Ocean islands. A total of 25 successful pathogens were identified. Papers were published by Conlong and Ganeshan (2011, 2015), Mabveni and Mgocheki (2012), Mgocheki et al. (2012), Ngobane et al. (2012), Behary Paray et al. (2012a,b), Way et al.
Project 2.2: Optimizing phosphorous fertilizer application in sugarcane to decrease production costs and to protect water resources (MSIRI – Mauritius)

Phosphate applications for optimum sugarcane production and the control of phosphate already present in soil to prevent losses, thus protecting natural water resources, were achieved. The partners in this research were Fiji, Jamaica and Mauritius. A reliable determination of phosphate contents in soils to predict the agronomic and environmental status of sugarcane soils, the P index, and the identification of regions hazardous to natural water sources in the ACP states have been produced.

The KPI was met namely, the development of a decision tool for the optimum use of phosphate fertilizers, without affecting cane yields and natural water quality. A simple method to estimate phosphorous losses in runoff was developed and distributed to ACP countries; this eliminates labour intensive experimentation and costly equipment. A Phosphorous Index was developed to estimate requirements for specific regions using a Site Vulnerability Chart; the optimum quantity of phosphate fertiliser is then obtained. Papers were published by Mardamootoo et al. (2010, 2011, 2013a,b, 2014, 2015b,c), Mardamootoo (2015a). Fearon and co-workers have submitted papers for publication in the Jamaica Association of Sugarcane Technologists Journal, Volume 70 in 2012, Volume 71 in 2013 and Volume 72 in 2014, which are yet to be published.

Project 2.3: Increasing sugarcane yields for small holder farmers through improvements in irrigation scheduling (SSATS – Swaziland)

This project improved management for smallholder farmers through the use of simple and locally available technology. It targeted irrigation scheduling, electricity management, the use of rain gauges, maintenance, and record keeping. This was achieved through relevant training.

The KPI that water use and electricity consumed by small sugarcane farmers would be reduced by 20%, while sugar yields were met was met. Sugar yield increased by 7% over 3 years; electricity costs were reduced by 12% and water costs by 9%. This was achieved by the use of messages (SMS) with mobile telephones to transfer information to and from growers. Ninety five percent of the growers attended the training sessions; 85% now use irrigation scheduling. This success is of particular value as it addresses the needs of small farmers in remote areas. Two papers (Mkhaliphi et al. 2013, 2015) were published.

Project 2.4: Efficient conjunctive use of water for sustainable sugarcane production (MSIRI- Mauritius)

The objective was the development of an easy-to-use irrigation management tool. The partners were Cameroon, Côte d’Ivoire, Guyana, Senegal and Tanzania. A user-friendly and site-specific Irrigation Management Information System (IMIS) for collecting and analysing irrigation data was produced - this enabled farmers to enhance water use efficiency, thus reducing costs. The KPIs were the development of IMIS, its promotion and an improvement of 20% in water use efficiency, which have been met.

A users’ guide was distributed. A presentation was made at the ISSCT Agronomy Workshop in Townsville, Australia by Ng Cheong and Teeluck (2012). Two workshops on the theme Irrigation Water Management were held: (1) from 21–25 September 2015 with 10 English-speaking participants; and (2) from 28 September to 2 October 2015 with 14 French-speaking participants. The 24 participants came from 13 countries. The workshop included a series of theoretical presentations, field visits and with hands-on training on the IMIS software.

Project 3.1: The development of an alternative method for determining dextran in process materials in ACP sugar producing countries (SIRI - Jamaica)

The aim was to develop a rapid, robust and simple analytical method to identify dextran, and use it to measure concentrations of dextran along the process chain. Belize, Fiji, Jamaica and Guyana partnered this project. The Dextran and Sucrose Analysis (DASA) instrument was evaluated.
The project was intended to identify and reduce levels of dextran in cane and in the raw sugar produced by approximately 50% after year 3. This KPI was partially met; a method was developed in Jamaica, but no results from juices and sugars were obtained. The work is continuing. Two papers have been presented by Bryan et al. at the meetings of the Jamaica Association of Sugar Technologists in 2013 and 2014.

**Project 3.2: Efficient use of energy resource in cane processing (MSIRI – Mauritius)**

This project enhanced the competitiveness of ACP factories through the efficient use of energy. Fiji, Burkina Faso, Mauritius, Tanzania, Burundi, Uganda, Rwanda, Cameroon, Zambia and Madagascar were involved. The benefits include the assessment of the actual energy situation and related training needs and an awareness on the benefits of the efficient use of energy achieved in Mauritius. The three KPIs were met namely, the assessment of energy usage, relevant software development, and improving the efficiency of usage.

The partners were visited and specific conditions examined; training was provided; software was shared, its use illustrated and local application developed to manage energy. It is expected that with future contacts, significant savings in energy will result, promoting cogeneration and co-products developments. A presentation was made at the ISSCT joint Factory and Engineering Workshops by Ah Foon Lau (2014).

**Project 3.3: Technology development for the disposal of vinasse (MSIRI - Mauritius)**

The original plan was modified by the Scientific Advisory Group (SAG); a comprehensive ‘Desktop Study’ for re-assessing strategies on vinasse disposal/treatment was undertaken. The best combinations of technologies for the safe and sustainable disposal of vinasse were identified and the information made available. This KPI was met.

Two processes were identified. Firstly an anaerobic digestion followed by biomethanation and biocomposting, and secondly the agricultural application of CMS (concentrated molasses stillage) enriched with nitrogen and phosphorous. Which of the two techniques to adopt depended on the specificities of individual ACP countries. A booklet describing the results of the project has been made available to all partners, to help in selecting the process suitable to local conditions. Soobadar and Umrit (2015) presented the outcome of the study at the ISSCT Co-Products Workshop in Mauritius from 30 November to 4 December 2015. The attendees from 15 countries, who were mostly specialists in co-products, expressed appreciation of the value of the study as a decision-making tool.

**Project 3.4: Production of polyhydroxyalkanoates (PHAs) from sugarcane trash and vinasse (MSIRI - Mauritius)**

This project demonstrated how the revenue base of the sugar sector in Mauritius and other ACP countries could be enhanced. It developed a cost effective technology for the production of PHA from unused/cheap carbon sources from sugarcane. Bioplastics offer significant advantages both from an ecological as well as an economical viewpoint. The expected KPIs were the development of a technology to produce bioplastic at a lower cost than that of petrol-based plastic, on a large scale and utilizing unused/cheap sugarcane biomass, and a technical description of the characteristics of the identified bioplastics. Both KPIs were met, except that cost of production, which cannot be determined on a laboratory scale, will be studied with a bioreactor.

Vinasse was not a suitable feedstock, even when combined with cane trash, so this approach was abandoned.

The use of cane trash, an inexpensive vegetable product from the sugarcane plant, on its own produced excellent results. The trash was treated to yield a hydrolysate; a bacterium was added producing a PHA, which was then extracted. The PHA was analysed to reveal its molecular structure, confirming that it was a PHA of a high purity. Samples of the bioplastic were produced. It is now required to optimise the biofermentation step to increase the yield of PHA and to scale up to a pilot plant.

The MSIRI is investigating the possibility of collaborative partnerships. The findings were presented through three papers, Umrit (2014) and Umrit et al. (2014, 2015).
CONCLUSIONS

The KPIs of 11 of the 13 projects were met completely. For the other two projects, some of the KPIs need to be completed, mostly because of the time constraints.

The projects have had a large positive effect on the abilities of individual technical personnel and of institutes. Researchers and technicians have increased their scientific knowledge, many obtaining university degrees; their cooperating and team building skills have been sharpened; they have attended seminars, congresses and workshops establishing new contacts, networking, presenting and discussing technical information. The institutions have developed financial skills to manage external funding; they have dealt with commercialisation, patents and IP issues. They have built modern infrastructure, acquired state-of-the-art laboratory and field equipment and developed the skills required to operate them.

Another positive aspect of the ACP-SRP programme is that it promotes free sharing of technical information. This is not always the case in technical congresses held within the sugar industry, diminishing the value of such undertakings.

Considering the main objectives of this programme, namely the production of new cane varieties, the reduction of sugarcane production costs and of negative environmental impacts, the reduction of sugar losses during processing, and the development of co-products to add value, we conclude that the results achieved have been significant. They have contributed to the advancement of knowledge, not only on the sugarcane plant, but also on its production and processing, in addition to adding value through the development of better co-products.

Five projects addressed the first section; the analytical part of breeding has been optimised and the complete process shortened; high sucrose/early ripening varieties are being developed; an international quarantine station for safe movement of cane germplasm is in operation; the use of *Erianthus* is progressing; and the basis for evaluation of family selection has been set.

The reduction of environmental problems has been addressed through the bio-pesticide project: a biopesticide has been produced at the laboratory scale and found effective against specific pests; a process to prevent phosphorous fertiliser from polluting waterways has been developed; and a programme to use water sustainably distributed. Cost reduction has been particularly successful for small growers through a well organised practical system which has been implemented in Swaziland where it is working well.

Processing losses have been addressed by a method to determine dextran. Three projects dealt with co-products. The first improved energy efficiency in factories thus releasing bagasse for cogeneration or for co-products. The second developed a document describing processes to handle vinasse. Finally, the possibility of producing bioplastic from cane trash was successful; this had never been reported for the sugarcane biomass.

We conclude that the projects have been innovative, non-academic and demand driven. Stakeholders have always been involved. Co-products have been valorised; there has been potential for industrial applications and a number of favourable environmental outcomes have emerged. The large number of papers and presentations testify to the scientific value of the work carried out across the programme and have ensured the visibility of the ACP-SRP.

The low price of sugar at present on the world market and the end of preferential prices in European Community in September 2017, make it imperative that industries within and even outside the ACP states become more efficient and diversify for niche as well as large scale markets. The outcomes of the ACP-SRP will certainly increase the competitive edge of the sugarcane industries of the ACP states.

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Le Programme de Recherche Sucrerie des pays ACP: une analyse des réalisations et perspectives

Résumé. Le programme de recherche sucrière (SRP), de l’état Afrique, Caraïbes, Pacifique (ACP) est une entreprise innovante de la recherche scientifique; elle aborde les défis technologiques du secteur de la canne à sucre des pays ACP. Treize projets ont été entrepris pour : la recherche de nouvelles variétés de canne à sucre, le développement des coproduits, la création de nouvelles sources de revenus, la réduction les impacts environnementaux, et l’accroissement la productivité. L’ACP-SRP a permis la constitution des réseaux entre les centres de recherche de canne à sucre des pays ACP à savoir la: Maurice Sugarcane Industry Research Institute (Maurice); Sugar Research Institute of Fiji (SRIF) (Fiji); Sugar Industry Research Institute (Jamaïque); Technical Services of the Swaziland Sugar Association (Swaziland); and West Indies Central Sugarcane Breeding Station (Barbade). L’ACP-SRP a été conçu dans les années 2000, des projets ont été approuvés en 2007 et mis en œuvre de 2010 à 2015. Cet article décrit les objectifs généraux, les principales activités techniques et les résultats obtenus, pour chacun des projets. Des indices de performance clés (KPI), basés sur les temps d’achèvement et le degré auquel ils ont été accomplis, et les objectifs techniques sont présentées. Les indicateurs de performances clés de 11 des 13 projets ont été complétement accomplis. Pour les deux autres projets, seulement certains des indicateurs de performance clés doivent être complétés, principalement en raison de contraintes de temps. Il est conclu que les projets ont été novateurs, d’ordre pratique et pertinent. Les partenaires de l’industrie ont toujours été impliqués, des coproduits ont été valorisés; il y a eu des possibilités d’applications industrielles et un certain nombre de résultats favorables pour l’environnement ont vu le jour. Avec un prix du sucre particulièrement faible sur le marché mondial, il est impératif que les industries au sein et même en dehors des États ACP, deviennent plus efficaces et se diversifient pour être compétitifs sur tous les marchés. Les résultats de l’ACP-SRP augmenteront certainement l’avantage concurrentiel de l’industrie de la canne à sucre des pays ACP. Un deuxième programme basé sur 53 résumés a été soumis.

Mots-clés: ACP-SRP, biopesticides, bioénergie, variétés, bioplastiques

El Programa de Investigaciones Azucareras de ACP: Una reseña de logros y perspectivas

Resumen. El Programa de Investigaciones Azucareras (SRP en inglés) del Grupo África- Caribe- Pacífico (ACP en inglés), todo con las siglas (ACP-SRP), es una iniciativa innovadora de investigación científica, dirigida a los retos tecnológicos del sector azucarero de los países de ACP. Se abordaron trece proyectos para invertir acerca de nuevas variedades de caña de azúcar, el desarrollo de co-productos, la creación de nuevas fuentes de ingresos, la reducción del impacto ambiental e incrementar la productividad. El ACP-SRP desarrolló una red entre los centros de investigación del Grupo ACP, esto es entre: El Instituto de Investigaciones de la Industria Azucarera de
Mauricio, el Instituto de Investigaciones Azucarera de Jamaica, los Servicios Técnicos de la Asociación Azucarera de Suazilandia y Estación Central de Mejoramiento Cañero de las Indias Occidentales (West Indies) de Barbados. El ACP-SRP fue concebido a inicios de los años 2000’, los Proyectos fueron aprobados en el 2007 y la implementación de se realizó entre el 2010 y el 2015. Este artículo describe los objetivos generales, las principales actividades técnicas y resultados, para cada uno de los Proyectos. Se presentan los índices clave de desempeño (KPIs en inglés), basados en los objetivos técnicos establecidos y el tiempo de conclusión, así como el grado en que cada uno se alcanzó. Los KPIs de 11 de los 13 Proyectos se alcanzaron completamente. Para los otros dos Proyectos solo algunos de los KPIs deben ser completados, principalmente debido a limitaciones de tiempo. Se concluye que los Proyectos fueron innovadores, no-académicos y requieren continuación. Los accionistas han tomado parte siempre. Los co-productos se han valorado, habiendo potenciales para la aplicación industrial y han surgido un número de resultados ambientales favorables. Con los actuales bajos precios del azúcar en el mercado mundial, resulta imperativo que las industrias dentro y fuera del Grupo ACP, sean más eficientes y diversificadas tanto en los nichos como en el mercado a gran escala. Los logros del ACP-SRP incrementarán, sin dudas, el perfil competitivo de las industria azucareras de los países de ACP. Actualmente se prepara un segundo Programa, basado en 53 Conceptos que se han presentado.

Palabras clave: ACP-SRP, bio-pesticidas, bioenergía, variedades, bio-plásticos