INNOVATIVE APPROACHES TO ENHANCING SUGAR INDUSTRY PRODUCTIVITY AND PROFITABILITY: THE CONTRIBUTION FROM CRC SUGAR

By

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Abstract

Enhancing Productivity is one of three research programs within the Cooperative Research Centre for Sustainable Sugar Production (CRC Sugar). The program was established to undertake research and education to improve the profitability and international competitiveness of the Australian sugar industry through the development and adoption of novel management practices across the raw sugar industry value chain. The program has drawn heavily on seconded staff and resources from BSES, Bundaberg Sugar, CANEGROWERS, CSIRO Tropical Agriculture (now Sustainable Ecosystems), CSR, James Cook University, Mackay Sugar, Sugar North and the University of Queensland, supplemented with SRDC cash and competitive project funding, and complemented by five staff funded using the CRC Program cash grant. Research is broadly divided into two themes: on-farm management practices and whole-of-industry management issues related to the production and supply of cane. Within each research area, activities have sought to add value to the research and expertise of the several joint venture parties. Enhancing Productivity (Program 3) has made a significant contribution in several key areas including the development of improved ways of utilising limited irrigation water supplies; gathering important information for improved decision-making on managing time-of-harvest, crop age and season length; identifying opportunities for managing the sugar yield of early harvested crops; developing a more rigorous approach to the collection and storage of industry experimental data; improved methods of crop forecasting; significant advances in understanding the constraints to productivity in the wet tropics; and the identification of more profitable cane supply arrangements. The novel research approach adopted for exploring alternative cane supply options has significantly changed industry thinking on the role of a whole-of-industry systems approach for achieving better use of industry resources and sustained international competitiveness. Also the collaborative and participative approach to R&D followed by many Program 3 activities, where industry and researchers work in partnership to explore different options and develop and implement solutions, is likely to be increasingly used to evaluate and manage change as the problems to be solved assume greater complexity.
Introduction

The Cooperative Research Centre for Sustainable Sugar Production (CRC Sugar) was established in 1995 as part of a program by the Australian Government to enhance linkages between science, industry and the universities. It was a joint venture between the growing and milling sectors of the Australian sugar industry and its major R&D and education providers. Each of the 13 joint venture parties contributed cash and/or in-kind resources, which attracted cash funding from the Australian government. The government funding facilitated the cooperative arrangements linking the industry, R&D and university joint venture parties and enabled substantial new R&D initiatives to be undertaken.

Enhancing Productivity (Program 3) is one of the three research programs established within CRC Sugar. It addresses the third of CRC Sugar’s sustainability goals, which is to improve the profitability and international competitiveness of the Australian sugar industry through the development and adoption of novel management practices across the raw sugar industry value chain (CRC Sugar, 1998). The approach taken to achieve this goal was to use databases and modelling, supplemented by field experimentation, to develop strategies that can be extrapolated across the diverse soil and climatic regions of the industry. Cooperative linkages were formed between nine of the host agencies: BSES, Bundaberg Sugar, CANEGROWERS, CSIRO Tropical Agriculture (now Sustainable Ecosystems), CSR, James Cook University, Mackay Sugar, Sugar North and the University of Queensland. Research in Program 3 is broadly divided into two themes: the development and adoption of on-farm management practices that best utilise available genetic potential in diverse production regions; and the development and evaluation of optimal solutions to whole-of-industry management issues relating to the production and supply of cane. These themes are supported by the development of a database of field experiment and weather information for use in crop modelling studies across the whole of CRC Sugar.

While the Australian sugar industry has an impressive track record of innovation and increases in productivity with gains of around 300% over the past 100 years, the past 7 years in which CRC Sugar has been in existence have seen the industry facing rapidly increasing cost/price pressures associated with intense market competition and significantly reduced sugar prices. These pressures dictate that the industry must innovate and achieve greater efficiencies if it is to remain profitable. The need for new, cost-reducing technologies and further industry improvement has become critically important. As the economic viability of the production system is the most important element of sustainability, these technological advances will, at the same time, aid the implementation of practices that promote sustainability.

Over the life of CRC Sugar, around $18 million cash and in-kind resources will have been invested in research and training to enhance the productivity and profitability of the industry, about 80% of it through Program 3. This is a significant investment and as CRC Sugar nears completion it is important to assess the impact of that investment in terms of how the approach to sugar R&D taken by CRC Sugar differed from the approach adopted by the sugar industry prior to the CRC, what have been the main achievements, what could have been done differently, what still needs to be done and finally what are the key legacies from Program 3. This paper is one of five in these Proceedings that evaluate the impact of CRC Sugar’s activities both as a whole (Lawn, 2003) and as separate research areas (Rayment, 2003; Kingston and Lawn, 2003; Bristow and Keating, 2003).
A different approach to sugar R&D

Some of the key differences in the approach to R&D adopted by Program 3 of CRC Sugar were described by Lawn (2003) in his introductory paper. These are:

- collaborative, multi-organisational activities addressing new issues that the individual parties could not easily have addressed alone;
- tackling difficult or complex or contentious research issues while playing the role of the ‘honest broker’;
- actively engaging with the end users of R&D to facilitate acceptance and adoption of research findings; and
- adopting a systems approach to whole-of-industry analysis and planning.

The novel approach to R&D adopted by the Centre required the appointment of new staff with skills not previously available in the sugar industry. In Program 3, key staff were recruited with skills in mathematics, operations research, systems agronomy and crop physiology. These new skills helped to fill gaps in the expertise of the staff seconded from the parties. Some of the innovative approaches adopted in Program 3 research activities are described below.

The sugar industry had traditionally conducted disciplinary research aimed at delivering incremental improvements to the different sectors of the industry such as farming, harvesting, milling and marketing. However, the industry faces increasingly difficult and complex issues, which are difficult to solve using this traditional approach. Some of the complex issues that management strategies now need to take into account have been outlined by Muchow et al., (2001):

- sustainability where options for improving profitability must maintain the resource base and minimise impacts on other ecosystems;
- a huge diversity in soils and production systems and a highly variable climate, not only across locations but also from season to season;
- differences between farms in terms of size, production systems, cost structures and labour supply;
- the industry is an integrated value chain from farm to mill to markets, with the individual components being interdependent;
- variability in sugar price and exchange rate; and
- community expectations in terms of off-site impacts.

To account for the complexities of the sugar system and its place in the broader landscape and to achieve solutions for future competitiveness and sustainability, CRC Sugar has pioneered a multidisciplinary approach using a whole of systems analysis framework. Central to this approach has been the need to develop or enhance simulation or optimisation models that have been used and subsequently refined in partnership with industry. In most cases, strategic research has been required to improve the knowledge and data on which the models are based. Novel research techniques have been required to develop implementation strategies for the modelled outputs. These have commonly been developed in close participative collaboration with industry to ensure that the
adoption of new options for enhancing whole-of-industry profitability occurs in harmony with other sustainability considerations.

This approach was first applied to improving the management of harvest and cane supply arrangements in different sugar mill areas. Traditional operations research methods were used to optimise the decisions of harvest date for all paddocks within a mill region, resulting in a model containing over 500,000 variables for a typical mill area (Higgins, 1999). The model was solved using novel heuristic techniques that accommodated constraints imposed by harvesting, transport and milling capacity (Higgins, 2001). Financial gains of more than 10% were demonstrated by following an optimised rather than a fixed harvest rotation so that geographical differences in sugar yield could be exploited during the harvest season (Higgins and Muchow, 1998). An action research approach based on a strong partnership between growers, harvester contractors, millers and researchers has been used for pilot implementation projects in different regions to find out the extent to which these gains can be realised in actual industry practice (Muchow et al., 2000). The participative research partnership developed in this project has proved invaluable for identifying other areas where the optimisation modelling can be applied. For example, a model to optimise harvester rosters has been successfully implemented in the Mackay region (Higgins and Langham, 2001) and a model to optimise the allocation of harvesting groups to sidings throughout the harvest season was used commercially in the Mackay region during the 2002 season.

A similar participative approach was used to develop a mathematical model that improves pre-season crop estimates during the harvest season as block productivity data for paddocks harvested progressively become available. The model, when adopted for use in the Mossman Mill area, proved to be a quicker and more accurate tool for cane inspector use than the existing methodology for crop re-estimation (Higgins et al., 1999).

A systems approach has also been used for evaluating options for improving the use of limited irrigation water supplies by sugarcane crops (Robertson et al., 1997). The installation and operation of supplementary irrigation systems involves a complex set of interacting factors such as variability in rainfall, crop demand for water, different soils, together with decisions on whether to water plant crops or ratoons, which varieties to use and which irrigation schedule to use. A systems approach made it possible to evaluate the interaction between financial and biophysical factors in response to climatic variability and led to the development of guidelines that help growers decide when to irrigate and how much water to apply (Inman-Bamber et al., 1999a, b). The capability of deriving regional forecasts indicating when limited allocations of water might best be used over the season is being improved by integrating seasonal climate forecast data with this approach (Everingham et al., 2002).

Central to the systems approach linking field experimentation with modelling techniques has been the development of the innovative SUGARBAG database system that has been developed over a number of years to accommodate weather, soils, crop management and crop growth data from field experiments (Robertson et al., 1996). There are relatively few comprehensive datasets available from field experimentation on sugarcane and these data are expensive and time consuming to obtain. The SUGARBAG database system facilitates the consolidation and standardisation of fragmented data from field experiments which have examined sugarcane growth in response to a range of constraints to production including climate, water, nitrogen and time-of-harvest. SUGARBAG is aimed primarily at field researchers and arose from the recognition of the need for standardised climate, crop and soil management data from widely contrasting environments.
One of the contentious research issues undertaken by CRC Sugar Program 3, where it has had to play the role of ‘honest broker’, has been the area of managing time-of-harvest and season length. Increasing the length of the harvesting season is one option available to the sugar industry to increase the efficiency of utilisation of industry capital, in regions where expanding production has increased pressure on mill capacity. In reviewing the literature on the effects of time of harvest on sugarcane productivity, previous studies were found to have confounded the effects of time of ratooning with crop age (McDonald et al., 1999). While comprehensive assessments were available from overseas, the Australian industry lacked conclusive data on the yield and CCS consequences of harvesting crops at different times of the year. Accordingly, a series of time-of-harvest experiments were conducted in different regions over a number of seasons to collect accurate and objective data, so that different options for season start and finish times could be examined participatively with industry to maximise efficiencies within different mill regions (McDonald and Wood, 2001). This information has been used to assist negotiations between millers and growers in the Burdekin when developing plans to accommodate larger crops.

The research has shown that, while early harvested crops have high cane yields, one of the main impediments to starting the season earlier is low CCS. One option for managing the CCS of early harvested crops is the use of chemical ripeners which have significant potential to increase sugar production and on-farm profitability, particularly if the harvesting season is extended forward (McDonald et al., 2000). While previous ripener research in Australia was inconclusive, strategic field experimentation showed considerable variability in the responsiveness of current Australian sugarcane varieties to different chemical ripeners (McDonald et al., 2001).

In order to integrate the time-of-harvest research with the analysis of different cane supply options, further field experimentation is continuing on understanding the effects of early ratooning on productivity in areas with naturally high early CCS in both the Herbert and Burdekin, as it will be these areas that will be favoured for early harvesting as harvest season length is extended.

For areas with naturally low CCS, particularly early in the harvest season, like the northern wet tropics, CRC Sugar has made a strategic contribution towards our understanding of a very complex productivity issue. Initially, the Centre joined with SRDC to support a comprehensive analysis of productivity data over a 35-year period (Leslie and Wilson, 1996). This analysis showed that while improved varieties had made a positive contribution to productivity, this had been more than offset by increases in extraneous matter and billets derived from suckers in the cane supply. Subsequent research focussed on the impact of lodging (Singh et al., 1999, 2000) and suckering (Salter and Bonnett, 2000) on cane yields, CCS and industry profitability. The impact of these two traits together with degree of trashiness is particularly serious in affecting mill CCS and cane yields and can vary considerably between varieties. A model, which estimates the economic impact of different traits at a regional level, was developed to assist with decision-making on the release of new varieties (Jackson et al., 2000). This new approach provides a more objective framework for evaluating the economic value of new varieties from a whole-of-industry perspective.

Probably the most significant difference in approach to sugar R&D in the productivity area has been the active engagement of end users in the research process. CRC Sugar took the bold decision of departing from the traditional research model of R&D being largely research driven and research results being ‘extended’ to end users and instead focussed on achieving industry outcomes and improved adoption of R&D. There was far more consultation with end users and with industry representatives than in the past. Not only did Program 3 have its own Program Consultative
Committee that met at least once a year, but also set up was an additional high level consultative group consisting of industry leaders to provide feedback on the focus, methodology and interpretation of the cane supply and harvest management research. In many activities in Program 3, growers and millers became involved in helping to set the research direction, discussing appropriate parameters for the models, interpreting data and working out the best ways to move forward. Research staff were asked to operate outside of their ‘comfort’ zone, to consult and interact with groups of millers, growers and harvester operators on a regular basis and ensure that the group was comfortable with the research results and interpretation before moving onto the next stage. This approach required research staff to pay much more attention to their communication and facilitation skills and differed from the traditional ‘linear’ technology transfer process. It was also much slower than conventional research but helped to ensure that research outputs were what end users required and thus would be adopted. This is essentially the action learning approach used for implementing a change in practices in the context of evaluating and implementing different options to exploit opportunities for gains in industry efficiency, as outlined by Muchow et al., (2000).

**Key achievements**

Research in the *Enhancing Productivity* program of CRC Sugar has made significant contributions in the following areas:

In the area of achieving best use of limited water supplies, CRC research has shown that the strategic use of limited irrigation water can produce crop responses well in excess of the industry standard of 12 t/ML (Inman-Bamber et al., 1999a). Considerable advances have been made in developing tools to assist with the timing of irrigations when limited water allocations are available and that lead to the most profitable outcomes.

In the area of crop forecasting, the use of satellite imagery for improving the accuracy and cost effectiveness of crop forecasting was pioneered in a pilot study in the Herbert region looking at crop area estimation (McDonald and Routley, 1999). Remote sensing and the mathematical model developed for use in the Mossman area have both been successful in leading the industry forward in the development of more automated methods of crop estimation and an integrated approach, which capitalises on the strengths of different methodologies, is currently being developed.

Significant advances have been made in understanding the constraints to productivity in the northern wet tropics. As part of a PhD project, innovative field experiments, where plots were prevented from lodging by bamboo scaffolding, have shown that lodging can significantly reduce yields and CCS in high yielding crops causing sugar yields to be 15%–35% lower (Singh et al., 1999, 2000). Another PhD project investigating environmental factors affecting suckering has for the first time quantitatively described morphological and developmental differences between normal tillers and suckers and has shown that increased nitrogen availability is a key factor in stimulating suckering (Salter and Bonnett, 2000).

A more rigorous, orderly and integrated approach to the collection and storage of sugar industry experimental data has been established with the development of the SUGARBAG database. Protocols and quality controls for the collection of experimental data ensure high quality data are stored in a standardised, easily retrievable form that is appropriate for use in crop modelling activities.
The key achievements of the cane supply work have been the development of a participative process for industry and researchers to evaluate and implement changed practices, the development of a capability to run optimisation models using novel solution techniques to integrate across the sugar value chain, the identification of alternative cane supply arrangements with potential gains in industry profitability of at least 10%, and the establishment of an implementation process across the sugar industry. This pioneering work has challenged the wisdom of retaining an equity-based system of harvesting. The optimisation modelling uses sugarcane block productivity data which prior to CRC Sugar was collected and stored in many mill areas but never used to any great extent. The true value of block-based data is now being realised as this and other applications have been identified (Keating and Lawes, 2001).

**What should have been done differently and why**

While some difficulties were encountered during the years that CRC Sugar has operated, it is difficult with the benefit of hindsight to suggest ways in which they could have been overcome by doing things differently. Early progress was slow due to the need to find the right staff for the new positions in the CRC. However, the time taken was worthwhile as the new staff turned out to be exceptional young scientists. In addition, it was not always easy for seconded staff to make a rapid transition to new research programs due to commitments in other areas. The need to get some ‘runs on the board’ early on in the CRC caused some frustrations as the establishment of early trials or pilot evaluations may have compromised some scientific rigour. For example, with the time-of-harvest research, we learnt that more complex, carefully designed experiments with a wide range of harvest time treatments and with the different treatments managed separately to avoid any confounding effects were required rather than the simpler field experiments initially established in the different regions.

The early years of CRC Sugar encountered some misunderstandings about the prime objectives of the Program 3 research portfolio. The sensitive nature of the research, dealing with issues such as equity and season length, did not help the situation. While industry leaders had a good understanding of what CRC Sugar was trying to achieve, this knowledge did not always filter down to growers and mill staff. Clearly, there was a need for better communication throughout the industry to prepare people for some of the critical, but sensitive issues that scientists from CRC Sugar would be working on. By the time this had been realised and a comprehensive information program established, the misunderstandings had created suspicion and doubts in some peoples’ minds and this hindered progress in some regions. As a consequence, the research was targeted at mill regions where a trusting, open relationship existed between the parties and where there was a long-term commitment to developing the research together. Expansion of the research to other areas was delayed until an effective relationship could be developed and the research was sufficiently well advanced to allow a short timeframe between the start of the project and implementation.

**What needs to be done in the future**

Many of the research activities initiated under Program 3 will continue beyond the life of CRC Sugar. The cane supply scheduling research and associated activities aimed at improving decision-making across the value chain will continue with strong support from SRDC and from industry in the participating districts. Improved crop forecasting methodologies will continue to be developed into the future and there is strong support for an integrated approach combining the existing mathematical modelling, remote sensing and climate forecasting methodologies (Wood and
DeLai, 2001). Upgrades to the SUGARBAG experimental database system will ensure its future use in the sugar industry as a stand-alone, user-friendly package. Best management practices that improve water use efficiency and profitability of irrigated sugar production will continue to be adopted and modified as water supplies become scarcer and more costly. Finally, objective and reliable baseline data for assessing opportunities for different harvest season strategies and for making more efficient use of existing capital will continue to be needed and interpreted in areas like the Burdekin where production is expanding.

**Key program legacies**

Among the achievements of the *Enhancing Productivity* program are several legacies that will survive CRC Sugar. The novel research approach adopted for exploring alternative cane supply arrangements has significantly influenced industry thinking on the role of a whole-of-industry systems approach for achieving better use of industry resources and sustained international competitiveness. This novel approach to R&D is likely to remain with the industry with the reorganisation of the SRDC operational plan into a systems-based structure. The collaborative and participative approach to R&D involving industry and researchers working in partnership to evaluate and implement change using tools such as operations research methods to integrate across the industry value chain and developing novel implementation pathways is likely to be increasingly adopted to evaluate and manage change in the different regions of the Australian sugar industry as the problems to be solved assume greater complexity.

In retrospect, the group of people who developed the blueprint for CRC Sugar back in 1993–1994 must have had a clear vision of what R&D could deliver for the sugar industry, provided the research could be structured along very different lines to traditional industry R&D. They were courageous in what they set out to do and history has shown that many of the initiatives pioneered by CRC Sugar have been successful in changing the way that the sugar industry conducts its R&D and in achieving beneficial outcomes for the Australian sugar industry.

**REFERENCES**


